

# **Water and Range Resources and Economic Development of the West**

**Report No. 9**

## **Economic Analysis of Multiple Use The Arizona Watershed Program —A Case Study of Multiple Use**

**Conference Proceedings**

**Committee on the Economics of Water Resources Development  
and**

**Committee on the Economics of Range Use and Development  
of the**

**Western Agricultural Economics Research Council**

**Tucson, Arizona**

**January 23 and 24, 1961**

WATER AND RANGE RESOURCES AND ECONOMIC  
DEVELOPMENT OF THE WEST

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Each of the departments of agricultural economics represented on the Committee on the Economics of Water Resources Development and the Committee on the Economics of Range Use and Development, has a limited supply of additional copies. This report may be obtained by writing to one of the western agricultural economics departments, or to John O. Gerald, Secretary of Western Agricultural Economics Research Council, 211 Post Office Building, Berkeley 1, California

## FOREWORD

Over the past 10 years the Committee on the Economics of Water Resources Development and the Committee on the Economics of Range Use and Development, of the Western Agricultural Economics Research Council, has devoted a series of meetings to the discussion of the policies and problems associated with economic development of water and range resources. This report is a joint report of the Water and Range committees, and is listed as No. 9 in the series of proceedings publications of the Water Resources Committee. Other reports of the Water Committee are as follows:

- Report No. 0 Direct and Indirect Benefits, December 1951
- Report No. 1 Research Needs and Problems, March 1953
- Report No. 2 Institutions and Policies, June 1954
- Report No. 3 Benefits -- Cost Analysis, December 1954
- Report No. 4 Impact and Measurement; Organizational Integration; Small Watershed Development; and Desert Land Development, June 1955
- Report No. 5 Ground Water Economics and the Law, December 1956
- Report No. 6 Small Watershed Development -- Rehabilitation and Reorganization of Irrigation Projects, November 1957
- Report No. 7 Rehabilitation and Reorganization of Irrigation Projects: Evaluation Methodology of the Upper Colorado River Development; Alternative Water Uses, November 1958
- Report No. 8 Political and Economic Problems in Budget Allocation; Development Planning; Impact of Resources Development

Reports released by the Range Resources Committee are as follows:

- Report No. 1 A Methodological Anthology, 1957
- Report No. 2 Economics of Range and Multiple Land Use, 1959

The major functions of the two committees are: (1) to review the economic problems connected with water and range resources development, the research being done and further research needed, (2) to isolate problem areas and develop proposals for regional research projects as needed, and encourage the implementation of cooperative research by appropriate means other than by regional research funds, (3) to improve the quality of regional research through promotion of workshops and seminars on research methods and techniques, and (4) report annually to the Western Agricultural Economics Research Council on research problems, going research, and needed research.

In 1960 the Council's two committees decided that problems should be investigated in the economic analysis of multiple use of water and range resources. The members of the Committee recognized that multiple use concepts were common to both water and range development. The committees felt that a joint meeting of the two committees would be the most promising and efficient way of attacking these problems.

A joint Program Committee was appointed to arrange the program, consisting of:

Glen Fulcher, Chairman, Range and Water Committees; Douglas Caton and James Gray, Range Committee; Helmer Holje and Stephen Smith, Water Committee.

In January, 1961, the committees met at Tucson, Arizona. This Report contains the major papers and discussions of papers which were presented at the Tucson meeting. Payment of travel expenses for the Committee members, guest speakers and consultants was made possible by a generous grant given to the Council and Committee by the Farm Foundation. Reproduction costs associated with this report were paid by funds contributed by the Agricultural Experiment Stations of the eleven western states and various subsections of the U. S. D. A. Special credit goes to the members of the Program Committee for their efforts in the development of the program and for making arrangements for the meeting.

Glen Fulcher, Chairman  
Committee on the Economics of  
Range Use and Development

Owen L. Brough, Jr., Chairman  
Committee on the Economics of  
Water Resources Development

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# MULTIPLE USE AS A CONCEPT FOR WATER AND RANGE POLICY

S. V. Ciriacy-Wantrup<sup>1</sup>

## Multiple Use: A Perennial Topic

My assignment covers what may be called a perennial topic in natural resource policy both in the academic and in the political arena.

In looking back over the many contributions of the Water and Range Committees of the Western Agricultural Economics Research Council, the multiple-use theme recurs in a number of variations from the meeting of the Water Committee in 1951 up to the meeting of the Range Committee in 1959. The papers by Drs. Kelso and Upchurch at the latter meeting deal explicitly with today's topic.<sup>2</sup>

For me, the topic is an especially hardy perennial. One of my first papers after coming to California was under the title "Multiple and Optimum Use of Wild Land under Different Economic Conditions."<sup>3</sup> Although published 23 years ago, I was tempted to read it today. I was afraid, however, that my colleagues present here would not let me get away with such an easy discharge of my obligation.

Shifting our backward glance from the academic to the political arena, the multiple-use topic is even older. It seems to have arisen as a reaction to the narrow-use policy implicit in the U. S. Forest Reserve Act of 1897. Since that time, the concept has been one of the most significant ones for the administration and management of the U. S. National Forests. It has been continuously and hotly debated inside and outside the Forest Service.

In view of this perennial nature of the topic, it is not easy to say something that has not been said before. In any event, I should like to confine myself to three selected aspects that still appear interesting and relevant at the present juncture.

First, multiple use will be considered as a concept in the economic theory of natural resource allocation. A question will be raised regarding the logic of using the concept as an objective or a criterion for public allocation policy. The conceptual and operational usefulness of "optimum use" will be

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<sup>2</sup> M. M. Kelso, "Objectives of Public Resource Allocation," and M. L. Upchurch, "Resource Allocation under Conditions of Multiple Use of Land," Economic Research in the Use and Development of Range Resources, Economics of Range and Multiple Land Use (Logan, Utah, 1959), pp. 117-129 and 135-147. (Report No. 2, Conference Proceedings of the Committee on the Economics of Range Use and Development, Western Agricultural Economics Research Council.)

<sup>3</sup> S. V. Ciriacy-Wantrup, "Multiple and Optimum Use of Wild Land under Different Economic Conditions," Journal of Forestry, vol. XXXVI, no. 7, July, 1938, pp. 665-674.



appraised as an alternative to "multiple use." Second, the history of the multiple-use concept will be traced in public policy affecting resource allocation in the U. S. National Forests. This history is of interest for the third aspect, for appraising whether the multiple-use concept can serve for public policy as a part of allocative systems irrespective of its usefulness in the economic theory of resource allocation.

### Multiple Use as a Concept in the Economic Theory of Natural Resource Allocation

In economic theory, multiple use of natural resources is the actual or hypothetical result of economic conditions, including those influenced by public policy. That multiple use is a common result of economic conditions does not mean, however, that such an outcome is always necessary economically or desirable for policy. To regard multiple use as a general objective or criterion for policy is not warranted logically--it puts, if you permit, the cart before the horse.

Whether or not multiple use actually occurs is determined by the economics of joint production. These have been discussed elsewhere.<sup>4</sup> Economists know that relations between uses may be complementary, competitive, or independent. These relations are defined through marginal benefits and costs or, more precisely, through the second cross partial derivatives of benefit and cost functions. The occurrence of multiple use depends, therefore, on levels ("intensity") of uses under static assumptions and on changes of cost and benefit functions over time. Thus, multiple use may be merely a passing phase following upon or being followed by single use, both in terms of levels of uses and in terms of time.

To analyze under what conditions multiple use replaces or is replaced by single use is one of the most important tasks of resource economics. Such an analysis is identical with an investigation of changes in the optimum combination of uses. For a given resource, for example, the scenic qualities of an area of land, a population of plants or animals, a flow or stock of water or oil, we are dealing with the problem of optimum resource allocation among uses. Differentiation between resources and uses is not merely semantic. A part of some current confusion in the economic analysis of outdoor recreation, for example, is due to the fact that recreational resources and recreational uses are not distinguished. Since uses are frequently different between private and public users, and since private users are frequently specialized with respect to uses, the problem of optimum resource allocation among uses is intricately related to that among users.

Quantitative determination of optimum resource allocation is a goal of many current studies in economics. Encouragement for such attempts comes

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<sup>4</sup>S. V. Ciriacy-Wantrup, "Economics of Joint Costs in Agriculture," Journal of Farm Economics, vol. XXIII, no. 4, November, 1941, pp. 771-818. See also: S. V. Ciriacy-Wantrup, Resource Conservation Economics and Policies (Berkeley: University of California Press, 1952), Chapter V.

from the impact of formal programming during the last decade.<sup>5</sup> In resource economics, judicious expansion of quantification is desirable for reasons often not sufficiently appreciated.<sup>6</sup> On the other hand, quantitative optimizing involves serious difficulties that are often overlooked. Time does not permit dealing with them in detail. But exploration of the concept "optimum use" is unavoidable here in order to appraise its significance as an alternative of "multiple use."

The difficulties are more severe for optimizing in public policy than for optimizing in subsectors of the economy such as individual farms and firms. My assignment is to focus on the former. It may also be mentioned that these difficulties apply no less to informal programming, for example, benefit-cost analysis, than to the formal kind. However, they are more concealed in the implicit assumptions of formal programming and its comparative efficiency, and the precision of its results tends more toward overlooking its limitations.

Difficulties of quantitative optimizing in public resource allocation may be discussed as three interrelated problem areas which may be called: (1) the problem of valuation, (2) the problem of institutional constraints, and (3) the problem of uncertainty.

The problem of valuation has recently been discussed elsewhere.<sup>7</sup> For this problem area, therefore, I can be brief. Absence of market prices leads to a systematic bias if optimum use is calculated on the basis of market prices. Recreational uses are especially affected. A good illustration is the repeated refusal (withdrawn only recently) of the U. S. General Service Administration to sell military surplus land in the Bay Area to the state of California and the City of San Francisco for development as a park. The explicitly stated reason was that such land is "too valuable" for recreational use and should be used for subdivisions instead. No attempt was made to investigate what the comparative value for recreational use actually would be. The statutory discount from existing market prices that applies when surplus land is sold for public use was regarded as sufficient support for classifying use for subdivisions as optimum.

Absence of market prices, however, is only a small part of the difficulties. More significant is the question: To what extent are market prices, where they exist, valid and relevant indicators for public policy? The functioning and the results of the price system are profoundly influenced by public

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<sup>5</sup> The origin of formal programming--as linear programming--is generally dated with the unpublished papers by Jerome Cornfield (1941) and G. B. Dantzig (1947). The latter paper was published as "Maximization of a Linear Function of Variables Subject to Linear Inequalities" in T. C. Koopman's (ed.) Activity Analysis of Production and Allocation (New York: John Wiley and Sons, 1951). The title of the Dantzig paper can serve as a definition of linear programming.

<sup>6</sup> S. V. Ciriacy-Wantrup, "Benefit-Cost Analysis and Public Resource Development," Journal of Farm Economics, vol. XXXVII, no. 4, November, 1955.

<sup>7</sup> S. V. Ciriacy-Wantrup, "Philosophy and Objectives of Watershed Policy," Economics of Watershed Planning, ed. G. S. Tolley and F. E. Riggs (Ames: Iowa State College Press, 1960), pp. 1-14.

policy through income distribution, market structure, taxation, property rights, and in many other ways. Quantitative optimizing looks at these influences as institutional conditions that--together with the technological ones--are introduced into the optimizing calculus as constraints. The implications are so important that two of them need to be mentioned in the present context.

First, when social institutions are used as constraints, they become conceptually indistinguishable from policy objectives. In this respect, they are different from technological constraints. In natural resource policy, changes of social institutions are among the most significant controllable variables and relations. In other words, in natural resource policy, social institutions must frequently be regarded as means rather than ends of policy. Hence, the distinction in quantitative optimizing between the part of the model that constitutes the "objective function" to be maximized or minimized and the part that constitutes the constraints describing the structure of the operation and the relations between variables becomes misleading if the conceptual difference between technological and institutional constraints is not sufficiently recognized.

Secondly, when social institutions are used as constraints in a quantitative optimizing calculus, a new optimum must be calculated for each combination of constraints that is considered. The optima calculated for different sets of constraints are then compared. Recently, a whole literature has grown up around this approach, known as "the theory of second best."<sup>8</sup> This term merely indicates that there is at least one constraint additional to the ones existing in the so-called "Pareto optimum."<sup>9</sup>

The exponents of this theory claim that the major contribution is a negative one: If a deviation from one of the Pareto optimum conditions prevails, the best course of action is not an attempt to attack this deviation and keep all others intact. On the contrary, a second-best solution is usually obtained only by departing from all other Pareto conditions. To apply only a part of the Pareto conditions would move the economy away from rather than toward a second-best position. In consequence, the exponents of this theory direct their criticism against what they call "piecemeal welfare economics."

If this criticism is valid--I believe it has some merit--does it not point to a basic weakness in the logic of economic optimizing itself? If one tries to avoid the futility of piecemeal welfare economics and strives for bold changes in the combination of constraints, can one be sure that quantitative optima are comparable in a meaningful way? Is it not unavoidable that such bold changes affect some structural elements of the optimizing calculus--among them especially preferences, technology, and the motivation of human agents in their various functions in the economy? Are we not confronted with a problem of identification, in the econometric sense, on a grand scale?

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<sup>8</sup>R. G. Lipsey and R. K. Lancaster, "The General Theory of Second Best," The Review of Economic Studies, vol. XXIV (1), no. 63, 1956-1957, pp. 11-32. The earlier literature is cited in this article.

<sup>9</sup>Vilfredo Pareto, Cours d'Economie Politique (Lausanne: F. Route, Libraire-Editeur, 1897). An excellent bibliography of welfare economics is appended to: E. J. Mishan, "A Survey of Welfare Economics, 1939-1959," The Economic Journal, vol. LXX, June, 1960, pp. 197-265.

In view of these questions, I should like to submit that "optimum use" is a construct in the sense of a useful scientific fiction.<sup>10</sup> Such a construct is not a quantitatively specifiable policy objective. In the strict mathematical sense, "optimum use" is not operational. There is danger that the two are confused when attempts are made to use quantitative optimizing as a basis for decisions in public allocation policy.

The conceptual usefulness of optimizing in the analysis of the private and the social economics of natural resources has been explained in detail elsewhere.<sup>11</sup> No repetition is needed here. The following discussion is not concerned with the construct but with the quantitative specification of an optimum allocation of natural resources in policy decisions.

Let us turn, first, to the difficulties in quantitative optimizing created by uncertainty. The probability of some uncertainties, for example, the occurrence of floods, drought, and hailstorms, can be measured quantitatively. Economists frequently refer to these uncertainties as "risk." Techniques to allow for uncertainties of this kind are being developed in formal programming.

On the other hand, the probability of the most important uncertainties, those created by changes of technology, of preferences, and of institutions, is not amenable to precise quantitative measurement. At best, the direction, the relative speed, and the range of such changes can be vaguely projected. This kind of uncertainty imposes severe and, as far as I can see, insurmountable limits on the validity and relevance of quantitative optimizing for policy decisions.

Practitioners of formal programming who are also competent economists are aware of these limitations. Robert Dorfman, for example, in a recent article appraising operations research, states: "Another important limitation, in which less progress has been made, is that linear programming formulations do not allow for uncertainty."<sup>12</sup>

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<sup>10</sup>The nature of scientific fiction as a class of constructs was explained elsewhere: "A fiction is permissible in science if its character is clearly understood. A fiction is a deliberate, conscious deviation from reality. A fiction, however, is not a hypothesis or theory. By itself, a fiction is not intended to be validated by testing with empirical evidence. But a scientific fiction should be useful as a stimulus for or as a part of hypotheses and theories which can be so tested. That means the test of a scientific fiction is its conceptual usefulness, its expediency, in understanding, explaining, and predicting reality. A fiction becomes mere dogma and, therefore, unscientific, if its two characteristics--consciousness of its fictional nature and conceptual usefulness--are obliterated. There are many examples in the history of science of fictions changing into dogma." See S. V. Ciriacy-Wantrup, "Policy Considerations in Farm Management Research in the Decade Ahead," Journal of Farm Economics, vol. 38, no. 5, December, 1956, pp. 1301-1311.

<sup>11</sup>S. V. Ciriacy-Wantrup, Resource Conservation, *op. cit.*, especially chapters 6, 17, and 18.

<sup>12</sup>Robert Dorfman, "Operations Research," The American Economic Review, vol. 50, no. 4, September, 1960, pp. 575-623.

In the economics of flow resources, allowance for uncertainty is best made through the formulation of the policy objective itself. Such a formulation I have called "the safe minimum standard of conservation." A detailed explanation of the theoretical development of this concept and its operational application is found elsewhere.<sup>13</sup> Time limitations permit merely stating that one aspect of the economic rationale of the safe minimum standard as a policy objective is to minimize maximum possible social losses connected with avoidable irreversibilities. In this respect, the safe minimum standard of conservation may be regarded as a conceptual relative of the min-max solution or "saddle-point" in a two-person, strictly determined game.<sup>14</sup> This is not to suggest, however, that all aspects of the economics of flow resources should be forced into the framework of modern game theory--as "man playing against nature" in an almost literal sense.

It is interesting to observe that the more sophisticated practitioners of formal programming formulate their models in such a way that the three difficulties just reviewed are involved as little as possible. The resulting models, however, are engineering rather than economic ones. Examples in water resources programming are Dorfman's "Simple Valley" and Tolley's "Optimal Water Allocation."<sup>15</sup> The former model is purely hypothetical, designed to illustrate the technique. The latter model deals ex post with an actual allocation among users through existing social institutions. Under assumptions most favorable to formal programming, allocative efficiency is improved by no more than five per cent. Careful comparative studies of this kind are only too rare.

Quantitative allocation may actually be harmful because it introduces an element of rigidity into public policy. Such allocation is based on detailed and usually expensive studies that cannot be repeated year after year. This becomes important under dynamic conditions when demands for different uses are changing rapidly over time at different rates or even in different directions. Let me illustrate this point by an example from range resources.

In 1947, after several years of detailed study through the California-Oregon Interstate Deer Herd Committee, optimum allocation of forage on the deer winter range, used by livestock during the spring and summer, was determined on a 50-50 basis. The logic of this particular ratio as an optimum allocation has never been satisfactorily explained to me. But I am more concerned now with the problem of rigidity.

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<sup>13</sup>S. V. Ciriacy-Wantrup, Resource Conservation, op. cit., especially chapters 17 and 18.

<sup>14</sup>Johann von Neumann and Oskar Morganstern, Theory of Games and Economic Behavior (New Jersey: Princeton University Press, 1944), 625 p. See also: Robert Dorfman, Paul A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis (New York: McGraw-Hill Book Co., 1958), chapters 15 and 16.

<sup>15</sup>Robert Dorfman, "Simple Valley," Economics of Watershed Planning, ed. G. S. Tolley and F. E. Riggs (Ames: Iowa State College Press, 1960), 352 p., and G. S. Tolley and V. S. Hastings, "Optimal Water Allocation," Quarterly Journal of Economics, vol. 74, no. 2, May, 1960.

During each season, livestock has the first crack at the forage; the deer have to take what is left. During dry years, it is largely the deer that suffer. Faced with a series of dry years during the 1950's, game managers, constrained by the 50-50 ratio, had no other choice but to reduce the herd through opening the season for does. During the same period, demand for hunting increased at a rate far greater than the demand for livestock. Hunting pressure on the bucks increased correspondingly. At the present juncture, measures will be necessary to conserve the remnants of the interstate herd. Game managers are under heavy public criticism. This criticism appears not entirely just. The crux of the matter is that, under conditions of economic change, a quantitative allocation tends to become a harmful constraint for policy.

On the positive side, it may be concluded that resource programming must include the programming of social institutions. Resources programming must be pragmatic; that is, it must regard institutions as means (tools or obstacles), as well as ends (objectives), depending on the purposes of the analysis.<sup>16</sup> In natural resource policy, an analytically oriented institutional economics is by no means obsolete.

In such an approach, institutions are regarded as structured systems, each with particular patterns of change over time. These systems can be analyzed in structure, functioning, performance, and change over time. In the jargon currently in vogue, such systems may be called "optimizing systems." Their purpose, however, is not to obtain quantitative optima of social welfare at given points in time under conditions projected for these points. Rather, their purpose is to increase social welfare continuously under constantly changing conditions that at any point in time can be projected only vaguely and are always uncertain with respect to actual occurrence. Responsiveness of these systems to economic change is more important than their efficiency in optimizing under particular sets of projected conditions.

It follows that to appraise the performance of these systems by introducing arbitrary temporal cross-sections of them as alternative constraints is inadequate. Performance can be appraised only by criteria applied to alternative systems as they function over time. In this functioning, direction, speed, and range of changes brought about by them are especially important. Criteria need not always be pecuniary. For a system that is of special interest for water allocation, namely, water law, it has been shown elsewhere that nonpecuniary criteria can effectively be employed.<sup>17</sup> Such an appraisal is an integral part of the field of economics, which includes econometrics, but is not restricted to it.

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<sup>16</sup> For an interesting statement on the schism between "orthodox" and "pragmatic" attitudes toward social institutions, see: F. O. Sargent, "A Methodological Schism in Agricultural Economics," Canadian Journal of Agricultural Economics, vol. 8, no. 2, 1960, pp. 45-52.

<sup>17</sup> S. V. Ciriacy-Wantrup, "Concepts Used as Economic Criteria for a System of Water Rights," Land Economics, vol. XXXII, no. 4, November, 1956, pp. 295-312. Also published in The Law of Water Allocation in the Eastern United States, ed. David Haber and Stephen W. Bergen (New York: The Ronald Press Co., 1958), pp. 531-552.

Multiple Use as a Concept in Public Policy Affecting  
Resource Allocation in the U. S. National Forests

If the foregoing reasoning is correct, it may not be a waste of time to take another look at the concept "multiple use." True, as a theoretical construct, it must be replaced in the economic theory of resource allocation by the concept "optimum use." Still, in view of the difficulties just reviewed in applying the latter concept in public policy in terms of quantitative allocations, one may ask whether the concept "multiple use" can serve as a part of allocative systems in spite of lack of usefulness in economic theory. As already mentioned, there is evidence concerning such a role of the multiple-use concept. This evidence is available over many years in public policy affecting resource allocation in the U. S. National Forests.

Following the legislation of 1891, establishing the National Forests, the Forest Reserve Act of 1897 limited their expansion to areas where water flow and timber were the dominant uses. Land more valuable for agricultural purposes and minerals was specifically excluded. Forage and recreation were not mentioned as important uses. The emphasis on water flow, of course, was necessary because it made establishment of federal forests constitutionally possible on the basis of the Interstate Commerce clause. In essence, however, the 1897 Act favored a single use, namely, timber.

In 1905, administration of National Forests was transferred from the Department of the Interior to the Department of Agriculture under the leadership of Gifford Pinchot. Immediately after this transfer, the concept "multiple use" was inaugurated, not in name but in fact. All important potential uses, besides timber, were referred to in the first issue of a booklet that, in its later issues, became known as the Forest Service Manual. This emphasis was repeated in all subsequent revisions of the Manual--the first being issued in 1906. At least since the beginning of the 1930's, the term "multiple use" has become generally accepted.

One important structural aspect of this development needs emphasis. The Forest Service Manuals did not spell out a criterion by which potential uses could be quantitatively combined. This left a great deal of discretion to administrative officers at different levels. This administrative discretion was not defined by later statutes. Even the "Multiple-Use, Sustained Yield Act" of 1960<sup>18</sup> still leaves essential decisions to administrative discretion. Thus, the multiple-use concept was essentially developed by and for the administration of the National Forests. The concept, therefore, must be appraised as a part of an administrative system of resource allocation.

In appraising the social performance of this allocative system, one must note that the multiple-use concept gave the administration of the National Forests the flexibility needed to counteract the single-use philosophy of the 1897 Act. The concept facilitated administration and expansion of the National Forests under western conditions where forage was and still is a significant use. The concept made possible the gradual acceptance by the Forest Service and by economic interests of recreation as an important and, in many areas, a dominant use. Here again, such acceptance, for example, through setting

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<sup>18</sup>Public Law 86-17, 86th Cong. H. R. 10572, 74 Stat. 215, June, 1960.

aside areas in the various categories of "wilderness," "wild," "primitive," and "roadless," was and is an administrative, not a legislative, decision. Generally speaking, administrative discretion is less objectionable in the structure of an allocative system if a competent and devoted civil service exists. In this respect, the Forest Service is one of the best in this country.

One may conclude that this administrative system of resource allocation, with the multiple-use concept as an important part, has responded well to changes of economic conditions when such changes favored replacing a single use, namely, timber, by multiple use, including timber, forage, and recreation. In such a situation, the multiple-use concept gave flexibility to the allocative system for responding in a socially desirable direction with adequate promptness and extent.

I am well aware, of course, that the administration of the Forest Service is frequently criticized for responding to pressure by economic interests too much or not enough--depending on who does the criticizing. For example, the Forest Service policy of gradually reducing grazing permits has been criticized by grazing interests. I believe this policy is a more adequate response to changing economic conditions than the "optimum" quantitative allocation of the range between livestock and deer referred to previously.

The extent and the administration of the various categories of wilderness areas have been criticized from all sides. The timber, grazing, and some water interests wish these areas reduced and their administration liberalized. Some influential recreation interests wish them protected more securely and enlarged. Here again, the response of the allocative system to changing economic conditions has been adequate. But I should like to confine this statement primarily to past performance. The reason is the following.

In the past, as just shown, the multiple-use concept imparted flexibility to the allocative system in the right direction; namely, when replacement of a single use--timber--through multiple use was economically and socially desirable. The question arises: Will the multiple-use concept impede flexibility of the allocative system when a change in the opposite direction is desirable, that is, when multiple use should be replaced by single use? This question is posed by economic changes that point to recreational use as the dominant use on large areas under the administration of the Forest Service. The characteristics of these economic changes were analyzed 23 years ago in the paper mentioned in the beginning.<sup>19</sup> Politically, this question has already become acute.

In some quarters, multiple use is being used as an argument in favor of reducing wilderness and other areas devoted largely to recreational use. Strong interests on the other side believe that administrative classification by the Forest Service is not a sufficient protection for wilderness areas. They argue that special statutory protection must be given to such areas. Some go even so far as to advocate transfer of wilderness areas from the National Forests to the National Parks. In the National Parks, recreational uses are established as dominant by statute. The last Congress saw the introduction of a bill generally known as the "Wilderness Bill" (S. 1123) that would give statutory protection to all wilderness areas in a National Wilderness Preservation System. In such a system, wilderness areas in National Forests, National

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<sup>19</sup>S. V. Ciriacy-Wantrup, "Multiple and Optimum Use of Wild Land under Different Economic Conditions" op. cit.



Parks, National Wildlife Refuges, and National Ranges would be included. But, otherwise, this bill would not interfere with existing administration. The same or similar legislation will, no doubt, be introduced in the 1961 Congress.

It is not easy to take a definite position in these controversial matters without being misinterpreted by some interested group. On the other hand, resource economists have some responsibility here in terms of the topic of this paper. Let us not shirk this responsibility.

It is fairly obvious, I believe, that the increase in the demand for recreational uses relative to the increase in the demand for all other uses will be so great that ways must be found to make other uses such as timber and grazing compatible with recreation in areas where one of these other uses is now dominant. The technological problems are not too difficult. Compatibility is largely a question of economics and of enforcing appropriate regulations of lumbering and grazing practices. Such practices should first be firmly established on public land. In the future, however, a good portion of both public and private land used for timber and grazing will also be needed for recreation. In this perspective, multiple use will remain a useful concept in natural resource policy.

But compatibility with wilderness recreation is a different question. To preserve wilderness values, regulations must be so strict that grazing and lumbering will usually be uneconomic.

There are three economic factors to consider in deciding whether wilderness areas should be reduced or preserved: first, the uncertainty of future changes in demand for various types of outdoor recreation; second, the irreversibility of depletion of wilderness resources, and the consequent permanent loss of flexibility if such areas are once developed; and third, the low value of wilderness areas for timber, grazing, and readily accessible recreation. These considerations have been developed in detail elsewhere, with emphasis on the uncertainty and irreversibility problems.<sup>20</sup>

On the basis of these considerations, the "Wilderness Bill"--or a bill similar to it--should be enacted now. Those who fear that a change from administrative to statutory protection is contrary to the principle of flexibility stressed above should not forget that the direction and speed of change are no less important considerations for structuring an allocative system than the provision for change per se.

A transfer of wilderness areas to the Park Service would not seem desirable. Park Service policy is a rigid, single-use policy even with respect to different recreational uses, and even if potential additional recreational uses are complementary to existing ones. The wilderness area of the National Parks are closed to all hunting and to those hikers and friends of nature who object to keeping their dogs on a leash at all times. Serious wildlife problems have arisen in some parks because of lack of hunting. If a National Wilderness Preservation System is established, a transfer of wilderness areas from the National Parks to the National Forests would seem sounder than a transfer in the opposite direction.

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<sup>20</sup> S. V. Ciriacy-Wantrup, Resource Conservation, op. cit., especially chapter 18.

## Conclusions

What are the conclusions of this survey of "multiple use" as a concept for water and range policy? They have already been implied, but a short summary may be helpful.

First, as a theoretical construct in the determination of objectives or criteria of public policy, the concept "multiple use" must be replaced by "optimum use." This conclusion is not surprising to professional economists. But it needs emphasis at the present juncture because powerful economic interests are insisting that "multiple use" per se constitutes an objective or a criterion for public policy.

Second, "optimum use," although superior to "multiple use" as a theoretical construct, is limited in its quantitative specification by three difficulties called here the problems of valuation, of institutional constraints, and of uncertainty. The concept should not be applied in allocation policy in terms of quantitative optimizing under particular sets of projected conditions. Instead, it should be interpreted in terms of direction, speed, and range of continuous reallocation in response to constantly changing conditions that can be projected only vaguely and are always uncertain with respect to actual occurrence.

Third, for applying the concept "optimum use" in the latter interpretation, social institutions and their changes are of paramount interest. Historically, the multiple-use concept has been an important part of such an institution, namely, the legislation and administration affecting allocation of forest and range resources within the U. S. National Forests. Administration of the federal forests constitutes an allocative system for forest and range resources that is reviewed here with respect to structure, functioning, and performance. For water resources, likewise, an allocative system exists that has been studied elsewhere.

Fourth, in the past, the allocative system, of which multiple use has been an important part since the beginning of the century, has performed well. The multiple-use concept gave flexibility to the system for responding in a socially desirable direction with adequate promptness and extent. During this period, changes of economic conditions favored replacing a single use, namely, timber, by multiple use, including timber, forage, and recreation.

Fifth, in view of the uncertainty about future demands for the various types of recreation, the irreversible nature of depletion of wilderness areas, and their relatively low value for other uses, the large degree of administrative discretion which was shown to be characteristic for the structure of the existing allocative system should, looking into the future, be supplemented by statutory provisions similar to the "Wilderness Bill" (S. 1123) introduced in the 1960 Congress. This supplement is needed in order to insure an adequate response of the allocative system when changing economic conditions favor one particular use, namely, recreation. Still, the multiple-use concept will remain an important and useful part of the system. Extension of the concept to similar systems, for example, the administration of the national parks and of the national game ranges, would seem desirable.



MULTIPLE USE AS A CONCEPT FOR WATER AND RANGE POLICY<sup>1</sup>Emery N. Castle<sup>2</sup>

Professor Wantrup has brought us one of his typically interesting, provocative, and closely reasoned papers. Those of us working in resource economics should be grateful for having a person such as Dr. Wantrup in our field who asks such searching questions and who consequently forces us to think through the implications of our work. If every area of specialization had such a person, it would be richer as a result.

Having said the above in all sincerity, I can be equally sincere in saying that I wish Dr. Wantrup had clarified certain points more completely. Dr. Wantrup mentions three difficulties of quantitative optimizing: (1) the problem of valuation, (2) the problem of institutional constraints, and (3) the problem of uncertainty. I certainly have no quarrel with him on these points and believe he has performed a service by analyzing them so thoroughly. However, it may be possible to admit these difficulties and yet believe there is fruitful work to be done on natural resources policy issues using quantitative optimizing techniques as an aid. I will attempt to be explicit and demonstrate what I mean.

Professor Wantrup says "the difficulties are more severe for optimizing in public policy than for optimizing in subsectors of the economy such as individual farms or firms," and "this kind of uncertainty imposes severe and, as far as I can see, insurmountable limits on the validity and relevance of quantitative optimizing for policy decisions." One might conclude from such remarks that he believes formal programming has no usefulness as an aid to policy decisions. He goes on, however, to state that the more sophisticated practitioners of formal programming try to avoid the above-mentioned difficulties as much as possible by the way they formulate their problems. He singles out Tolley and Dorfman as examples of such practitioners. Professor Wantrup in one place may leave the impression that he rejects all quantitative optimizing. But in another he makes clear that he recognizes that the difficulties he so carefully explains may not pertain with equal force to all programming work in this area that has policy implications. Programming models vary all the way from general formulations of the entire economy of a state to within use and single watershed studies. Most, if not all, of these studies have policy implications. This, plus the fact that they use some form of programming, is all many such studies have in common. One may question whether Wantrup's paper conveys the degree of variation that exists among such studies.

The difficulty may stem in part from our general understanding of the words "policy decision" and "optimizing." If by "policy decision" one has in mind a final, once and for all, answer to a problem of (say) resource allocation for the entire nation and uses formal programming for this purpose, one kind of criticism applies. If the consequences of certain explicit assumptions

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<sup>1</sup> A discussion of the paper by S. V. Ciriacy-Wantrup

<sup>2</sup> Department of Agricultural Economics, Oregon State University.

or relationships are deduced for the purpose of providing information to decision-makers and programming is used for this purpose, quite a different situation may prevail. Many people doing the latter know they are not optimizing resource use in the welfare economics sense. Their objectives are much less ambitious. Optimizing can be defined in terms of a "Pareto optimum," and the conditions for achieving this optimum are well spelled out in the literature on welfare economics. An "optimum" programming solution may be something quite different depending upon the function which is maximized or minimized, and the restraints that are chosen. My position is that programming studies may be able to tell us something. The trick is to formulate the programming problem in such a way that the results will be relevant to policy issues and that they are interpreted in light of the difficulties previously mentioned. The point I am making is that formal programming may be used at various levels of aggregation and the function that is maximized or minimized may or may not represent a social optimum in the traditional theoretical sense. The results may aid in choosing a direction to move or the speed with which movement is made, or to avoid making mistakes rather than in searching for a precise quantitative "optimum" to a particular policy problem on a highly aggregative basis. This is not to suggest that highly aggregative studies are of no value nor that suboptimizing studies necessarily have great value. It is to suggest that the same criticisms do not apply with equal force to all studies that use techniques which maximize or minimize. I would not expect Professor Wantrup to disagree with the above, and he might argue that all of this is either covered or implied in his paper. Perhaps so, but I believe it is sufficiently important to be made explicit.

The only other point that I would mention in the time available to me pertains to the desirability of flexibility in allocative institutions. I agree with Professor Wantrup that it is desirable to have this flexibility so that changing economic forces can be reflected in allocative decisions. But is it enough to provide for such flexibility and leave it there? When flexibility is achieved, decisions must be made at a particular time and place to resolve conflicts. Having worked rather closely with civil servants in the field of water in recent years who have been vested with such authority, I have no desire to reflect on either the ability or the dedication of these men. However, they are often uncertain about the economic consequences of some of their decisions. It would seem that an appropriate activity for economists is to investigate tools of potential usefulness to these people. It is too early to say whether formal programming models will prove useful here or not; certainly the difficulties Professor Wantrup mentions are present, but I doubt this is a question that can be decided on an a priori basis. The question will be decided, I believe, on the basis of continual empirical testing. Ex post analysis of experience, with all its limitations, appears to deserve more attention as a means of testing our predictions and isolating the reasons for our errors. I am in full agreement with respect to Wantrup's comments on Tolley's study in this respect.

Again, I would not expect Professor Wantrup to disagree on the basis of this paper or his other writings. Perhaps it is expecting too much to ask him to go into detail on every point he raises. But it is appropriate for a discussant to do so.

MULTIPLE USE AS A CONCEPT FOR WATER AND RANGE POLICY<sup>1</sup>John A. Edwards<sup>2</sup>

The phrase "multiple use" is recurrent throughout the literature of public resource policy since the U. S. Forest Reserve Act of 1897. It is indeed "an especially hardy perennial," as Dr. Wantrup observes. The persistence of this phrase and the abundance of literature concerning the role of multiple use in policy formulation testify to its importance in the minds of public resource managers, their employers, their friends, and their critics. Perhaps, the most surprising thing about multiple use, however, is not its persistence as a subject of conversation and discourse, but, rather, the amount of this discussion which has taken place in an atmosphere of confusion regarding its meaning. As a consequence, we find advocates of "multiple use" employing arguments in its defense as a goal of public policy that are practically indistinguishable from those used by its detractors.

The paper that Dr. Wantrup has presented here represents an attempt to consider thoroughly the nature and meaning of "multiple use" as the phrase is commonly used. He approaches this undertaking by a consideration of the economic-theoretic concept to which it is related, and of the operational concept which provides the basis of a number of our allocative policies. The consequences of this investigation take the form of two tentative conclusions:

(a) multiple use is theoretically sterile, representing merely an allocative pattern which may or may not be optimal; an analysis of the conditions under which "multiple use replaces or is replaced by single use is... identical with an investigation of changes in the optimum combination of uses;"

(b) despite its theoretical sterility, multiple use has had operational significances as practiced by the U. S. Forest Service.

Neither of these is satisfactory--the first because it is merely tautologous, the second because it substitutes an object for an idea, a person for an abstraction. More importantly, I feel that its premise is incorrect, and, therefore, I necessarily disagree with the inferences concerning the concept of an optimum which Dr. Wantrup draws from his discussion of "quantitative optimizing." I shall attempt to convey the nature of my dissatisfaction in the following discussion. Perhaps, incidentally, the definition of multiple use can be made somewhat clearer as a consequence.

I would begin by removing "optimal use" from the category of a useful scientific fiction and reinstating it as a valid operational concept as well as an explicit policy goal. Dr. Wantrup defines a useful scientific fiction as "a deliberate, conscious deviation from reality... not an hypothesis or theory... not intended to be validated by testing and empirical evidence... but useful as a stimulus for or as a part of hypotheses and theories which can be so tested.

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<sup>1</sup>Discussion of paper by S. V. Ciriacy-Wantrup.

<sup>2</sup>Department of Agricultural Economics, Oregon State University.

That means the test of a scientific fiction is its conceptual usefulness, its expediency, in understanding, explaining, and predicting reality."<sup>3</sup> The optimum allocation of resources among alternative uses and users can be defined as that allocation which is the most favorable, or conducive, to the attainment of a specified goal, or set of goals. It is commonly recognized that the majority of individuals attempt to allocate their relatively scarce resources among alternative uses in a manner which is most likely to lead to the attainment of their personal goals, however they may be formulated. It is instructive to note that, even at the minimum level of social aggregation, it is impossible to specify an absolute quantitative optimum. This is true for either one or both of the following reasons:

1. the nonsatiety of human wants, i. e., an optimum once achieved becomes suboptimal at the instant at which it is achieved; and
2. problems of immeasurability, uncertainty, changing physical environment, etc., result in less than perfect knowledge; this in turn implies that an optimum can only be specified in a stochastic framework.

Recognition of this nonspecificity, however, does not invalidate the concept of an optimum, nor the assumption that optima exist and motivate behavior.

At higher levels of social aggregation two types of allocative procedure are followed. The first with which we are concerned is typified by the institutional arrangements collectively termed a market. In an economy where the ownership of productive resources is not always invested in their employers, and where the consumption of commodities is not performed solely by their producers, the market provides a method whereby the scarce resources and products of the society are allocated among the competitive goals of the individuals comprising the society. If the market is a competitive market, it is possible to define an optimum allocation as one that is most conducive to the attainment of the goals of each and every individual comprising the society.<sup>4</sup> The presence of monopolistic, or monopsonistic power, in the market precludes the resultant allocation most conducive to the attainment of the goals of any individual other than those of the holder of the monopoly, or monopsony, power.

It is, of course, highly improbable that an optimum allocation exists in any market at any point in time. The same factors which serve effectively to limit the de facto attainment of an absolute optimum in the individual solution are operative in determining the operation of a market. A given allocation will more nearly approximate an optimum the greater the degree of knowledge,

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<sup>3</sup>S. V. Ciriacy-Wantrup, "Policy Considerations in Farm Management Research in the Decade Ahead," Journal of Farm Economics, vol. 38, no. 5, December, 1956, pp. 1301-1311. It is interesting to note that the same test that Wantrup applies to ascertain the usefulness of a scientific fiction, M. Friedman and others use to test the validity of a theory. However, Wantrup denies that a scientific fiction is a theory since it is not intended to be tested. It follows, therefore, that it is impossible to distinguish between a "useful" or a "useless" scientific fiction. It also follows that what Wantrup calls a useful scientific fiction is, in fact, a theory.

<sup>4</sup>Such an optimum may vary with changes in the distribution of income and asset ownership.

the greater the stability of tastes, technology, and asset distribution, the greater the mobility of resource and product supplies, and the more effective the control of monopoly power. Such a market, a perfectly competitive market, constitutes an optimal allocative system.

Needless to say, such a market does not exist, but equally certain is the statement that the more nearly an allocative system approximates a perfect market the more nearly it approximates an optimal allocative system. By and large, the role of the Federal Government in U. S. economic history has been one of attempting to increase the degree of perfectability in imperfect markets. Certainly, the legislation and subsequent court interpretation of statutes defining monopolistic practices and prescribing the permissible limits of this power have been of this nature. Marketing information and regulatory and supervisory agencies established by Congress and operating under the direction of the executive have been of a similar nature.

In addition to these activities, however, the government is directly involved in the allocative process through its tax power and as a owner of resources. Tax policy and its impact on allocations is not in question here, but the policies of the Federal Government as a monopolist owner of resources is of concern.

In attempting to delineate an optimal allocative system in relation to government-owned resources, the definition of a perfect market is relevant, as is the distinction between allocative systems optimal in competitive and non-competitive markets. The essential feature of a perfect market--that which makes it an optimal allocative system--is its responsiveness to changing economic, cultural, and social conditions. If it is conceded that a perfect market constitutes an optimal allocative system with respect to privately owned resources, it follows that a governmental allocative policy which most nearly approximates a perfect market in its essential features, i. e., responsiveness to change, will most nearly approach an optimal allocative policy as well. This conclusion is independent of the question of the ability of the policy formulator to quantify an optimal allocation at any point in time, flexibility constituting the sole criterion.

I submit that the so-called multiple-use policy of the U. S. Forest Service is, perhaps, the most nearly optimal allocative policy of any governmental administrative organization in the United States today. This statement, although strong, is based upon a comparison, not of the allocations that each agency has made, but rather on the possibilities of changing the allocations. It would appear that the sources of this flexibility are twofold: the nature of the legislation by which Congress established the agency, and the administrative procedures developed by the agency within the framework of this legislation.

All of these points, I am sure, are in accord with Dr. Wantrup's views. Yet, somehow, one is uncomfortably confronted with the statement that the "Wilderness Bill--or a bill similar to it--should... be enacted now." If flexibility in allocations is the desired objective, then a change in allocation should not require an act of Congress, but should be vested in an administrative agency, the decisions of which are subject to appeal to higher levels of executive decision, as well as to the Congress. Yet, this is what the Wilderness Bill envisages--an allocation of resources to a single use, such allocation being immune to change except by a change in the law of the land. This is the same type of allocative system which pertains to the resources administered by the National Park Service that Dr. Wantrup finds to be objectionable.



It might also be noted that Dr. Wantrup's exclusive identification of recreational use of public resources with wilderness use is also open to question. Beyond doubt, the demand for recreation has increased and will continue to increase. However, wilderness recreation is only a part--and a small part--of the total recreational demand. Since wilderness recreation and the more conventional forms that do not require as large an expenditure of time and treasure, e. g., motoring, fishing, and hunting, as they currently are conducted in the nonwilderness areas of the public domain, are in the majority of instances competitive uses, the relevant question is the relative changes in the demands for these types of recreation<sup>5</sup>--not the change in demand for all recreation relative to that for lumbering and grazing products. These non-recreational uses are not necessarily competitive--in fact are often complementary<sup>6</sup>--to the more conventional recreational uses. In the absence of any evidence to indicate that either of the contentions is untrue, Dr. Wantrup's endorsement of the Wilderness proposal now before Congress must be considered to be a normative judgment reflecting his personal preferences and not the results of an objective investigation. Such judgments are perfectly legitimate in every respect provided that they are so designated explicitly. The implication in Dr. Wantrup's paper is to the contrary.

What then, is the concept of multiple use applied to resource policy? Simply stated it would appear to be the idea that the maximum amount of flexibility should be maintained in the procedures of resource allocation to the end that such allocations will more readily reflect the optimum allocation of resources based upon societal preferences. Consequently, optimum allocation is an operational policy objective.

Dr. Wantrup and I reach essentially the same conclusion. We disagree, however, in terminology. The basis of this disagreement is, I feel, Dr. Wantrup's insistence that optimum use as a policy goal depends upon measurement--"quantitative optimizing" as he refers to it. That this insistence is unwarranted, I have attempted to show. To his colleagues who do attempt to define optimum allocation--by imputing to them the idea that they are attempting to apply formal programming techniques to the overwhelming problem of total public resource allocations between competitive uses, and by inferring that they are so self-satisfied that they do not recognize that such allocations as they do make change over time--it is also unfair. The majority of such attempts by economists have been in reference to situations in which the major allocation--between irrigation and recreation in a water project, for example--has been made on other grounds, the formal allocation being confined to that between various sub-uses and sub-users within one of the major uses--irrigation of hay versus potatoes, water for farmer A versus farmer B. Such an allocative procedure would appear to be more acceptable than any ad hoc allocative basis that might be employed. Any subsequent difficulties in changing such an allocation are due to human nature (a reluctance to participate actively in one's own execution) rather than to the programming procedure itself.

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<sup>5</sup>According to a letter from the Regional Forester, Region I, U. S. Forest Service, Missoula, Montana, recreational use, as indicated by the number of visits, in the Selway-Bitterroot Primitive Area increased 32 percent during the period 1953-58; during the same period total recreational visits in the non-primitive areas of Region I increased 90 per cent.

<sup>6</sup>E. g., access, increased game cover and browse.

MULTIPLE USE AS A CONCEPT FOR WATER AND RANGE POLICY<sup>1</sup>

S. V. Ciriacy-Wantrup

"Glorious confusion," remarked Professor Joan Robinson recently at a faculty seminar at Berkeley when a young staff member attacked her for views she had never held. Her remark could well serve as heading for this reply to one of my discussants. While I am not concerned about any disagreement with my views--in fact, I always welcome a closely reasoned criticism of them--I am interested that they are not distorted. It is for the latter reason that I accept the invitation for a reply kindly extended by the Chairman of the Water Resources Committee.

To read Dr. Edwards' discussion is to step, with Alice, through the looking glass and find my views on the main issues exactly reversed. Thus, I am represented as insisting "that optimum use as a policy goal depends on measurement--quantitative optimizing." Is it possible that, during the many years when I supposed myself to be insisting that optimum use as a policy goal does not depend upon and should not be identified with quantitative optimizing, I have all along been understood to be saying just the opposite? Or has Dr. Edwards stepped through the looking glass by himself?

Another argument from the other side of the glass is his claim that I identify recreational use of natural resources with wilderness use, whereas, on the reality side of the glass, I identify wilderness use with one recreational use.

Not content with looking glasses, must Dr. Edwards also tilt at wind-mills and valiantly defend optimum use as a theoretical concept against my nonexistent attack? I hesitate to refer him to chapters 6, 17, and 18 in my book, Resource Conservation, Economics and Policies, where the relevance of optimum use as a theoretical concept is discussed; who can say how my analysis might appear viewed through the looking glass? A major point of the present paper is that the conceptual value of optimum use should not be compromised by the oversimplifications built into the programming tools that are so efficient in quantitative optimizing.

As to Dr. Edwards' polemics, he evidently does not know the meaning of the word "tautology." He also does not know that qualitative operations (identification, classification, comparison, rank-ordering) and clinical analysis of unique situations are not identical with normative judgments. To imply that they are less "objective" than quantitative operations and statistical inference is a part of the glorious confusion. Graduates of the University of Chicago remember that the Social Science Research Building bears Lord Kelvin's famous dictum: "If you cannot measure, your knowledge is meager and unsatisfactory." But, evidently, some have forgotten Professor Frank Knight's suggestion that to social scientists the "practical meaning [of Kelvin's dictum] tends to be: 'If you cannot measure, measure anyhow.'"<sup>2</sup>

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<sup>1</sup> A reply to the papers by Castle and Edwards.

<sup>2</sup> Eleven Twenty-Six, A Decade of Social Science Research, ed. Luis Wirth (Chicago: The University of Chicago Press, 1940), p. 169.

The optimizers are not at all reluctant to criticize those economists who are not carried away by the apparent efficiency of some presently popular quantitative tools and who maintain that reduction in qualitative variety is attained at the cost of quantitative indeterminacy. I am dismayed, therefore, that Dr. Edwards can answer my criticism of quantitative optimizing only by crying that I am "unfair." But I find consolation in the thought that if some people cry "unfair" it merely means "touché"!

Dr. Castle is too good an economist to be satisfied with stepping through the looking glass or tilting at windmills. His point, that the usefulness of linear programming should be appraised a posteriori, is well taken. I would have been grateful, therefore, if he had mentioned at least one actual study that convincingly demonstrates the superiority of formal programming over other approaches to those types of policy decisions--changing the "rules of the game"--in resource allocation and development with which my paper is concerned. For other types of problems, quantitative optimizing may well have a place, provided (1) the model employed is little concerned with values; (2) the treatment of social institutions as constraints is logical; and (3) the influences of time and uncertainty are small. Usefulness for natural resource policy is limited on all three counts.

Dr. Castle recognizes these limitations. I am afraid, however, that his contention that these limitations are sufficiently recognized by "everyone" does not correspond to the facts. I did not cite examples of lack of such recognition because the orientation of my paper was not intended to be polemical. No constructive purpose would be served by supplying these citations now. Readers familiar with our professional journals and the current research programs of departments of agricultural economics will have no difficulty in finding examples.

# MEASUREMENT PROBLEMS RELEVANT TO THE IRRIGATION PHASE OF WATERSHED DEVELOPMENT<sup>1</sup>

A. R. Blanch<sup>2</sup>

## Introduction

In recent years, many papers and much discussion have been concerned with watershed policy, with the basic concepts and economic principles applicable to benefit-cost analyses, and with the growing competition for water among agriculture, industry, municipalities, and recreation. The broad concepts involved have been explored more adequately than I could hope to do. Accordingly, the scope of this paper is confined to a relatively small segment of the larger complex problem and to areas within this segment which, I believe, warrant greater attention.

The discussion is developed from the viewpoint of a practicing economist faced with the task of developing an economic base for consideration of remedial action for the solution of agricultural water problems. As such, it is more concerned with specific measurement problems encountered in the application of economic theory than with a discussion of the theory itself. This restricts the discussion to some of the economic concepts and measurement problems in the quantification of physical and economic data needed to evaluate adequately the agricultural benefits that accrue from resource development.

The primary objective is to present some physical concepts and data needed from the physical scientists and to explore briefly the relationship of the physical data to the problem of economic evaluation. The discussion is restricted to four measurement problem areas: (1) The production function of water; (2) the demand for irrigation water; (3) interfarm relationships in use of irrigation water on projects; and (4) project impacts or external economies and diseconomies. For purposes of orientation, a review of the pertinent economic and physical concepts is necessary.

## Orientation

### Economic

The basic economic principles and concepts as set forth in Chapter II of the "Report to the Inter-Agency Committee on Water Resources," prepared by the Subcommittee on Evaluation Standards, provide the conceptual economic framework for the discussion. Three of these principles are especially pertinent: (1) "The most effective use of economic resources required for a project is made if they are utilized in such a way that the amount by which benefits exceed costs is at a maximum rather than in such a way as to produce a maximum benefit-cost ratio or on some other basis; (2) for federal projects, a comprehensive public viewpoint should be taken. Such a viewpoint would

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<sup>1</sup>The opinions expressed herein are those of the author and do not necessarily represent the views of the Farm Economics Research Division, Agricultural Research Service, or of the U. S. Department of Agriculture.

<sup>2</sup>Farm Economics Research Division, Agricultural Research Service, U. S. Department of Agriculture.

include consideration of all effects, beneficial or adverse, short-range or long-range, that can be expected to be felt by all persons and groups in the project's entire zone of influence; and (3) the project as well as any separable segment or increment thereof selected to accomplish a given purpose should be more economical than any other actual or potential available means, public or private, of accomplishing that specific purpose."

### Physical

Evaluation of direct irrigation benefits consists of economic interpretation of physical quantities and relationships. The economist must appreciate and understand the characteristics of water and its relationship to land and plant growth if he expects to evaluate it.

As a factor of production, water has some unique characteristics. Its fugitive nature and its propensity to escape confinement and to move through the land as well as on the surface have given rise to the epigram: "Water, a fugitive in nature, has confounded the legislature." This ability of water to move through seemingly solid substance is appreciated by the homeowner plagued with a solid concrete but leaky basement, and the hard rock miner, whose mine, in seemingly solid rock, is flooded by copious quantities of water. Cross-sectional capacities of surface channels are undoubtedly minute in relationship to the cross sections available underground for water movement.

The fugitive nature of water may be illustrated by the waters of the Sevier River in Utah. Along this river the flow of the stream is systematically diverted for irrigation at successive downstream diversion points. A part of the water thus diverted escapes evaporation and transpiration use by plants, returns to the stream via underground percolation and surface drainage, and in turn is rediverted at successive downstream points. This process is repeated along the length of the river; it gives rise to the popular concept that the waters of the river are reused seven or more times. In one 20-mile reach with 16 separate diversions and total decreed rights of 120 cubic feet per second, it is reported that when 60 per cent of the 120 CFS or 72 CFS are available at the first diversion point, 100 per cent of decreed rights can be diverted at each of the 16 diversion points.<sup>3</sup>

One other important physical characteristic of water that has economic implications is soil storage--the ability of soils to hold water against the pull of gravity and thus to provide a supply of water in the root zone for plant use. The amount of water retained in the soil for plant use depends mainly upon soil texture and depth. The range is from about 2.5 inches per foot of soil for the clays to about half an inch for the coarse sands. A deep silty clay soil will retain a reservoir of available water in the first five feet of soil of about 12.5 inches, and in the first 10 feet of 25 inches. The supply of water that is retained as soil storage for use by deep-rooted crops such as alfalfa can be fairly large.

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<sup>3</sup>Dudley Crafts, "Problems in the Reorganization of Irrigation Companies in the Sevier River Basin, Utah," unpublished paper, 1958, p. 7.

Studies of transpiration use of water by alfalfa at Mesa, Arizona, found that alfalfa used 64.3 inches of water, two-thirds of which was obtained from the first five feet and one-third from the second five feet of soil.<sup>4</sup> Under these conditions, a silty clay soil would retain sufficient water in 10 feet of soil for two to five months of consumptive use by alfalfa, depending upon the months considered and the percentage of the total available water that the plants could extract without materially affecting the rate of growth. This principle is also demonstrated in the Humboldt River Basin in Nevada. In this basin, it is generally recognized that upon saturation of the meadowland soils in May and June sufficient moisture will be retained to produce a crop of meadow hay without subsequent irrigation. Percolating ground water may also be a contributing factor.

A review of the portion of the hydrologic cycle in which water is on or in the land, from the viewpoint that economic implications are involved, may be helpful.

The typical hydrograph and its use in irrigation analyses is familiar to all. Of more immediate interest is the route water traverses from the time it falls on the watershed until it is consumed, evaporated, or discharged into the ocean or inland sea.

Precipitation falls on the watershed in the form of rain, hail, sleet, or snow and in various amounts according to geographic location. In areas where the total amount of precipitation is not sufficient to replace accumulated soil-moisture deficiencies, precipitated water either evaporates or infiltrates into the soil and is subsequently consumed in the transpiration process at the location at which it falls. In other areas of the watershed, the quantity of precipitation exceeds the soil-moisture deficiencies at the time of occurrence or at the time of snowmelt. The excess water percolates through the soil mantle, and part of it is intercepted at lower elevations by the depressions occupied by streams. Occasionally, rainfall intensities exceed the infiltration rates of the soil and result in flow of water over the surface of the land to the stream. But the percentage of all water appearing in a stream that reaches the stream via the overland surface route is usually small. Hydrologists have estimated that in Utah only about five per cent of the water appearing as streamflow reaches the streams via surface flow.

It may be argued that diversion of the stream for irrigation and the application of quantities of water to the soil in excess of the soil-moisture deficiencies set up the same conditions at the location of the canals, laterals, and irrigated fields as occur naturally in the water-yielding areas of the watershed. Apparently, there are at least four possibilities for the disposition of that part of the water infiltrating into the soil that is in excess of that needed to bring soil moisture up to field capacity.

1. It percolates through the soil mantle and reappears as streamflow at lower elevations.
2. It enters ground-water aquifers as recharge.

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<sup>4</sup>Carl Harris, "Irrigation, Yuma, Ariz.," unpublished paper, 1956

3. Because of moderate restrictions in the underground transportation route it is forced close enough to the surface enroute to the stream to be consumed by plants.

4. Because of severe restrictions in the underground transportation route it is forced to the surface and evaporates.

The latter results in waterlogged areas and drainage problems.

Tail water from irrigated fields, canals, and laterals is disposed of by one of these four methods, is trapped in low areas and evaporated, or is returned to the stream through drainage ditches, natural and manmade.

The pertinent economic and physical concepts applicable to the discussion that follows and briefly outlined.

### Production Function for Water

A satisfactory technique for the development of the production function for irrigation water is not available. The problem is a complex one. The wide range in water-holding capacity of the different soils, the practical problems involved in operation of distribution systems, and methods of irrigation result in wide differences in the amount of water required at the farm headgate to obtain the same level of yields of a specific crop. To illustrate, results of a survey designed to obtain information on the amount of water used by farmers on different crops in the American Fork-Dry Creek area of Utah<sup>5</sup> indicated that water used to produce a five ton yield of alfalfa ranged from about 20 to 108 inches. There were no indications that the management abilities of farmers using large quantities of water were inferior to those using small quantities. The soil resources they were managing, however, differed greatly. The group using large quantities of water was irrigating rather coarse-textured soils 10 to 20 inches deep and underlain with coarse gravel. The other group was irrigating fine-textured soils that were more than five feet deep. Because of location, irrigation of the coarse-textured soils may also have resulted in subsurface irrigation of the fine-textured soils through percolation of ground water. Attempts to correlate total quantities of water applied with crop yields without first rigidly classifying areas by physical characteristics including soils, distribution systems, and timing of water supply is a fruitless process.

Based on observations and limited investigations, other aspects of the production-function problem include the apparent sensitivity of crop yields to critical increments of water. This is especially true of annual crops that must reach maturity or the fruiting stage before yield is obtained. At any time during the growing period that soil moisture in the rooting zone approaches or reaches the wilting point, the plants either die or growth is severely curtailed and yield is either reduced or eliminated. The incremental quantity of water that actually results in variations in yield, in relation to the total quantity required to complete the life cycle of the plants in order to obtain any yield, is probably very small.

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<sup>5</sup> A Method of Evaluating Irrigation Benefits of Watershed Protection, American Fork-Dry Creek Watershed, Utah, Interim Report of Study, USDA, ARS, 1960.

The principle is also applicable to forage crops and is discernible in historical records of harvested acres and crop yields during the years affected by irrigation water shortages. For example, the effect of the drought in Nevada in 1959 resulted in a reduction in the acreage of irrigated meadow hay harvested between 1958 and 1959 of 62.5 per cent, and a reduction in yield per acre for acres harvested of only 22.5 per cent. The effect of the drought during the 1930's was greater, with a decrease in acres harvested between 1930 and 1931 of 82 per cent and a decrease in per acre yield of only 20 per cent.

Cropping patterns are also affected by prolonged drought periods and in areas with consistent water shortages. Acreages of crops that mature early and crops that can be harvested before reaching maturity are increased, while acreages of crops that must reach maturity before yields are obtained and that require late-season water are curtailed.

The impact of drought and conversely the production function for water is, therefore, a three-pronged affair involving reduction in per acre yields, reduction in harvested acres, and adjustments in cropping patterns.

### Demand for Irrigation Water

The total quantity and seasonal distribution of water required to produce crops is essential to any economic evaluation. But quantification of water requirements at the farm headgate is difficult because of the wide range in physical situations -- water-holding capacities of different soils, soil-moisture levels required for production of different kinds of crops, irrigation methods, physical features and methods of operation of the distribution systems, and lack of adequate historical data on the quantity of water used in producing different crops. As a consequence, a theoretical procedure has evolved which, in general, entails establishment of the amount of water consumed by each crop, the aggregation of water requirements for all crops, and the division of the result by an estimated irrigation efficiency with the latter expressed as a percentage. Although this theory appears to be sound, in practical application difficulties are encountered.

Consumptive use requirements seem to imply an optimum situation in which soil moisture is maintained at desirable levels throughout the growing period. This technique is useful in establishing an ideal water-supply situation, but it does not satisfy the need for quantification of the actual gross water supply and net consumptive use in areas subject to periodic or chronic water shortages.

Recent studies of consumptive use of water by alfalfa at Mesa, Arizona<sup>6</sup> and Reno, Nevada<sup>7</sup> also indicate the need for considering the entire 12-month period rather than only the frost-free or growing period.

The Arizona studies found that transpiration use by alfalfa varied from 1.2 inches in January to 11.8 inches in July.

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<sup>6</sup> Carl Harris, op. cit., p. 4.

<sup>7</sup> Clyde E. Houston, Consumptive Use of Water by Alfalfa in Western Nevada, University of Nevada Bul. No. 191, 1955.



At Reno, Nevada, continuous soil-moisture and water-application studies were made from May 9, 1950 to November 29, 1951, on an alfalfa test plot of one-third of an acre. The study showed a consumptive use of irrigation water of 35.92 inches from May 6 to September 26 in 1950 and 33.41 inches from April 12 to October 4, 1951. Irrigation water applied, in 11 irrigations each year, measured 55.2 and 56.9 inches, respectively.

If, however, the total losses in soil moisture for the 12-month period from May 24, 1950, to May 19, 1951, are considered, the consumptive use of irrigation water totals 38.99 inches or the consumptive use of an additional five inches of irrigation water during the nonirrigation season.<sup>8</sup>

Corresponding tank studies at the Reno location showed consumptive use of irrigation water by alfalfa during the irrigation seasons of 1951, 1952, and 1953 of 33, 40, and 44 inches, respectively. Yields, oven-dry basis, were equivalent to 2.5, 4.0, and 4.9 tons per acre, respectively.

Average consumptive use of irrigation water by alfalfa in the Truckee Meadows area of Nevada, developed by use of the theoretical approach, is reported to be 23.3 inches.<sup>9</sup> The difficulty of establishing reliable consumptive use requirements is illustrated by the range in estimates of consumptive use of water by alfalfa in the Reno area.

A pertinent conclusion of the Reno studies is stated as follows: "Soil moisture sampling during the nonirrigation season indicates need for a post-season or preseason irrigation to bring soil moisture to field capacity prior to the irrigation season."

The point to be emphasized, I believe, is that regardless of when irrigation takes place, each irrigation requires a supply of water, and the quantity required should be included in the estimate of the total annual quantity of water required to maintain satisfactory levels of irrigated crop production. In areas where additional water is required to leach salts in order to maintain or improve salt balance, the amount of water so required should also be included in the estimate of the total annual irrigation water requirement. Failure to do so will result in allocation of the total available water supply to too many acres and in overevaluation of water.

The other element involved in the demand for irrigation water is its seasonal distribution or timing. The purpose of irrigation is the replacement of soil moisture as it is depleted by plant growth. As such, the demand for irrigation water precedes evapotranspiration use. Water must be added to soil storage before it can be used by plants. Timing of demand, therefore, seems to depend upon (1) the total available water-holding capacity of the soil, (2) the percentage of the available soil moisture the plants can extract without adversely affecting rate of growth or quality of yield, and (3) the rate of evapotranspiration.

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<sup>8</sup> Clyde E. Houston, op. cit., p. 18

<sup>9</sup> Clyde E. Houston, Consumptive Use of Irrigation Water by Crops in Nevada, Nevada Agr. Expt. Sta. and Division of Irrigation and Water Conservation, Soil Conservation Service, USDA, Bul. No. 185, 1950, p. 10.

To illustrate the economic principles involved, a hypothetical watershed was assumed, and monthly demand for irrigation water, water shortage, and storage capacity required were computed by the use of two methods (Table 1). The evapotranspiration use of irrigation water shown in the table roughly approximates the results of the consumptive-use studies at Reno. All other basic data used, although hypothetical in nature, are believed to be sufficiently similar to typical situations in the arid West to serve the purpose of illustration.

Method 1 assumes that during the irrigation season the timing of monthly demand for irrigation water is synchronized with monthly evapotranspiration use.

Method 2 assumes that demand for irrigation water precedes evapotranspiration use and depends upon the available water-holding capacity of the soils, rate and total of annual evapotranspiration use, and soil-moisture level at the beginning of the irrigation season. A maximum limit of available soil-moisture depletion of 60 per cent was also imposed. Both methods assume irrigation of 20,000 acres and a technical irrigation efficiency of 50 per cent.

In method 2, it is assumed that at the beginning of the irrigation season, the soil-moisture level would be brought up to field capacity on the entire 20,000 acres as rapidly as the water supply from the stream would permit. Under practical irrigation conditions, this would not occur because systems are not designed with sufficient capacity to bring all acres to field capacity at a given point in time. To test the effect of reducing the total quantity of water that could be stored in the soil, method 2, alternate 1, was computed. Conditions assumed for alternate 1 involve a reduction in soil depth, as well as total available water-holding capacity. An alternate assumption would be to assume a different depth and storage capacity of the soil and impose a limitation of, say, 90 per cent of the total storage capacity as the upper limit of soil water storage at any point in time. This reduction in the total quantity of water that could be stored in the soil did not affect the differences between the two methods.

A comparison of the results of use of the two methods shows that with method 2 used in preference to method 1, in the hypothetical situation, the total quantity of irrigation water required to meet demand is increased by 6,667 acre-feet and includes evapotranspiration use during the nonirrigation season. Water shortage and water required from storage are decreased by 10,834 acre-feet, or 23.2 per cent, and streamflow available for storage is decreased by 21,667 acre-feet, or 26.3 per cent. The economic impacts of these differences on storage costs, storage rights, redistribution of water supplies, and equity among holders of water rights are readily apparent. The two methods are graphically illustrated in Figure 1.

Under practical situations, the magnitude of the difference between the two methods would be modified. It would not, however, be eliminated until the water-holding capacity of the soils decreased to very low levels. Underestimates of the total annual quantity of water required to maintain satisfactory levels of crop yields would intensify the economic impacts. These impacts would materially affect the economic efficiency of resource use and the maximization of project benefits.

TABLE 1. TWO METHODS OF ESTIMATING DEMAND FOR IRRIGATION WATER, IRRIGATION WATER SHORTAGE, AND STORAGE CAPACITY REQUIRED TO SATISFY DEMAND.

	Oct.	Nov.	Dec.	Jan.	Feb.	March	Irrigation Season					Total	
							April	May	June	July	Aug.		Sept.
<b>Basic Information-Hypothetical Watershed-Arid West</b>													
Evapotranspiration use exclusive of precipitation acre-inches per acre	1.0	0.5	a/0.0	+1.0	+0.5	2.0	3.0	4.0	6.5	9.0	7.5	4.5	36.5
Consumptive use, 20,000 acres, 1,000 acre-inches	-20	-10	---	+20	+10	-40	-60	-80	-130	-180	-150	-90	-730
Water available from stream, 1,000 acre-inches	60	60	60	60	60	80	150	450	550	180	50	50	1,810
<b>Method No. 1. Demand for irrigation water synchronized with consumptive use. (Irrigation season only.)</b>													
Conditions: 50 per cent irrigation efficiency; 20,000 acres irrigated													
Irrigation water required, 1,000 acre-inches							120	160	260	360	300	180	1,380
Surplus water, 1,000 acre-inches	60	60	60	60	60	80	30	290	290				990
Water shortage, 1,000 acre-inches										180	250	130	560
Summary: Irrigation water required 1,380,000 acre-inches or 115,000 a. f. ; water shortage 560,000 acre-inches or 46,667 a. f. ; water available for storage 990,000 acre-inches or 82,500 a. f. ; active storage capacity required exclusive of evaporation and transmission losses, 560,000 acre-inches or 46,667 a. f.													
<b>Method No. 2. Demand for irrigation water precedes consumptive use, soil storage considered. Conditions: Irrigated soils have available water-holding capacity of 2.0 inches per foot, 20 inches in first 10 feet of soil and a total capacity of 400,000 acre-inches; 20,000 acres irrigated; 50 per cent irrigation efficiency; depletion of available soil water during the irrigation season limited to 60 per cent of total or a minimum level of 160,000 acre-inches.</b>													
Available water in soil, 1st of month, 1,000 acre-inches	310	290	280	280	300	310	270	285	400	400	400	400	---
Consumptive use during month, 1,000 acre-inches	-20	-10	---	a/+20	+10	-40	-60	-80	-130	-180	-150	-90	---
Addition to soil moisture by irrigation, 1,000 acre-inches							75	195	130	180	150	---	730
Irrigation water required, 1,000 acre-inches							150	390	260	360	300	---	1,460
Water available from stream during irrigation season							150	450	550	180	50	50	1,430
Surplus water, 1,000 acre-inches	60	60	60	60	60	80		60	290				730
Water Shortage										180	250	---	430
Summary: Water required 1,460,000 acre-inches or 121,667 a. f. ; water shortage 430,000 acre-inches or 35,833 a. f. ; water available for storage 730,000 acre-inches or 60,833 a. f. ; active storage capacity required exclusive of evaporation and transmission losses 35,833 a. f.													

Difference between methods 1 & 2:

Water shortage and storage requirement 46,667 - 35,833 - 10,834 a. f. or a 23.2 per cent reduction in storage capacity required.

Water available for storage 82,500 - 60,833 - 21,667 a. f. or a 26.3 per cent reduction in water available for storage.

Method No. 2, alternate 1. Demand for irrigation water precedes consumptive use, soil storage considered.

Conditions: Irrigated soils have available water-holding capacity of 2.5 inches per foot, 12.5 inches in first five feet of soil and a total capacity of 250,000 acre-inches; depletion of soil moisture during irrigation season limited to a minimum level of 100,000 acre-inches; all other conditions same as method No. 2.

Available water in soil, 1st of month, 1,000 acre-inches	160	140	130	130	150	160	120	135	250	250	250	250	---
Consumptive use during month, 1,000 acre-inches	-20	-10	---	a/+20	+10	-40	-60	-80	-130	-180	-150	-90	---
Addition to soil moisture by irrigation, 1,000 acre-inches							75	195	130	180	150	---	730
Irrigation water required, 1,000 acre-inches							150	390	260	360	300	---	1,460
Water available from stream during irrigation season, 1,000 acre-inches							150	450	550	180	50	50	1,430
Surplus water, 1,000 acre-inches	60	60	60	60	60	80	---	60	290				730
Shortage of water, 1,000 acre-inches										180	250	---	430

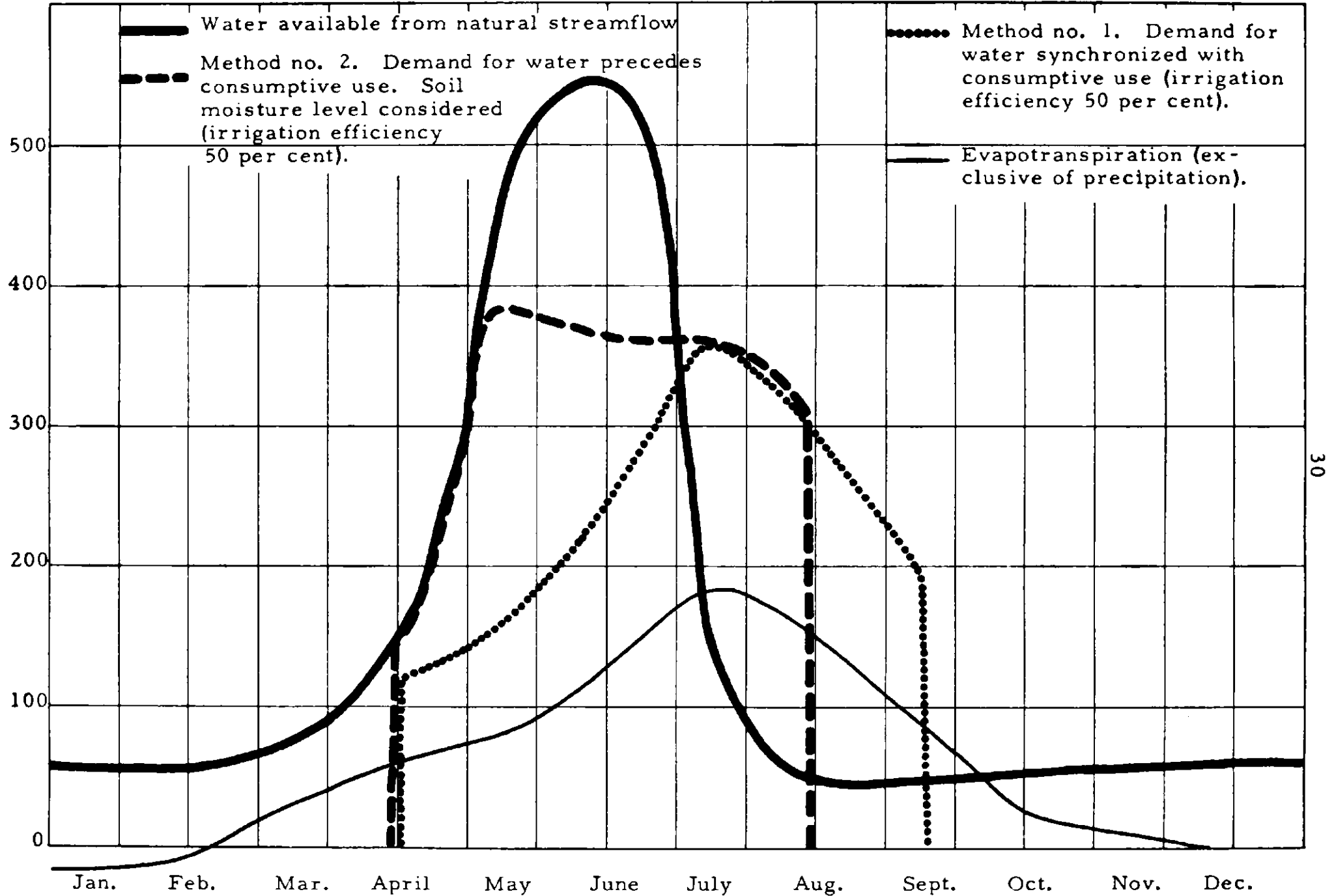
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Summary: Irrigation water required 1,460,000 acre-inches or 121,667 acre-feet; water shortage 730,000 acre-inches or 35,832 a. f. ; active storage capacity required exclusive of evaporation and transmission losses 35,833 a. f. ; difference between methods same as method No. 2.

a/When precipitation during the month exceeds evapotranspiration a net increase in soil moisture occurs.

1,000 acre-inches

### Demand for Irrigation Water



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Figure 1. Two methods of estimating the timing of demand for irrigation water.

## Project Interfarm Water Use Relationships

In many watersheds, the irrigated and irrigable lands are located in relatively narrow bands bordering the stream. Both surface and underlying strata slope toward the stream channels. The stream provides a natural drainage channel for drainage of the irrigated lands.

In many instances, topography of the irrigated area is such that tail water and percolating ground water from irrigation of farms at the highest elevations appear in natural drainage channels and are diverted and reused in irrigating farms at lower elevations. When project lands extend for considerable distances along the stream channels, separate diversions and canals are frequently used to serve the project area. Return flow that reaches the river and appears as addition to streamflow between project diversion points is also available for diversion and reuse. When these conditions exist, both technical irrigation efficiency and economic efficiency of use of project water supplies are increased over those on individual farms.

To illustrate this principle, let us assume that four acre-feet of water per acre are required at the farm headgate of individual farms, and that direct agricultural benefits are computed at \$12 per acre of \$3 per acre-foot of water. That one-half of one acre-foot of the four acre-feet applied reappears as return flow and is intercepted and reused on a lower farm. An additional one-half of one acre-foot of return flow appears in the stream above the last project diversion point and is diverted and reused with corresponding benefits. The benefit per acre-foot of water delivered to the farm headgate from the storage reservoir would then consist of \$3 on the first farm, \$1.50 on the second farm, and \$1.50 on the third farm, or a total of \$6 per acre-foot. This principle is applicable also to return flow resulting from seepage losses in the canals and laterals, which is intercepted and reused within the project area.

Operation of this principle is especially evident on the Smith Fork, Paonia, and Silt projects in Colorado. Irrigated lands on these projects lie on the floodplains of the streams, benchlands, and mesa tops. Differences in elevation of these lands are relatively large. Abrupt changes in elevation range up to several hundred feet. Return flow, involving both tail water and percolating ground water appearing as surface flow at lower elevations, is intercepted within the project areas and reused. In many instances, percolating ground water subirrigates lower-lying fields without appearing on the surface.

The maximum extent of reuse of irrigation water is illustrated by the case of two farmers interviewed on the Smith Fork project. One farmer's land is on the floodplain, his neighbor's land is adjacent to his but on a mesa about 100 feet higher. These farmers have an agreement whereby the total water to which both are entitled is delivered to the farmer on the mesa. Return flow from his fields is collected by the second farmer in a ditch at the base of the mesa and reused by him to irrigate his farm. The farmer on the mesa has agreed that in exchange for the privilege of using the floodplain farmer's original supply of water, he will not divert tail water from his lower fields in another direction, which would be physically possible. Reuse of irrigation water on these Colorado projects is common practice, not a rare occurrence.

Benefit-cost analyses of irrigation development have been restricted primarily to individual farms. Beneficial effects of reuse of irrigation water within the project area have not been considered, except to the extent that the hydrologists have included return flow as a part of project water supplies.

Because of the difficulties involved in locating and quantifying return flow, evaluation in either physical or economic terms is believed to have been negligible. Although it is difficult to locate and quantify, reuse of return flow within project areas is a significant item on many projects.

### External Economies and Diseconomies

Economic evaluation of external economies and diseconomies resulting from proposed irrigation development has received relatively little attention. I believe this is due, primarily, to three reasons. First, the quantification of the physical effects of project development on the regimen of the streams below the project areas has not been established; second, during the initial phases of irrigation development, the external effects of projects are largely beneficial; and third, the principle of return flow, its magnitude, and its relationship to ground water have been given inadequate attention by technicians. The latter, however, has been one of the primary causes of the long, costly, and sometimes bitter history of water litigation between individuals and between groups. As more of our rivers approach full development and competition for water within agriculture and between agriculture and other uses is intensified, both litigation and the problems of external economies and diseconomies of project development become more acute.

Prerequisite to an understanding of the problems involved in evaluating external economies and diseconomies is an appreciation of the physicist's concept of water as matter, one aspect of the doctrine of beneficial use, and the implacability of watershed equations. The law of physics referred to is the simple concept that matter, in this instance water, may change its form but cannot be destroyed. Through manipulation, man can change the rate, the place, and the service water performs as it changes form, but he cannot destroy it. In the broader sense, he can also contaminate it. Irrigation water development is concerned with the rate, place, and services provided by water as it changes form through the evaporation and transpiration processes. The indestructibility of water should be kept in mind.

In an economic sense, the right to beneficial use of water is a vested right with monetary value. The right, however, extends only to beneficial use. It does not go beyond this point. The vested right is usually established by demonstrated beneficial use over a given period of time. In the case of irrigation, demonstrated beneficial use is evidenced by production of plants that have value to man.

In essence then, the right of beneficial use applies only to water consumptively used in production of plants that have value to man. The right, therefore, does not extend to that portion of the total water that is diverted from the stream but which escapes beneficial use and returns to the stream. Such water may be visualized as an essential transportation medium for the water beneficially used. Enroute to the farm and from the farm to the stream, nonbeneficial use of water also occurs through evaporation and through transpiration use by plants with no value, or limited value, to man.

Upon return to the stream, the water that functioned as a transportation medium is subject to appropriation by another user. Upon diversion of the return flow by the second user, it too is divided into three parts--that used beneficially, that used as a transportation medium, and that used nonbeneficially. The water used as a transportation medium again returns to the stream. The

process may be repeated until all water in the stream is consumptively used both beneficially and nonbeneficially. The law recognizes the vested right of beneficial use of the second and subsequent users.

Once this regimen has been established for initial irrigated areas, subsequent irrigation development or adjustments in water use within specific localized areas in a watershed sets in motion a series of adjustments in the regimen. These effects can be either beneficial or adverse.

The total supply of water in a watershed is limited by the total volume of water falling on the watershed in the form of precipitation. This assumes that there are no transbasin imports or exports of water. To obtain the total yield of water, the total volume of consumptive use occurring in place or enroute to streams on all watershed surfaces is subtracted from the total volume of precipitation. This may be expressed in the form of an equation ( $TVP = ET_{Up} + TWY$ ). That is, the total volume of precipitation equals the evaporation and transpiration use of precipitated water either in place or enroute to the streams plus the total water yield. Total water yield in turn is equal to evaporation and transpiration use of streamflow plus discharge ( $TWY = ET_{Us} + D$ ). These two implacable equations are controlling. Man's use of water must occur within the limits imposed. It is recognized that man can change the total volume of water yield by manipulating watershed plant cover and that discharge can include both surface and subsurface flows.

For simplification, the following discussion assumes that the geology of a watershed is such that: (1) Irrigation water diverted from the stream in excess of that used consumptively in the evaporation and transpiration processes returns to the stream; (2) geology restricts discharge to surface flows; and (3) there are three irrigated areas in the watershed. The water yield-use-discharge equation for this watershed may be expressed as follows: Total water yield equals evapotranspiration use in each irrigated area plus discharge ( $TWY = ET_{U1} + ET_{U2} + ET_{U3} + D$ ). Separation of evaporation and transpiration between beneficial and nonbeneficial use can be made-- $TWY = ET_{Ub1} + ET_{Un1} + ET_{Ub2} + ET_{Un2} + ET_{Ub3} + ET_{Un3} + D$ .

These equations establish the limits of water use. When discharge is large, project development and expansion of irrigated areas with accompanying increases in consumptive use, both beneficial and associated nonbeneficial, will, in general, result in external economies. Discharge will be reduced, and the seasonal fluctuation in the stream below the new development will be modified. Streamflow, augmented by return flow from the new irrigated area, will likely increase during the irrigation period, thus enabling the lower irrigated areas also to increase their beneficial consumptive use, through either an increase in irrigated acreage or more adequate irrigation of existing acres. As discharge approaches zero, irrigation developments that result in increases in consumptive use in upstream areas which exceed unused discharge will impinge upon the water supplies and vested rights of the lower areas. Because water is required to perform the essential transportation function and maintenance of salt balance, discharge from the watershed cannot be reduced to zero. As a transportation medium, water also performs the service of leaching or maintaining favorable soil salt balances in all of the irrigated areas.

Projects or programs that result in reductions in the quantity of water nonbeneficially consumed will increase the quantity of water available for irrigation and beneficial consumptive use. As a part of the salvaged supply would normally be used as a transportation medium, return of this water to the stream will augment streamflows below the area of initial use and external economies may also accrue to downstream areas.





MEASUREMENT PROBLEMS RELEVANT TO IRRIGATION  
PHASE OF WATERSHED DEVELOPMENT<sup>1</sup>Emery N. Castle<sup>2</sup>

Watershed planning and project evaluation have received increased attention in recent years as is witnessed by the theoretical literature on the subject of benefit-cost analysis. Yet benefit-cost proponents assume that a rather frightening amount of technical information is available to the planner and that he has the knowledge and the techniques to make efficient use of this information. The previous paper makes clear that there are a number of unknown interesting physical relationships that have considerable economic relevance. I have had the opportunity of reviewing Mr. Blanch's outline and commenting on an earlier draft. Rather than discussing all of his paper in detail, I have decided to select what, to me, are the more interesting points and illustrate their importance by reporting on some work I have been doing with and for the Soil Conservation Service.

In connection with individual farm measurement problems, Blanch mentions a lack of information on (1) the quantity and seasonal distribution of water required economically to produce adapted crops and create or maintain favorable salt balances and (2) the production function for water by productivity land classes under various levels of management efficiency and of land and irrigation system development. With respect to project measurement problems, Blanch describes the interdependency that exists among various parts of the watershed and details the type of information needed to make this concept useful in project and watershed planning.

If one assumes, for the moment, that he has at his fingertips all of the technical information desired to plan a watershed, the problem of specifying the interrelationships involved in a conceptual framework capable of solution in an empirical way is a challenging one. On the surface it would appear that activity analysis used in conjunction with modern computing facilities would provide a means of handling this situation. By reporting on some of my work with the Soil Conservation Service I believe I can do two things: (1) underline the importance of knowing more about actual production functions for water, and (2) indicate that even if we knew all of the physical relationships involved, difficulties would still remain before the information could be aggregated in a meaningful manner.

To illustrate some of the problems and potentialities of activity analysis in watershed planning, an irrigation problem is analyzed in some detail.<sup>3</sup> Green Valley, typical of many of the intermountain valleys of the West, has more irrigable land than there is water for irrigation. The stream from which

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<sup>1</sup> Discussion of the paper by A. R. Blanch.

<sup>2</sup> Department of Agricultural Economics, Oregon State University.

<sup>3</sup> This problem was posed by Carroll Dwyer of the Soil Conservation Service as being typical of numerous situations in the western United States. The data were supplied by Mr. Dwyer and are taken from a particular project area where this problem exists.

water is obtained is a typical snow-melt stream. Its peak run-off coincides with the snow-melt period (March-May). By June 1, normal streamflow is inadequate to provide a full irrigation supply unless supplemented by storage. By July 1, the streamflow is negligible.

The net acreage now irrigated is 5,100 acres. Green Valley reservoir, with a usable capacity of 12,650 acre-feet was built to store excess spring flows. The total water supply--streamflow and storage--is 18,000 acre-feet. Normally, with the cropping pattern and system and farm irrigation efficiencies now prevailing, reservoir drawdown starts in June, since the streamflow in June is limited on the average to about 4,183 acre-feet. After July 1 the entire irrigation supplement comes from storage.

The canal system from the reservoir to the irrigated land loses an average of 40 per cent of the amount diverted. The present farm irrigation efficiency is 45 per cent which gives an over-all irrigation efficiency figure of 27 per cent ( $.60 \times .45 = .27$ ).

It is possible to make the following changes that might make more efficient use of the limited water supply.

1. Rehabilitate the canal system to provide 90 per cent instead of the existing 60 per cent efficiency.
2. Improve farm irrigation system efficiencies from 45 to 60 per cent.
3. Maintain the present cropping pattern but increase the amount of water applied to each crop.
4. Change the cropping system to make a more profitable use of the limited water supply.
5. Any combination of the above.

The project limitations as determined by the Soil Conservation Service are:

1. Soil and topographic conditions require that land be in soil-conserving crops (hay or pasture) 50 per cent of the time.
2. 3,700 tons of alfalfa must be produced for winter feed.
3. Not over 510 acres of wheat may be grown because of acreage limitations.
4. No additional water is available.
5. Potato acreage cannot exceed one-fourth of the acreage in soil-conserving crops.

The questions to be answered are:

1. Is the present water usage the most profitable assuming the existing cropping pattern and irrigation system efficiencies?
2. Is the present cropping pattern optimum given the existing efficiencies?

3. What benefits would be forthcoming from improvements in (a) the canal system, and (b) farm irrigation efficiency?

Activity analysis can be used to answer these questions. The alternative crops (seven in this situation) can be treated as processes. Restrictions are water supply in May, June, and after July 1, the conservation requirements, acreage restrictions, and the hay requirements. Water requirements by months for each crop are necessary to construct the matrix. Additional processes are needed to permit stored water to be transferred from one period to another if that becomes necessary to maximize profits.

The interpretation of the results illustrates some of the problems associated with programming in that they bring out some of the basic assumptions relative to the decision-making situation. Income could be improved by 27 per cent simply by applying more water per acre and leaving the cropping system unchanged. This would mean that some land now farmed would be left idle. With an optimum cropping pattern and with increased water application on a per acre basis, income could be increased by about 93 per cent. This means that considerable improvement could be made in income with existing irrigation efficiency. Why are these improvements not made? There are various economic and noneconomic reasons underlying the present pattern. Increasing water usage while preserving the existing cropping pattern would result in a reduction of acreage irrigated. Changing the cropping pattern and increasing water application would cause two drastic adjustments. Acreage would be reduced by about 12 per cent from the existing situation. This might mean the acreage irrigated on some farms would decline severely. The other change would be in the direction of greater specialization in crop production. Farmers might believe that this specialization would be associated with greater income variability.

If an investment in the improvement of irrigation efficiency is being evaluated, can the assumption be made that farmers will use the increased supply of water more effectively than they are using the present supply? The results make it possible to compare points on the "high" level of management (Table 1). Moving to the "high" level of management involves the assumption of the perfect economic man. Should plan 3 and 4 be compared or should the level of technology prevailing at present be used in evaluating investment possibilities? (Figure 1) The probable productivity of the investment would be somewhere between these two extremes. The investment undoubtedly would open up opportunities to the farmers; therefore, it is doubtful that the existing level of achievement would be appropriate. It is also doubtful that optimum cropping combinations and optimum water application levels would be appropriate.

The above brings out two important considerations with respect to the present discussion. If we use "theoretical" water requirements in watershed planning we may find they deviate substantially from the use farmers are actually making of the water. This can lead to a considerable overvaluation of water. In this case, there was a 27 per cent difference in benefits depending upon which set of water requirements were used. This merely underlines what Blanch has said.

The other consideration is highlighted by the difference in use plans 2 and 3 as given in Table 1. Assuming the theoretical water requirements, we find that the farmers are rather far from an "optimum" cropping pattern as predicted by the programming model. The following explanations of this deviation might be given:

(1) The enterprise data are incorrect, (2) incorrect or incomplete restrictions may have been entered in the model, (3) farmers have inadequate information, (4) farmers are irrational, and (5) it is inappropriate to reduce the decision-making situation facing farmers and the objectives of farmers to the single assumption of profit maximization.

If explanation (1) is given, additional empirical work will resolve the difficulty. Further study of the farms would permit any error in program restrictions to be uncovered (explanation 2). Farmers may have inadequate information about their business. If so, such results may have value in directing educational programs (explanation 3). I have no evidence that would suggest explanation (4) is valid and would not accept it as a likely hypothesis. If, as I suspect, explanation (5) has validity, then research in the area of decision-making is suggested.

In any case, if explanations (4) or (5) are valid the technique may be a poor predictor of the future and will be of questionable value in evaluating public investment potential. If explanation (3) is true, public investment should be accompanied by an education program. Further empirical work will suggest if improvement in the data or restrictions is needed.

I believe the above results emphasize the importance of knowing rather elementary physical relationships. Until we know these, we cannot determine if the difference in predicted and actual performance is because of error in the data or because of mistaken assumptions with respect to farmer motivation or farmer decision-making.

TABLE I. ACREAGE IRRIGATED, INCOME AND VALUE OF WATER FOR VARIOUS USE PLANS.

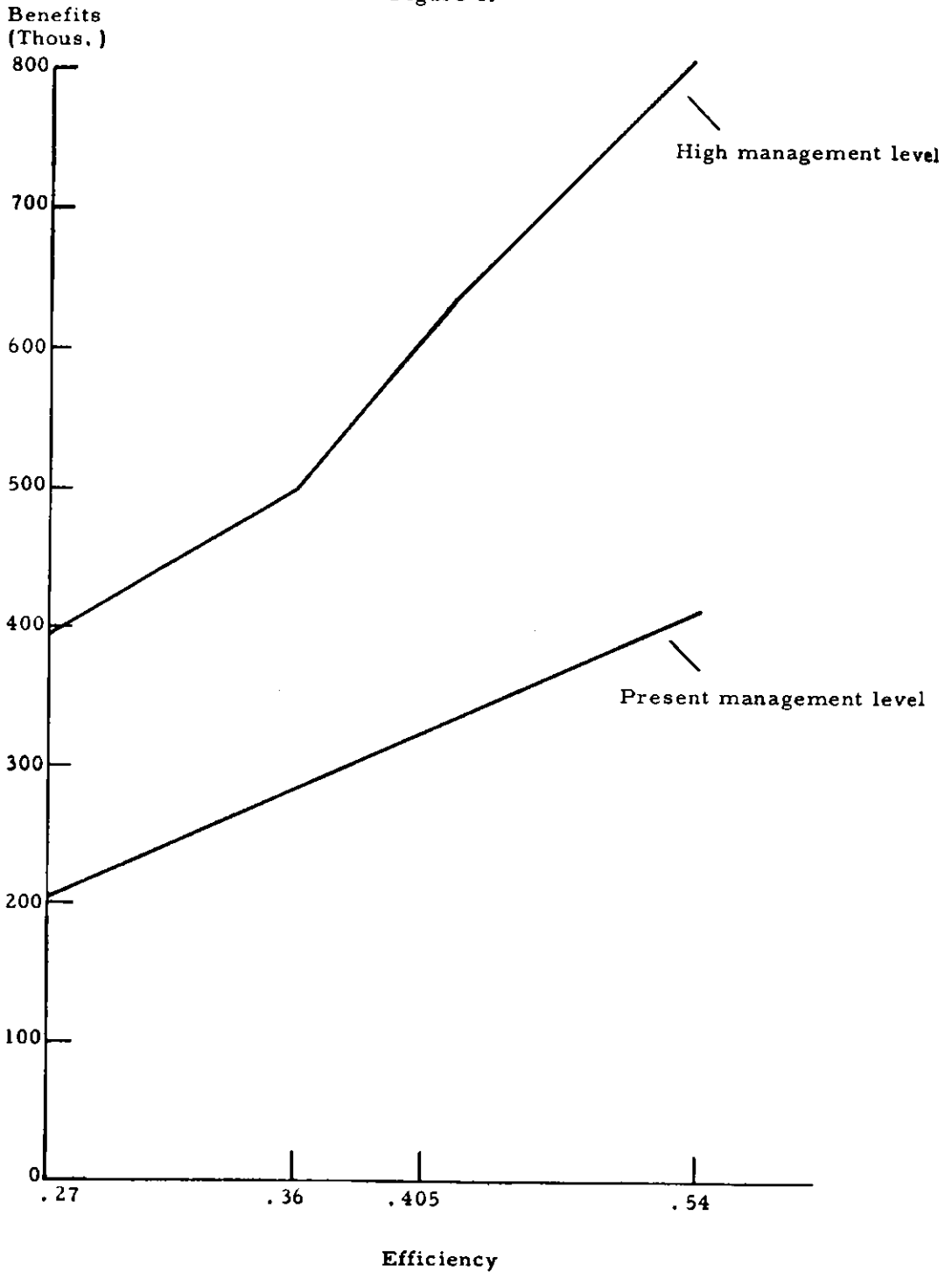
Use plan <sup>a</sup>	Acreage irrigated	Benefits (Dollars)	Value of water per acre-foot <sup>b</sup> (Dollars)	Benefits as a percentage of use plan 1	Efficiency
1	5,100	204,656	11.37	100	.27
2	4,851	261,127	14.51	127	.27
3	4,533	395,303	21.96	193	.27
4	6,799	454,990	25.28	222	.36
5	6,898	603,097	33.50	295	.405
6	9,248	808,498	44.92	395	.54

<sup>a</sup>The following use plans were evaluated:

1. Present use of water, existing cropping pattern, and efficiency of 27 per cent (.60 x .45).
2. Full use of water (recommended rates), existing cropping pattern, and efficiency of 27 per cent (.60 x .45).
3. Full use of water, optimum cropping pattern, and efficiency of 27 per cent (.60 x .45).
4. Full use of water, optimum cropping pattern, and efficiency of 36 per cent (.60 x .60).
5. Full use of water, optimum cropping pattern, and efficiency of 40.5 per cent (.45 x .90).
6. Full use of water, optimum cropping pattern, and efficiency of 54 per cent (.60 x .90).

<sup>b</sup>This is a gross value figure in that it is a return to the limiting factors.

Figure 1.



SOME ASPECTS OF LAND OWNERSHIP AND EFFICIENCY OF  
RESOURCE USE FROM THE PUBLIC VIEWPOINT<sup>1</sup>

Walter E. Chryst<sup>2</sup>

This paper proposes to deal in a preliminary way with at least some of the questions of economic efficiency that are raised when individuals have a right to control the use of, and receive the income from, natural resources. By and large, emphasis is on agricultural land, although I suspect that the more interesting problems deal with water. I have not succeeded in clarifying the basic principles of water law in my own mind--water law seems to have at the same time attributes of both extreme flexibility and extreme rigidity.

The question of the interrelation between the right to use a resource and the efficiency with which it will be used has a long history--according to the anthropologist Carleton Coon, the study of the question dates back some 8,000 years to the postglacial optimum. At that time, vegetable and animal life appeared in some abundance, man abandoned his transient life as a hunter, and his possessions were no longer limited to the weight he could carry on his back. Increasing mobility was followed by accumulation of possessions, which in turn was followed by the development of the property concept. With property, there could be trade, and with trade, there was an incentive to specialize in production. With specialization in production came the need to regulate the use of irrigation water; to regulate the use of irrigation water in the community interest, property rights in land were established; and to administer these rights, government was created.

This historical note is offered to establish two points: (1) That many people have been working in this field over the last 80 centuries--no doubt many very capable people--and that questions still remain; and (2) That the origin of land law was the need to increase output in the community interest. The latter point is the first page of tenure history, but one that was no longer applicable when Justice Holmes commented that in land tenure matters "... a page of history is worth a volume of logic."<sup>3</sup>

The pages of history upon which the courts now rely chronicle the growth of this child of the state to the point where it is stronger and more enduring than its parent. Aside from urban zoning, the state rarely reallocates the right to use land in order that a higher social interest may be served; indeed, in some countries of Latin America the right to use a tract of land is the most durable of all social institutions--it has survived all forms of social reorganization including civil revolution--and represents the safest of all investments.

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<sup>1</sup>The opinions expressed in this article are those of the author and do not necessarily represent the views of the Farm Economics Research Division, Agricultural Research Service, or the U. S. Department of Agriculture.

<sup>2</sup>Agricultural Economist, Farm Economics Research Division, Agricultural Research Service, U. S. Department of Agriculture.

<sup>3</sup>Holmes, *N. Y. Trust Company vs. Eisner*, 256 U. S. 345, 349. Quoted in Cardozo, The Nature of the Judicial Process, Yale University Press, New Haven, 1955, pp. 54-56.



In these countries, the question of productivity of the land and its potential contribution to the economic welfare of the population does not establish the use of land, nor has it done so in any large measure throughout the course of modern history. Use is established by the self interest of those who are legally entitled to receive any payment that might be offered for its use.

In considering the impact of the right to use upon use, perhaps it would be best to deal first with the conditions that relate to efficiency in the use of land and with some of the aspects of methods of holding and transferring land that may lead to its misuse.

### The Efficiency of Resource Use

It has become fashionable in these times to argue that in our present state of affluence we are no longer primarily concerned with the efficient use of our resources, and that our attention might better be directed toward the planning of our leisure time. Sophisticated arguments are offered to call the means-ends scheme into question. The inability to make interpersonal comparisons of utility and the changing of the optimum patterns of resource allocation induced by shifting incomes have been used to challenge the determinancy of the economic system, with the apparent destruction of the maximization concept as a consequence. If, however, profit maximization at the firm level can be achieved by reducing costs without economizing on the use of labor or if it can be achieved through increases in output of magnitudes insufficient to inconvenience any other producer by causing a decline in the price of the product, it is still honored as a worthy cause. Those who would restrict the output and divide the market will have little difficulty in finding professional support to demonstrate that these actions are not incompatible with the public interest.

Yet for all of these arguments, apparently there are some who continue to face an economic problem. A surprisingly large number of people indicate that they do not like their work; the demand for shorter hours, longer vacations, or another holiday for the same or more pay is heard rather frequently in union-management negotiations; and in more and more families, the wife is finding employment outside the home at the cost of considerable inconvenience to herself and her family. All these things suggest that for many, work has disutility, or, what amounts to the same thing, that many people engage in activities that they find more or less unpleasant in order to have something to exchange for some of the goods and services they want.

The maximization "dogma" notwithstanding--and recognizing that the current arguments are no doubt rigorously developed--if we treat the onerousness of labor as the basic cost, it would seem that under certain conditions two avenues are open to make those who work a bit happier. The number of items moving in the marts of commerce with completely inelastic demands, that is, items that would not be consumed in any larger quantities regardless of how low their prices might fall, is somewhat limited. Thus, if resources can be organized so that the onerousness of labor is not increased but the output of some items is increased without any diminution in the output of other items, at least some consumers will be made better off. A corollary of this, of course, is a situation in which the same amount of goods is produced with less labor and the gain is taken in form of a reduction in the disutility inherent in work.

The second avenue is somewhat more vulnerable to the fire of the critics of economics. However, society can and does redistribute income, and it can thus be assumed that the distribution of income is socially acceptable. Here within the framework of this socially acceptable distribution, we are concerned with the rearrangement of resources to produce more of the items that people seem to prefer, at the expense of production of items that are lower on the preference scale. We would suggest that the transfer of any unit of a specific resource from a given use to another use for which consumers are willing to exchange more, recognizing that these uses may be separated in time, is an improvement in the efficiency of resource use.

In this framework, the relevant costs are those utilities that are given up when a resource is transferred from one use to another. If efficient resource use is to be achieved, the cost, in terms of the utility lost, must be associated with the return, or the utility gained. Anything that interferes with this association must have as its consequence either an aggregate output that is less than the total possible output or a pattern of output that differs from the one desired. One criterion then in appraising the economic efficacy of an institution is the degree to which it serves to associate costs and returns.

### The Efficient Use of Land

In the economic process, land may be viewed as the naturally created environment in which economic activity takes place. Because it is naturally created, land has no cost to the group in the sense that tools may have in terms of deferred consumption or that labor may have in terms of disutility. It is recognized that land is rarely a direct source of satisfaction; that aside from such experiences as a beautiful view or the first warm wind of March, land usually extends its bounty in conjunction with labor and capital.

Specific combinations of labor and capital usually yield different results in different natural environments, a factor that accounts in large measure for regional differences in agriculture, geographical differences in population densities, and, when combined with historical accidents, the dispersion of industry. A society seeking the maximum return for its effort and saving must give a great deal of attention to the location of its economic enterprises if the naturally created factors are to make a maximum contribution.

The two points that follow seem relevant in considering the use of natural resources: (1) That all natural resources which will yield any product over and above the necessary reward to the labor and capital employed jointly should be used; and (2) That these resources should be allocated among their uses on the basis of the familiar equimarginal principle.

If these two conditions are met, a third condition will follow--land will have been substituted to the fullest possible extent for labor and capital in the productive process. Stated another way, if all of the land that has an economic

potential is used, and if it is allocated among its alternative uses so that no land could be transferred from one use to another without reducing the total output, land will function with maximum efficacy in saving labor and capital costs.<sup>4</sup>

### Some Effects of Land Tenure Rights on Efficiency of Resource Use

It is conceivable that our method of distributing rights in land may cause two types of separation of costs and returns. Rights in land are usually granted to individuals (or other legal entities) for the use of a specified resource existing at specified points in space and time. The economic activity of the land user is a time-consuming process carried out in a large physical environment, and quite often it has its consequences at another geographical location or in a subsequent time period. This spatial and time separation of the act from its consequences affords the opportunity to transfer costs and returns between individuals, and it may be expected that some types of economic adjustments will follow as a consequence.

The geographic separation has long been recognized and has been dealt with extensively in tenure literature. The example most often cited is that of the part-owner operator who may have an opportunity to shift part of the cost of his operation to the owner of the rented land by conducting his cropping operations on the rented land and his feeding operations on the owned land.

A second example that has received considerable attention comes from watershed and drainage development work. It is often suggested that an improvement on one farm will not yield enough to the farm owner to justify its installation, although its aggregate benefits would far exceed its cost. In some measure at least, this problem has been overcome by taxation according to benefits, or through the use of public subsidy.

Apparently, a similar situation exists in the use of the public range here in the West. It has been suggested that the problem of developing appropriate cost-sharing arrangements has prevented an effective program of range improvement--with the ranchers not having sufficient security of tenure to undertake the improvements on their own and the government being unwilling to do so, given the level of rents.

The more important consequence of the tenure-induced dissociation of costs and returns in the use of agricultural land is, in my judgment, the one involving time. The obvious and classical dissociation here is the one that gives rise to the conservation problem. The individual owner can use his land resource to maximize his return during his lifetime without giving a great deal of attention to the productivity of the land in the next generation. We have few impediments to prevent a landowner from bringing productivity forward and realizing the return therefrom, but the public bears much of the cost of mitigating the consequences of this intertemporal transfer.

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<sup>4</sup>This concept of land in the productive process as an economizing agent in the use of labor and capital, now all but disappeared from American economic thought, has recently been restated rather forcefully by Hawtrey. See Ralph Hawtrey, Productions, Functions, and Land--A New Approach, the Economic Journal, Vol. LXX, No. 227, March, 1960.

The second type of intertemporal transfer is less obvious, but its impacts are far broader. In general, the methods used to transmit rights in land require the purchaser or user to pay, or to commit himself to the payment of, land income before it is earned. The time involved may be very short, as with a one-year rental contract; or it may be very long, as with a 30- or 40-year amortized mortgage. In an economy as variable as agriculture, reality may deviate appreciably from the long-run expectations of the buyers and sellers of land, and current costs for the land factor may be a rather weak reflection of future returns.

Several interesting but neglected consequences stem from the capitalization of expected land earnings into current land values, particularly when money is borrowed on the strength of these expectations and the repayment of this money becomes an element of the fixed-cost structure of the farm firm.

First, variability in production and price is shifted largely to labor and capital. In the "intermediate run," our lending institutions and mortgage laws tend to give land a prior rather than a residual claim on agricultural income. This is most easily observed when there is a crop failure and the land has produced nothing, yet the land cost must be met. This cost can be met only from the return to labor and capital, through a reduction in standard of living and/or neglect of the maintenance and replacement of capital items.

This possibility is not wholly neglected in the decisions made by farm buyers. Buyers realize that their economic vulnerability is a function of the liability/income ratio and that the lower this ratio, the easier it is to withstand economic storms. Tenure data, which indicate that owner-operated farms are usually smaller than tenant-operated farms in the same area, suggest that land purchasers may adjust to the hazard of mortgage commitments by restricting the amount of the land input. To the extent that this restriction on the land input is offset by additional inputs of labor or capital, an uneconomic use of resources may result.<sup>5</sup>

Second, I suggest that the dissociation between cost and returns engendered by the land-transfer mechanism can be a source of market instability, which leads to further malallocations of resources. As a competitive producer, a farmer who is faced with a decline in the price of his products and the necessity of meeting his fixed commitments has only one line of action open--to increase output. If a large number of his fellow producers are in similar straits and the increased output is offered on an inelastic market, such as prevails in agriculture, prices will again fall and increased supplies will again be required. Thus, the land market and the mortgage market may tend inversely to correlate supplies of commodities with their prices and to generate general instability in the agricultural market. It is significant, for the thesis presented here, that this expansion is accomplished at the cost of the future. Production is increased in the period of falling prices so that the firm may exist in the future to produce in the future. This increase in output is gained by throwing into the current struggle some of the resources that had been reserved for the future--items such as soil fertility, machine maintenance and replacement reserves, potential breeding stock, and, as was observed in the

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<sup>5</sup> Miller, Chryst, and Ottoson, Relative Efficiencies of Farm Tenure Classes in Intrafirm Resource Allocation, Iowa Agr. Expt. Sta. Res. Bul. No. 461, Ames, 1958.

last depression, even the maintenance of health. This transfer from future to present uses can have as its consequence excessive production in one period at the cost of additional production in subsequent periods. This transfer is particularly unfortunate when population is increasing, as the subsequent period will be the one of greater need.

Third, it has been suggested that the land value capitalization phenomenon has tended to separate aggregate savings and capital formation in the economy. People save to buy land. In doing so, they deprive themselves of or postpone needed consumption in order to create more capital in the economy. But this saving is directed toward the acquisition of something that already exists and whose supply will not be increased regardless of the amount of saving done. It is necessary, of course, to determine the disposition of the purchase price by the seller of land before firm statements can be made about the relation of increasing land values to saving to capital formation. If, however, the seller has any propensity to consume, it would seem that the amount of capital formed would be less than the amount of saving accomplished.<sup>6</sup>

In a similar vein, Keynes<sup>7</sup> has suggested that land frequently commands a liquidity premium as it possesses two attributes of money: (1) A low elasticity of production, and (2) A low elasticity of substitution. The desire to hold land when there is uncertainty as to the future quantity and value of money may drive the mortgage rate of interest up, perhaps far beyond the earning capacity of the land, thus attracting money away from current investment in newly produced capital assets. This phenomenon probably is not present at this time in this country, as it may be in many underdeveloped countries of Latin America, but it is somewhat difficult to reconcile the \$129 billion valuation of farmland with a \$16 billion return to land, labor, and capital. The relationship among the land market, the mortgage market, and the business cycle would seem to be an appropriate subject for further exploration.

The last relationship between tenure institutions and efficiency of resource use with which I shall deal concerns the problems created for economic adjustments within agriculture.

I suggest that our property and land-market mechanism may preclude the possibility of any enduring prosperity for farm people. If there is any substantial advantage to engaging in agriculture, those who are capable of farming or collecting rent may be expected to compete for the basic requirement, land, until the advantage is lost and labor and capital can earn no more in agriculture than elsewhere. Let one generation enjoy a period of increasing demand and rising prices and there will be many in the next generation who, upon weighing their economic prospects in agriculture and given the price they must pay for the land factor, will conclude that their best opportunity lies elsewhere. And of those who remain, only those whom the market has favored with a miscalculation can expect more than the amount their labor would earn in some nonfarm alternative. This allocation is not objectionable from the standpoint

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<sup>6</sup> It has been pointed out that saving can also be negated in a stock-market boom without any new capital being created. This is probably true, but the occurrence of an event twice would not diminish its importance.

<sup>7</sup> J. M. Keynes, General Theory of Employment Interest and Money, Harcourt Brace, New York, 1936, pp. 241 ff.

of economics. It is reasonable to expect, however, that such costs of achieving the nonfarm alternative as locating employment, temporary loss of income in the transition period, and acquiring the requisite skills, will be deducted from prospective earnings with the result that even the costs induced by the friction of adjustment will appear in the value of the land.

More important is the tendency to overestimate the duration of the period of favorable prices and production with the consequent overcapitalization of this optimum into land values. There is no "short" market in real estate-- indeed, a host of forces ranging from community pride to the loss of the unearned increment will always act to drive land values up. The land booms and busts that form the alternate milestones of agricultural history attest to the hypothesis that "wishing doesn't make it so."

The projection of future earnings on the basis of past earnings, the capitalization of these expectations into current values, and the necessity of paying for the land factor in advance combine to imbed the prosperity of the past into the costs of the present. Or, in another way reminiscent of the pleasure-pain calculus, the "good times" of today tend to become the top half of the "cost-price squeeze" of tomorrow.<sup>8</sup>

When land values begin to come abreast of or pass agricultural prices, agitation for some public action to alleviate the farm income situation increases. The technique of letting land inflation run its course to widespread farm foreclosures and then making long-term loans to permit the dispossessed to buy it back has not proved popular. Land values do represent the savings and investments of individuals--to an even greater extent, they may represent hopes and aspirations for the young and security for the old. They also represent debt for some and security of collateral for others. They are not something that will be surrendered easily, and for this reason they may have had much to do with the shaping of current agricultural programs.

Income programs in agriculture have operated largely through a restriction on the land input. This has been particularly true of programs dealing with basic crops. This technique has not only maintained land values, but there is evidence that it has been responsible for some rather large and spectacular increases.<sup>9</sup> These increases have been the result of continually reducing the quantity of land that can be used, and of attempting to reduce the supply of land enough, through institutional procedures, to offset the gains in technology. With the reduction in the amount of land that can be used, the marginal productivity of usable land increases, rents increase, the imputed return to land increases, and land values rise.

I would suggest that in the new equilibrium situation, land values will rise to the level at which labor and capital are again left no better off than

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<sup>8</sup>This discussion is drawn largely from Walter E. Chryst and John F. Timmons, The Economic Role of Land Resource Institutions in Agricultural Adjustments, Mimeo., ARS-USDA, 1960. In press, Iowa State College Press.

<sup>9</sup>Maier, Gibson, and Hedrick, The Sale Value of Flu-Cured Tobacco Allotments, Virginia Agr. Expt. Sta. Bul. No. 148, April, 1960.

before, and that the land-market mechanism may introduce an element of futility into these programs so far as those who buy or rent land are concerned. This subject matter is beyond the scope of this paper, however, and is being developed elsewhere.<sup>10</sup>

From the viewpoint of total resource use, it is difficult to see how these restrictions on the use of land can contribute to an increase in the per capita level of consumption. American farmers are intelligent entrepreneurs, and, like any other entrepreneurs, they will attempt to substitute the cheaper factor for the more costly one. When the price of land rises relative to the price of capital items and labor, it can be expected that more capital items, such as machinery and fertilizer, and more labor will be used--that is, labor and capital will be substituted in the production process within the limits permitted by the technical transformation coefficients and the ratios of the factor prices.

In the long run, the labor and capital that are substituted in the production process can be used to produce something else. If this something else has any value, it would appear that there is an opportunity to increase the level of per capita consumption by substituting land for labor and capital. It is not conceivable that any society can increase its real income by refusing to use land that could be substituted for labor and capital in the productive process.

The adoption of programs leading to efficient use of the land resources would result in a drastic reduction of land values, and would increase, at least temporarily, underemployment in agriculture and those industries that supply agriculture. But the fact remains that the value of land is not a measure of national wealth--rather it is a reflection of our self-imposed poverty of natural resources, of the inadequacy of the land that we are willing to use to meet our needs. The land will not disappear regardless of its value; if land were so abundant that its price was zero, we could have no greater wealth of natural resources. The difference between the current value of land and the price that land would have if all of it were available for use is, in some degree, a measure of the inefficiency with which the resource is employed.

#### Need for Further Study of the Interrelationship Between Tenure and Economics

This is, at best, a brief and sketchy treatment of some of the economic factors involved in our institutions of property in land. The treatment is adequate, I believe, to show that there are some elements of the way in which we hold and transmit rights in land that result in a total output from our economy that is less than the maximum possible. There are many other aspects and conceptions of land that might be fruitfully explored by those interested in economic progress, if progress is to be measured by rising levels of per capita consumption. Among them is the feasibility of using land income to augment capital formation in the economy or to bear a larger part of the cost of government, and thus to reduce the tax on new capital and provide a stimulus for additional saving. A "total planner" would find it necessary to draw a

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<sup>10</sup> The National Study Group Activity sponsored by the Interregional Land Tenure Research Committee is studying how the incidence of costs and benefits of price-support programs, resource-development programs, credit programs, and research and education may have been affected by capitalization of land income.

fairly sharp distinction between naturally created factors and those representing some real sacrifice on the part of the living, and also a distinction between the dispositions that can be made of the respective incomes derived from these factors.

But this is a difficult question to discuss--any question that might involve the reassignment of rights in land resources falls in the most controversial area of economic inquiry. The tenure system has evolved in function as well as technique since it was first used as a means of increasing production by providing some certainty of expectation in the use of irrigation water. The tenure system developed until it became a system of government and an instrument of slavery in the feudal period. Use of tenure as a means of facilitating production was subordinated to its use as a distributive mechanism to such an extent that modifications of the feudal tenure system are identified as milestones in man's progress toward freedom. These modifications were hard won and widely spaced in time, and the rights to own land, to occupy it unmolested, to use it as a lord would have used his land, to be able to exact a payment for its use, and to dispossess the user, are high on the scale of values of the American people. Land ownership offers a measure of security and a measure of prestige, in the Veblen sense, from having some income that is not a product of one's daily toil. It is not surprising that nearly all of the acts of resistance to civil authority committed by farm people have had their origin in threats to security of tenure in the land. It is not surprising that any discussion of modifying the distribution of rights in land or the distribution of land income creates a feeling of uneasiness in a large part of the population--a feeling that may be rapidly and effectively articulated.

The problem of efficient use of the natural resources cannot, however, be avoided in the long run. A large part of the world has reorganized its tenure system along lines that emphasize full use of the land and the use of rent to provide either a more equalitarian distribution of income or a more rapid rate of capital growth. It is easy to see that in the primarily agricultural societies of Latin America, Asia, and Africa, where land ownership is concentrated and income distribution must closely follow the distribution of land, the promises of such a tenure program, whether or not they may be realized, will have a great deal of appeal. An understanding of the role of land institutions in the economic process is essential to an understanding of the problems of these people, whose potential effect on the future of the United States economy should not be ignored. Even if we elect to do nothing about our own tenure situation, at least a more complete knowledge of how it functions will be of assistance in understanding the world about us.

As a tentative framework of analysis, I would first urge that a reconsideration of the role of land resources in determining national welfare be undertaken. In this reconsideration, care should be taken to prevent the work from being halted by quarrels over the definition of land resources or the best way to measure welfare. Personally, I believe that there is something about the natural environment of the North Central area that makes Iowa a better place to locate economic activity than Greenland and that a reasonably prosperous society, with a rising level of education and an increasing proportion of its young people taking up the arts and letters, probably has a higher level of welfare than that enjoyed by the Alto-Plano Indians. If, however, alternative definitions of land and welfare are required, let them be developed and the work proceed. It is recognized that much good work has been done in this field with respect to specific resource problems by the various foundations, government agencies, and land-grant colleges.



As a second step, attention might be given to the function and operation of those institutions that either directly or through permission control the use of land and allocate land income. Here again, several alternatives might be investigated, ranging from the untrammelled common law rights that existed in this country in the preconservation period to complete state control as may be found in several Eastern European and Middle Eastern countries, with intermediate stops at mixed systems of private property functioning within a strong framework of public interest, such as may be found here and in Northern Europe.

The third step would involve the identification of those elements of the institutional environments that lead to uses of land and land income not in keeping with the objectives of national welfare--however, this may have been defined in the first step. Attention could then be given to the development of means of transferring control or income to the management most compatible with the public interest.

Such a study may be strictly an academic exercise so far as any application in the United States is concerned. Our present use of the land indicates that we are not really hard pressed for land resources and that we think we may even have a surplus. Also, some inefficiency may have value in and of itself as it may be viewed as a symbol of wealth, and certainly the right of the individual to use his land, within rather broadly prescribed limits, as he sees fit and without regard to the economic consequences is identified with our concept of freedom.

If however, we want maximum economic progress and the national security and cultural growth it would yield, it must be recognized that possibly these things cannot be achieved without evaluation of alternative forms of property organization applied to the economic environment of the United States. It is only with this knowledge that those who intercede on behalf of the public in the private contests of power that affect property law can be of greatest usefulness in shaping institutions to serve the public ends.

This work will need to be done by competent, objective men in an environment insulated from the economic pressures of those who have an interest in a particular situation or outcome. This is research into basic economic-legal relationships that should be useful in formulating economic-legal policy in the United States and in understanding some of the problems of our friends and foes abroad.

Regardless of how able the researchers may be or how well insulated their environment, any expectation of an early translation of this research into a bold new program of economic-social organization is an invitation to disappointment. Precedent and custom are tremendous forces in the allocation of resources. The invisible hand of economic competition may have become feeble and palsied through the years, but water in the Los Angeles area through the Pueblo Water Rights Doctrine is allocated between agriculture and industry by the hand of Charles III of Spain--dead since 1788. It may well be that the public priorities on the use of water are the same today as they were in Charles' time, when Los Angeles was a Spanish Pueblo, but the current use of this doctrine would seem to impose a considerable burden upon the king as a visionary. The extension of this doctrine in 1959 to New Mexico, in the Cartwright case, would suggest that the Holmes remark of a half-century ago is not without relevance today, "... a page of history is worth a volume of logic."

SOME ASPECTS OF LAND OWNERSHIP AND EFFICIENCY OF  
RESOURCE USE FROM THE PUBLIC VIEWPOINT<sup>1</sup>H. C. Holje<sup>2</sup>

The title of the paper assigned Dr. Chryst is an encompassing one. There are many directions one might take in addressing the topics presented. It is my intention to outline briefly what I consider to be some of the major highlights in areas where either economists disagree as to their responsibilities or where a dearth of economic theory and policy exists.

The public has a major interest in the way in which land resources are developed, controlled, and used. People, through their governments, have been creating institutional arrangements to protect both the private user and the public interest throughout the history of land resource utilization. Some of our earliest civilizations evolved most advanced legal institutions in relation to the use of land. The great Babylonian Empire developed one of the most advanced codes of law known anywhere. A major feature of the code of Hammurabi, famous ruler of the Babylonians, was the section which dealt with land control and use.

This matter of providing ourselves with institutional arrangements to fit the situation at hand has two aspects. First, the institutional arrangement should be permanent enough and should be well enough accepted to provide stability and assurance to the people who carry on economic activity within the framework of those institutions. Second, the institutions should provide sufficient flexibility to permit the economy to meet the demand of changing conditions.

Many aspects of land resources development require continued federal participation. Projects are often too large to be undertaken through private effort or by state and local units of government. Some projects may have long-run benefits that only the federal government can afford to finance.

On the other hand, there are many aspects of resources development in which state and local units of government might well play a more important role in view of the fact that the benefits, both private and public, are primarily state and local in character. It seems likely that one of the best ways to discourage the promotional aspects of resources development would be to increase the degree of state and local financial responsibility. This means more active participation on the part of state governments and the inclusion of other beneficiaries in the repayment responsibility in addition to the direct users of developed resources.

This complex interrelationship of interest and action in all levels of governmental organization gives further emphasis to the importance of the institutional arrangements that surround resources development. As the population grows and the pressures on available resources increase, it seems obvious there will be more public concern regarding the use of privately held

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<sup>1</sup> Discussion of paper by Walter E. Chryst.

<sup>2</sup> Department of Agricultural Economics and Rural Sociology, Montana State College.

resources. In the case of water rights, for example, the priority aspect is designed to protect the investment of the individual who came first and pioneered in the development of a water resource situation. But there is also a part of the appropriation doctrine which provides that an appropriator must make beneficial use of the water he takes. This is designed to protect the later arrivals from wasteful or excessive use by the holder of a prior right. It seems likely that there will be an increasing demand for demonstrated beneficial use in view of the steadily increasing demands for water. Any user who makes wasteful or excessive use of water may expect other users or potential users to question his right to the full amount now being taken.

In my opinion, the major goal of resource development is to increase the capacity of the resource base needed to support private enterprise. It cannot be otherwise in a capitalistic economy. The directing of public resource development in such a way as to contribute most to the foundation under private enterprise may involve at least three aspects: 1. improve the physical and economic availability of resources; 2. demonstrate the application of technology to resource development; 3. adjust the institutional arrangements where necessary.

This concept is not new or revolutionary. Throughout the history of the nation, the federal government has sponsored programs and policies designed to improve the usability of the natural resources of the nation for private enterprise. Public programs to develop hydroelectric power and construct irrigation and drainage projects are not too far removed from our historical experience wherein the federal government subsidized canals and wagon roads, made land grants to the railroads, and provided free public land to private enterprisers of all kinds.

Yet, a negative attitude regarding resource development and economic growth persists. This is due in part to the obvious fact that specific individuals, specific areas, and specific interests will be adversely affected by the development of resource projects and the economic and social changes that accompany them. These problems are of major importance to the individuals, areas, and interests involved. But it is characteristic of a growing economy that individuals, areas, and interests do suffer adverse effects of the progress which is deemed to be desirable and necessary to the community, the state, and/or the nation. I find it difficult to visualize how growth and development can take place without someone getting hurt, unless we are talking about a completely unpopulated area. And even then, some individuals or groups may have an interest in the proposed development site.

Second, there is the failure to distinguish between public expenditures for government services of a consumption nature such as monies spent for schools, roads, and postal services, and monies spent on the development of resources to increase their productivity and expand their ability to support the growth of private enterprise. The failure to distinguish between the two types of public expenditures caused President Roosevelt to suggest in the mid-thirties that the Executive Department should submit and the Congress should consider two separate budgets -- an operational budget and an investment budget. The suggestion was criticized long and loud as subterfuge and an attempt to fool the people. Nothing came of it. Interestingly enough, President Eisenhower came forth with the same suggestion when he faced the problem of a national budget for the first time. The same charges were hurled, and the matter was dropped. The dual budget would do only what individuals and business firms do regularly when, informally or formally, they separate their operational and investment

expenditures. It would appear appropriate that government, local, state, and national, should think in terms of investment expenditures for the future. This would be a more honest approach to the taxpayers.

Third, there is a disagreement regarding the role of government in resource development and the resultant conflict between public and private interests. As previously indicated, when private enterprise can and will develop a resource project, there is no place for government activity. There is, however, one important stipulation. The privately developed project should involve full development of the site. In some cases, the private project proposed as a substitute for a public project is not an equivalent development. I suggest that we have passed the time when as a nation we can afford to use our resources partially and wastefully. On the other hand, when private enterprise cannot or will not develop a project of importance to the growth and welfare of the nation, government has a definite responsibility. History indicates that many nations of the past disappeared because the resource base was not properly developed and maintained.

Fourth, there is the philosophy that land resources can be used and managed as the owner sees fit and that what we do with resources we control is of no concern to others. This is not true, of course, because society does place certain restrictions and limitations on the property rights that one holds.

If we decide that the present use and development of some types of land resources do not adequately protect the public interest, what alternatives are available to the public to protect those interests? Some of the more common ones would include: (1) change in institutions; (2) investment of public funds as inducements; (3) land-use regulations; (4) acquisition of ownership; and (5) research and education.

In a large number of instances where public and private interests do not coincide, the reason may be found in the customs, traditions, social sanctions, and laws that make up the rules governing an individual's activities. Rental arrangements, tax procedures, and inheritance practices are examples.

You are all familiar with the use of public funds as inducements for resource use and development in the public interest. Certain practices may be desirable from the public standpoint, but the individual does not get sufficient returns to warrant his investment. The public may contribute that portion of the investment that is not profitable for the individual to make.

Zoning and the establishment of special districts are examples of land-use regulations. Here public action transcends private action.

Public ownership can be secured either through eminent domain proceedings or tax reversion. It should be remembered that the acquisition of ownership does not in itself settle many of the use and development problems. Procedures have to be developed that are satisfactory to the individuals who will use the land.

The importance of research and education is self-evident. An informed public is a productive one.

Let me direct my final remarks to a consideration of the efficiency concept. Economic analysis of efficiency reached its most refined state in the theory of the firm. It provided a highly rigorous, but very restrictive, analytical framework. There is real question whether or not it can be of much

help in governmental planning. Still there are those who firmly cling to the maximization theory as the sole salvation for economists.

Our country is replete with examples of private resource use and development in which the profit maximization principle was used to its utmost, but which resulted in complete destruction of our public interests. The economics of Adam Smith has provided us with a fine lesson; but let us be more sophisticated than this.

All this is not to say that an individual should be condemned for acting to maximize his profits. Where his interests coincide reasonably well with the public interest, no problem exists. When an individual's quest for maximum profit leads him to do things which are not in the public interest, we should (1) be very careful that we have correctly determined what the public interest is and not some individual's statement as to what the public interest ought to be, and (2) look to the reasons for the existence of the disparity and try to make adjustments which will bring the two interests together.

I like a statement Margolis made at one of our Western Water Resources Committee meetings concerning an alternative role of the economist. He said, "Another form of resolution is for the economist to enter the political fray--to take positions on these other social values and to choose among projects according to equity, efficiency, and any other social values that he holds. In this case if he is to be effective his values must conform in some way to the values of a significant sector of society, but more important he is assuming the more dangerous, though rewarding, role of acting as a leader in the community in the formation of values. His job will be to make clear the nature of all the relevant goals achieved, to analyze them, to make them explicit in his defense of any given policy. In this case the economist ceases being a technician but assumes the mantle of an adviser, who is a social scientist, prepared to exercise leadership in social policy formation. . . . Too often some economists have condemned those of his brethren who have inserted political criteria, but if the criteria of the purist are to be meaningful even he must make political value judgments though they are often in the seemingly innocuous form of asserting economic efficiency as a goal instead of a means."

A supporting statement comes from one of our own committee members in which Stephen Smith says, ". . . it is not surprising that natural resource economists are so concerned with questions of public policy. The decision-making framework is not just the business or the farm firm but a democratically organized society. Responsibility runs to a particular clientele or 'consumers' on the one hand and to the taxpayer-citizen on the other hand. Because of this role of government, the natural resource economist is concerned with public policy analysis in his technical profession. His technical counsel must relate the economic, legal, administrative, and political elements, for it is through these institutions that the parties at interest exercise their desires rather than in the market place."

DISECONOMIES INHERENT IN WESTERN WATER LAWS:  
A CALIFORNIA CASE STUDY

Mason Gaffney<sup>1</sup>

Introduction

Is our system of water law compatible with economic use of the resource? This old question came again to the fore as the postwar cycle of resource development brought renewed pressures on limited water resources. For a time the negative answer seemed ascendant, at least in the intellectual world (it made somewhat less headway with the holders of superior water rights). More recently the positive has been accentuated by Professors S. V. Wantrup,<sup>2</sup> Stephen Smith,<sup>3</sup> George Tolley,<sup>4</sup> V. S. Hastings,<sup>4</sup> and others. Even Professor S. T. Harding, who once might have been regarded as a sharp critic of the system<sup>5</sup> (especially its riparian components), has recently risen to its defense.<sup>6</sup>

While it is hazardous to summarize so many authors, they seem to share the view that water law in its entirety does not work out in practice in nearly the absurd ways that one might expect from a priori analysis of the enunciated principles; that in fact it would be hard to improve on the allocation achieved in the field; the critics should be required to show how allocation might be improved.

This allegation shifts the emphasis of the debate from the analysis of principles to the observation of practice. For this purpose I have selected the Kaweah River system, which is in the southeastern San Joaquin Valley, largely in Tulare County. This system, like all local situations, is unusual in some particulars, but contains diseconomies of kinds and in degrees that in my observation prevail throughout the valley and the state.

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<sup>1</sup>Department of Agricultural Economics, University of Missouri.

<sup>2</sup>S. V. Wantrup, "Concepts Used as Economic Criteria for a System of Water Rights," 32 Land Economics (4) 295-312, November, 1956.

<sup>3</sup>Stephen Smith, "Legal and Institutional Controls in Water Allocation," 42 JFE (5) 1345-58, December, 1960.

<sup>4</sup>George Tolley and V. S. Hastings, "Optimal Water Allocation for the North Platte River," dittoed MS, nd (c. 1957).

<sup>5</sup>Sidney T. Harding, Water Rights for Irrigation, (Stanford: Stanford University Press, 1936).

<sup>6</sup>Sidney T. Harding, Water in California, (Palo Alto: N-P Publications, 1960.), pp. 59-60, 211-12. Professor Harding is specifically contrasting the established diligence principle favorably against the exemption from diligence of filings by the state. But his language and evident purport become much more general.

The Kaweah system makes a good study area for the following reasons:

- A. Unusually complete data on diversions are available. The stream has long been administered by a water master, and his 1920-55 records of daily flows in the ditches of some 21 water-user organizations are published in California Division of Water Resources Bulletins 49, 49A and 49B.<sup>7</sup>
- B. As the Kaweah River emerges from the foothills it fans out over an alluvial cone, in such wise that water may be shifted among the rival claimants through existing channels with minimal transfer costs. There is, therefore, no appreciable transportation cost barrier among the separate water users to complicate the analysis.
- C. There is no great problem of water quality to complicate the analysis.
- D. The unit is small enough for analysis in some depth, yet its institutions are complex and varied enough to present in microcosm many basic problems of water law.
- E. The river is located where water is clearly the limiting factor on economic expansion. A high-scarcity value imputes to Kaweah river water, so there are compelling economic reasons for allocating it to its best uses.
- F. The area is important for its own sake. It was the alleged crisis of this area that originally triggered off the Central Valley project in the 'twenties, and it remains the major payoff area for that project. It is the major state and national producer of navel oranges and plums, and an important producer of clings and freestones. In respect to water law, the Kaweah is the locale of at least two leading cases, Tulare Irrigation District vs. Lindsay-Strathmore Irrigation District,<sup>8</sup> and Ivanhoe Irrigation District and the State of California vs. McCracken, et al.<sup>9</sup>
- G. Toward the end of the period of study the area received a large imported water supply from the completed Central Valley Project. Observation of the reactions of the local water economy to this increment has brought out a number of significant points that are obscured in a static situation.

#### Diseconomies in the Kaweah River Distributary System

Indications of wide dispersion of marginal revenue productivities of water within the system.

It is a weakness of much grand-scale project planning to assume implicitly that there is an operative local market mechanism that has succeeded in

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<sup>7</sup>State of California, Department of Public Works, Division of Water Resources, Kaweah River Flows, Diversions and Service Areas, Bulletins Nos. 49, 49A, and 49B (Sacramento: State Printing Office, 1940, 1950, and 1956.

<sup>8</sup>3 Calif. (2d) 489, 45 Pac. (2d) 972 (1935).

<sup>9</sup>357 U. S. 275 (1958).

equating the marginal productivities of water among different users. Thus, one hears statements of the order "Down in Tulare County they pay \$15 an acre-foot for water." In fact, in the Kaweah system, the marginal productivity of water varies from less than zero in some areas (where it is applied in such excess as to damage crops and soil) to an upper figure that I hesitate to specify. To save a heavy citrus crop worth \$1,000 an acre on the tree, and to save the trees themselves, a marginal acre-foot at the critical moment assumes a short-run value many times greater than the maxima we ordinarily discuss. Within the area there have been citrus groves in just such straits at the very moment that water was wasting elsewhere.

So great is the range of marginal productivities obtaining in the system that it is possible, without pretending to fine accuracy, to establish the contrast beyond cavil. These contrasts have persisted over several decades because, as we shall see, the system's evolution has been almost completely arrested since before 1920.

Each of over 20 water-user groups has its own insulated supply-demand balance, hence its own marginal productivity. Lands without surface water using pumped wells of greatly divergent lifts have still more separate marginal productivities. This paper focuses on what is probably the most extreme divergence, that between the "thermal" areas, the "coves" and benchlands above about 350' elevation, and the lower Kaweah delta of cold nights and alkali-damaged soils. The thermal zone is adapted for citriculture; the lower delta at best for alfalfa and cotton, at worst for barley and pasture. These areas are in direct competition for the same water deliverable by gravity to either area through existing channels.

There are several means by which the outside observer can estimate the marginal productivity of water. In the larger study from which this paper is drawn many of these means were essayed. While some of them eventuate in only crude estimates, plus or minus considerable margins of doubt, they are adequate to the present purpose which is simply to establish the contrast between the lowest and the highest marginal productivities. Possible uncertainty attaching to single methods of estimate was resolved by the fact that the different methods consistently pointed to the same conclusion. The methods of estimate and their results are listed and described below.

Water conservation expenses. There is some index to the marginal value of water in the pains that water users take to conserve it. Let us take the Lindsay-Strathmore Irrigation District, extending east from Lindsay and Strathmore to the foothills, as the prototype of citrus water organizations. The following description applies to the period before its acute water shortage was relieved by the deus ex machina of the Central Valley Project.

This district pumps water up over 200 feet from the river to the top of its system (a cost, as we shall see, imposed not by nature but by water law). It distributes water in steel pipe under pressure throughout its area, so that sprinklers may be used. It operates a surface and an underground reservoir and has the necessary excess distributive capacity to serve water on demand so that operators need apply water only when the trees require it. It has



withal one of the most elaborate water conservation systems of any Irrigation District in the state, a fact reflected in persistently high tax rates and water tolls: in 1949, \$6.79 per assessed acre and \$8.14 per delivered acre-foot.<sup>10</sup>

By contrast, the Tulare Irrigation District (around Tulare in the south western Kaweah Delta) loses some 50 per cent of the water it diverts through a long unlined ditch.<sup>11</sup> When it finally reached the district, "... the use of water is very ununiform and generally wasteful" observed Frank Adams in 1915.<sup>12</sup> William Horn, in studies preliminary to the 1955 Bulletin 2,<sup>13</sup> assigned this district the low over-all "irrigation efficiency" of .39.<sup>14</sup> Let me emphasize that neither Mr. Horn, Mr. Adams, nor I are necessarily levelling any criticism at the management of this irrigation district. Its behavior may be perfectly rational within the framework of water law. It is rather that framework itself which is under examination here.<sup>15</sup>

The Tulare Irrigation District is not the worst example. Indeed it is, among our 20-odd water users, one of those more pressed for water. There is only one lined canal in the entire Kaweah system (Foothill Ditch in the thermal zone). Wasteful rotation systems of water distribution are the rule.

Marginal costs of lifting ground water. The marginal cost of lifting ground water in individual pumped wells is an excellent guide to marginal productivity, since individuals are in a position of complete control wherein they can pursue the natural tendency to equate private marginal cost and marginal revenue product.

The Lindsay-Strathmore Irrigation District, like much of the thermal citrus zone, is underlain by very poor aquifers. Lifts had increased to over

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<sup>10</sup> Computed from State of California, Dept. of Public Works, Division of Water Resources, Irrigation Districts in California, 1944-1950, Bul. No. 21-P (Sacramento: State Printing Office, nd). In 1929 the district charged \$24.50 per acre and \$10 per acre-foot. State of California, Dept. of Public Works, Div. of Water Resources, Permissible Annual Charges for Irrigation Water in the Upper San Joaquin Valley, Bulletin No. 34 (Sacramento: State Printing Office, 1930), p. 65, Table 39.

<sup>11</sup> Frank Adams, Irrigation Districts in California, State of California, Dept. of Public Works, Division of Engineering and Irrigation, Bulletin No. 21 (Sacramento: State Printing Office, 1929), p. 247.

<sup>12</sup> State of California, Dept. of Engineering, Irrigation Districts in California, 1881-1915, Bulletin No. 2 (Sacramento: State Printing Office, c. 1916), p. 88.

<sup>13</sup> State of California, Water Resources Board, Water Utilization and Requirements of California, Bul. No. 2, Vol. 1 (Sacramento: State Printing Office, 1955).

<sup>14</sup> Correspondence in writer's files.

<sup>15</sup> Messrs. Horn and Adams are not implicated, of course.

150 feet before 1920,<sup>16</sup> and costs were higher even than that would suggest because the underlying rock imposed high drilling costs and low yields per well.<sup>17</sup> From about 1913, many wells struck connate brines with boron, toxic to citrus.<sup>18</sup>

By contrast, along the lower reaches of the St. Johns River (the northern tributary of the Kaweah) between Goshen and Traver, ground water has damaged the soil by intermittently evaporating from the surface, and is not far down today.<sup>19</sup>

Despite this accessible water table, there is little pumping, due to poor soils.<sup>20</sup> A large amount of Kaweah water is nonetheless consigned to the area each year, under vested rights in surface diversion and channel seepage. In most of the Kaweah delta area over the period of study, pump lifts averaged less than 25 feet. Only in the southwestern delta were lifts much greater.<sup>21</sup>

Water applied per acre. Lindsay-Strathmore Irrigation District was forced by unfavorable court judgements to subsist for many years on 1.76 acre-feet per acre.<sup>22</sup> Even to achieve this depth it had to halve its acreage.<sup>23</sup>

As the other extreme, the Consolidated Peoples' Ditch Company mean annual diversion over 36 years has been about seven acre-feet per acre,<sup>24</sup> plus whatever may be lifted by private pumps from shallow wells after July when the river usually runs dry.

<sup>16</sup> State of California, Dept. of Public Works, Division of Engineering and Irrigation, Water Resources of Tulare County and their Utilization, Bulletin No. 3 (Sacramento: State Printing Office, 1922), Map No. 1.

<sup>17</sup> Hearings on S. 912 before Senate Public Lands Subcommittee, 80th Congress, 1st Session, 1947, p. 636.

<sup>18</sup> Ibid., p. 400.

<sup>19</sup> Irvin H. Althouse, "Water Requirements of Tulare County," Report to Tulare County Board of Supervisors, January, 1942 (mimeo.), p. 13.

Walter W. Weir, Transactions of the American Geophysical Union, 1941, cited in U. S. Dept. of Agri., Bureau of Agri. Econ., "San Joaquin Valley Water Investigations, Agricultural Aspects." (Berkeley, 1944) p. 149.

<sup>20</sup> U. S. Department of Agriculture, Bureau of Agricultural Economics Division of Land Economics, Water Utilization Section, "Area Proposal, Kaweah-Tule Area, California," September, 1941, p. 7.

<sup>21</sup> Note 13, supra; and U. S. Bureau of Reclamation, Central Valley Basin, Senate Document 113, 81st Congress, 1st Session, 1949, Plates 4-6 facing p. 104.

<sup>22</sup> Statement of Donald Burr, Manager, Lindsay-Strathmore I. D., 1958.

<sup>23</sup> S. A. Kerr, in Hearings on S. 912 ... supra (Note 14), p. 390.

<sup>24</sup> Computed from Kaweah River Flows ... supra (Note 6), Table 8. Cf. Permissible Annual Charges ... supra (Note 7), p. 81, on the lavish use of water by irrigators in the Kaweah Delta.

Let me repeat that it is physically possible to shift water from Consolidated Peoples' Ditch Company to Lindsay-Strathmore Irrigation District without cost, simply by changing the point of diversion. The only barrier is legal. Lindsay-Strathmore Irrigation District was prepared to make the shift in 1928, having bought shares in Consolidated Peoples' Ditch Company and an easement in Foothill Ditch, and was stopped only by injunction<sup>25</sup>

Value of output per acre-foot. We all know of course that the average revenue product per acre-foot is not the marginal revenue product. But it is a near relative, so that differences as great as those recorded here, especially in conjunction with the other data, are worth noting. In fact, the use of average products understates the contrast of marginal productivities, probably a good deal, since thirstier areas are nearer the stage of increasing average returns to water, and some are in that stage.

The Lindsay-Strathmore Irrigation District, before the advent of Central Valley Project water, grossed something like \$5,000,000 per year<sup>26</sup> from 16,400 acre-feet per year, or about \$300 per acre-foot. Consolidated Peoples' Ditch Company, I would estimate (exact figures are not compiled) grossed in the rough neighborhood of \$2,000,000 from its 66,000 acre-feet, or little more than 10 per cent as much per acre-foot.

If we go by crops instead of area, we can deduct current variable costs (i. e., cultural and harvest costs) and arrive at a more significant figure. Costs are higher for navels, of course, and that reduces their advantage, but leaves it still impressive. The average net product of water applied to navels, at current levels of prices and costs, would run from \$200-\$500 an acre-foot compared to around \$40 for cotton, \$20 for alfalfa, \$20 for barley, and \$10 for pasture.<sup>27</sup>

In the long run the advantage of navels would be still less because of their long development period and heavy fixed costs. But for our present purpose the short-run difference is relevant. For in the Kaweah area it was not just raw citrus land that was denied water for the benefit of downstream barley and pasture. It was also established citrus groves, with fixed costs already sunk. The economic pressure that water law has withstood is the full difference in the short-run values of water between citrus and pasture.

Contrasting to the high yields and low water requirements of citrus, irrigated pasture grasses in the lower delta are little more than domesticated phreatophytes. Irrigated pasture uses about five acre-feet per acre. Michael

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<sup>25</sup> Consolidated Peoples' Ditch Company v. Foothill Ditch Company 205 Calif. 54, 269 Pac. 915 (1928).

<sup>26</sup> Adapted from data compiled under supervision of Wm. Taggart, U. S. Bureau of Reclamation, Sacramento; from Annual Reports of Tulare County Agricultural Commissioner; and several contributing sources.

<sup>27</sup> Cost data supplied by Tulare County Farm Advisers.

Brewer has recently tabulated water cost as a percentage of all variable costs in pasture operation.<sup>28</sup> He finds it to be 23 per cent, a good deal more than for cotton at 5 per cent, Emperors at 2.7 per cent and even rice at 14.9 per cent.

But this contrast, striking as it is, understates the full economic contrast a good deal because only explicit outlays are considered. No opportunity cost value is assigned to the water itself, even though this may be the predominant social cost of water use. If, in the Kaweah area, we were to charge against irrigated pasture an opportunity cost of about \$15 per acre-foot, there would remain no net return at all to other variable inputs, the operator, or the equity. There would remain precious little return to growers of barley and alfalfa. These crops can be grown here only because water law insulates their growers from feeling the social cost of water as a personal cost.

Production response to increased water supply. From 1952, the Central Valley Project brought a prodigious increment to the area's water supply. According to Tulare County Agricultural Commissioner reports, the response of navel output was immediate and continuing. Tulare County navel yields for 1952-58 are about double those for 1943-51, and the division between 1951 and 1952 is clean and sharp. By way of a control, in neighboring Fresno County, where navels received no new Central Valley Project water, there was no significant change in yields between the two periods.

Crops grown in the middle and lower delta--plums, alfalfa, and walnuts--show no increased yields after 1952 (cotton is not used as an example because its intermittent acreage control program overshadowed other factors influencing yields).

Land-value response to increased water supply. In the thermal citrus zone, access to a reliable water supply today is worth something in the neighborhood of \$500-\$800 an acre. This is the difference in the price of raw land with and without water. Dry land, of which there is ample, would bring some \$50-\$100 an acre based on grazing income. Water raises this to \$500-\$900. Access to water is not free, but entails annual land taxes and water tolls of some \$30 an acre, and the land value increment is based on expected income net of these charges.<sup>29</sup>

This index is inflated by today's high land prices, based in part on speculative anticipations that may be unwarranted. Ten years ago the figure was less than half today's, and 10 years hence, in my opinion, it will be that low again, or lower, due to overexpansion of water-supply and related land-development projects.<sup>30</sup> Still it contrasts sharply with the lower delta, where

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<sup>28</sup>Michael Brewer, "Water Pricing and Allocation with Particular Reference to California Irrigation Districts," Giannini Foundation Mimeographed Report No. 235, 1960, p. 84.

<sup>29</sup>Interviews with local realtors and water officials, 1958. See also Hearings on S. 912 . . . , supra (Note 14), pp. 654-55.

<sup>30</sup>See Section IV, infra.

it is difficult to find evidence of any land value increment related to increased water supply, and for our present purpose it is the contrast, not the absolute quantity, that is important.

Willingness to pay for water and water rights. Lindsay-Strathmore Irrigation District before 1935 had bought, and downstream interests had sold, shares in most of the ditch companies in the Kaweah Delta, despite the high risk (which came to pass) that Lindsay-Strathmore Irrigation District could never use them. Consistently thwarted in her quest for water, Lindsay-Strathmore Irrigation District just as consistently put up whatever money seemed necessary to get it some other way.

In 1949 when the Irrigation Districts' Association sought to maintain a united front in bargaining with the Bureau of Reclamation, it was Lindsay-Strathmore Irrigation District which first broke ranks and consented to a contract with several unpopular features. By contrast the lower delta ditch companies have never even organized as irrigation districts to contract for Bureau water. The Kaweah Delta Water Conservation District, representing the whole delta, is unwilling to pay the Bureau's prices.

Competent appraisals of soil and climate. The excellence of the benchlands in soils and climate is documented in sources cited in the appended footnote.<sup>31</sup> Parts of the lower delta also have excellent soils, but the thermal qualities of the benchlands suit them for much more productive uses of water.

Size of farms. In Lindsay-Strathmore Irrigation District almost all the land is in unusually small and intensive farms, averaging about 15 acres.<sup>32</sup> At that size clearly the operator is in sore need to spread his overhead over as much output per acre as possible. He is likely to have on hand underutilized indivisible input items to make the fullest use of marginal water at the least marginal associated cost.

Nowhere else in the delta are farms nearly so small.<sup>33</sup>

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<sup>31</sup> USDA Bureau of Agr. Economics, "San Joaquin Valley Water Investigations, Agricultural Aspects" (Berkeley: 1944), Mimeo. A Report to the War Dept. U. S. Engineers Office, Sacramento District [made of public record by introduction by Paul Johnstone in testimony at Hearings on S. 912..., supra (Note 14) p. 842], Table 19, p. 44; Table 24, p. 60; Table 39, pp. 108-09.

USDA Bureau of Agricultural Economics, "Area Proposal, Kaweah-Tule Area, California," supra (Note 17), pp. 7 ff.

Irvin H. Althouse, op. cit. (Note 16), pp. 12, 96-97.

U. S. Dept. of Interior, Bureau of Reclamation, "Factual Report, Tulare Irrigation District" (Fresno: 1949), Mimeo.

<sup>32</sup> U. S. Dept. of Interior, Bureau of Reclamation, "Factual Report, Lindsay-Strathmore I. D." (Fresno: 1949), Mimeo.

<sup>33</sup> Marion Clawson and Edwin E. Wilson, "Agricultural Land Ownership and Operation in the Southern San Joaquin Valley," USDA Bureau of Ag. Econ. (Berkeley: 1945), Mimeo.

## Unreliability of water supply.

A common rationalization for rigidity of water allocations, and unresponsiveness to demands, is that this is simply the price we must pay for security and stability of supply. But this argument will not bear much weight in the Kaweah River situation, since the division of waters is such as to increase materially the system's aggregate variability over what it might be; and the allocation of the burden of variability among different users is such as to deprive a needlessly large share of the diverted water of much of its value, as will be shown directly.

It is natural to think that irregularity of irrigation water supply must reflect irregularity of demand, but such is not the case in the Kaweah system. Demand plays no part in timing deliveries. Diversions are regulated by an iron-bound schedule based exclusively on rates of flow in the river. Demand must adjust to the supply so determined.

Aggregate variability in the system. Nature imposes a certain variability on water supply, which man can reduce only by physical means, i. e., storage. But he can increase it, when dividing the supply among many claimants, by the counter-movement of diversions. That is, if one diversion rises as another falls there is new variability introduced in the system. Or if the diversions change disproportionately (even though perfectly correlated) there is a sort of increased variability introduced, if we define and measure "variability" in such a way (as I think we should) that deviations are weighted in step with their magnitudes (e. g., by squaring them).

For this purpose the variance divided by the mean makes an appropriate measure. For annual flows from 1920-55 this figure for the sum of all diversions was 63,016 acre-feet. This represents the variability which nature imposed on that portion of the river which man diverted. But the sum of the corresponding figures for the individual diversions was 98,050 acre-feet, or 56 per cent more.<sup>34</sup> Thus, man's division of the waters added, by this measure, 56 per cent to the burdens imposed by nature.<sup>35</sup>

Three user-organizations actually received supplies which were less steady than wasted flood waters, i. e., Kaweah River flows in excess of diversions. This hardship is clearly unnecessary, and is imposed by the system on junior appropriators to the benefit of no one.

Distribution of variability among water users. System variability is very unequally distributed. The steady portion of the flows, which is of course much the more valuable share, goes to a few. In general, these are the same which get the heavier per acre mean annual supplies.

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<sup>34</sup> Computed from Kaweah River Flows..., supra (Note 6).

<sup>35</sup> The percentage increase is greater in the summer months, which are by far the more important ones. Exact figures on this, however, have been derailed in a vacuum tube deep in the bowels of our computer and could not be located in time for this meeting.

The result is that few acres receive water supplies that are adequate in both quantity and reliability. To give some quantitative measure of this I have improvised a "coefficient of reliability" defined as  $.1 + [.1 + (\text{coefficient of variation})^2]$ . This is not the best such coefficient that human ingenuity might devise, but is frankly a Rube Goldberg gadget which simply corresponds to my intuitive evaluation of the importance of steadiness in water supply. I will rise to defend it against simple misunderstanding or sandbagging, but gladly abandon it to a better alternative.

After adjusting mean annual supplies with this coefficient, the acres getting adequate water supply are seen to be much less than they could be.

Eighty-nine thousand, five hundred acres get some Kaweah surface water. Mean annual flows could supply them nearly four acre-feet per acre. Multiplying by the coefficient of reliability for the river this becomes 1.13 adjusted acre-feet per acre. But, due to the unequal distribution of water and steadiness, the acreage receiving that good a supply or better is only 29,000. These acres receive very good supplies indeed. But they are only 32 per cent of the acres (89,500) that might receive that good a supply.

When we consider further that the 29,000 acres for whose benefit the others are deprived do not include the best combinations of soil and climate, we have a notion of the undeveloped potential in the Kaweah River.

Excess diversion capacity.

A third important diseconomy in the system is excessive diversion capacity. One would expect this from the excessive aggregate variability discussed above, but there is more excess than that accounts for. With few exceptions, ditch diversion capacity far exceeds all recorded diversions except perhaps one--one day in 36 years--and that one diversion apparently undertaken in the hope of stretching and/or nailing down a claim to water.

The sum of all diversion capacities is 4740 second-feet,<sup>36</sup> or 2.2 times the peak of the sum of all diversions reached on June 4, 1952,<sup>37</sup> and 11.5 times the mean diversion.

Excess canal mileage.

Excess canal mileage is one of the more conspicuous diseconomies in the Kaweah system. Probably over two-thirds of it could be dispensed with in a compact integrated system. I have not tried to demonstrate this directly. The indirect evidence happens to be easier to marshal, and it suffices.

Scattered service area. The 89,500-acre Kaweah service area is strewn over about 440,000 acres, or five times as much land, which is

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<sup>36</sup>Computed from Kaweah River Flows..., supra (Note 6).

<sup>37</sup>June 4, 1952, is not necessarily the all-time peak of the sum of diversions. The task of computing this series daily for 36 years was beyond my resources. But this was certainly near the all-time peak, and far above the normal annual peak.

contained within the perimeter of service.<sup>38</sup> Some of the bypassed lands are poor, but some are very good and better than those getting service, and in general the scatter cannot be rationalized as an effort to apply limited water to better soils. Neither is it an effort to bring surface water where underground water is costly, for there is clearly no such pattern. It is a heedless, haphazard scatter reflecting random historical forces now frozen tight.

Overlapping service areas. Shares of the separate ditch companies have traded freely over the area and reached the sort of reductio ad absurdum that might be lampooned in an elementary text to dramatize the inevitability of monopoly in public utilities, but which one hardly expects to meet face to face.

Only 12,000 acres are actually served by two or more companies, but the company service areas are now scattered among each other most intricately, so that there is much overlapping of the areas within service perimeters. The sum of the areas within the service perimeters of the separate companies is 356,000 acres, or four times the net area served (89,500 acres). One company, the Wutchumna Water Company, is so scattered that it serves only 11 per cent of the lands within its perimeter. Five other companies operate within this same area.<sup>39</sup>

Unintegrated ditches and cross-hauling. Many ditches in this system cross one another, some of them two or three times. A most conspicuous waste are the parallel ditches that work at cross purposes, carrying water in opposite directions, or at least with significant contrary vector components. For example, by long-standing tradition (and court order) the river must be split 50-50 at McKay Point between the St. Johns, or northern distributary, and the "Kaweah Branch," or southern distributary. This division has behind it no rationale that I have discovered deeper than that there is a ring of rough and ready justice to "fifty-fifty." The productivity of and demand for water are greater in the south. And so the Ketchum Ditch and Packwood Canal have been built to carry St. Johns water from below McKay Point back to the southern branch. The Tulare Irrigation District canal goes even farther north to tap the Wutchumna Ditch, whence it crosses both branches (with the most sanitary precaution against intermingling) and proceeds many miles southwest to lands which could be served from one of the natural distributaries of the south branch, Cameron Creek. From this same Wutchumna Ditch the Lindsay-Strathmore pipeline carries water not only back southeast whence it came, but back uphill to lands that the water could reach by gravity via an existing aqueduct, Foothill Ditch.

#### Conveyance losses

The problem has at least two important dimensions:

Loss of elevation. From about elevations 650 feet down to 250 feet the Kaweah River falls freely. This drop could hardly be used to generate power, but it could be used to move water southeast at high elevations. The gradient of marginal productivity rises rapidly to the southeast, and uphill, so this would be a very productive use of the elevation. This valuable elevation is

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<sup>38</sup> Computed from Kaweah River Flows . . ., supra (Note 6), map in back pocket.

<sup>39</sup> Ibid.



completely dissipated in the process of moving water through the present system to low lands that could be served by imported northern waters--if waters must be imported--much more cheaply than the higher and more southerly lands.

Channel seepage. Both the natural and artificial channels pass over porous materials and lose large fractions of their flow to the underground. Much of this water is later pumped and used, but it still represents significant loss.

First, much of it percolates in the wrong places, *e. g.*, the lower St. Johns channel, where ground water is too high already and the marginal productivity is zero. And once it has sunk it becomes subject to the paramount rights of overlying landowners and is very difficult to export.

Second, much of it percolates at the wrong time, that is in summer when pumps are busy lifting water from the ground reservoir, and surface delivery of this seepage water would save a needless round trip.

#### Inadequate use of the ground reservoir

Storage use. Below the surface of the Kaweah Delta lies a resource that is comparable in value to the river itself, *viz.*, a large underground storage reservoir in coarse gravel that is notable for ease of recharge and withdrawal, especially toward the apex of the cone. Like the river the reservoir has high location value, because in this area storage, like water, is scarce. Neither the Kaweah nor the neighboring Tule has a large and economical site for surface storage, and ground storage south and especially southeast from the Kaweah Delta is poor.<sup>40</sup> Clearly this ground storage should be filled in spring and drawn down in summer to regulate the flow.

But many overlying landowners have strong rights in surface water, so hardly need the ground water. And the reservoir cannot be used for the benefit of other lands. California law allows only "surplus" waters to be exported from a ground water basin, and in this area exports have been enjoined. Even if the "foreign" land holder supplies his own water by artificial recharge, wishing only to use the reservoir, he cannot, because the natural and artificial waters commingle underground. When he withdrew the equivalent of what he had "deposited" in this bank it would include some natural water, thereby threatening to establish a prescriptive right that overlying owners would be bound to enjoin.

The Lindsay-Strathmore Irrigation District did, it is true, operate a well-field in this area for several years up to 1952, but was forced finally to discontinue. It had only enough bargaining power to get consent to continue its use until Central Valley Project water became available. Even this well-field used only a small fraction of the underground reservoir capacity.

Permanent recharge. In some areas in recent years, recharge of aquifers would have been desirable. One of the most productive uses of water often is to submerge it permanently to support the water table and reduce pump lifts. In aquifers of 10 per cent water-holding capacity, for example, one acre-foot per acre should raise pump lifts 10 feet, worth about \$1.50 a year,

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<sup>40</sup>Wm. Gardener, testimony at Hearings on S. 912 . . ., *supra* (Note 15), p. 417.

if three acre-feet per acre are pumped. A dollar and a half a year at 5 per cent would be worth \$30, an exceedingly rough figure, but suggestive of the order of values involved.<sup>41</sup>

Recharge has not proceeded as fast as it should. The Tulare Irrigation District, interested in recharge, could not or did not pick up enough water from other organizations. The Kaweah Delta Water Conservation District, whose primary physical function is recharge, has acquired no water rights of its own whatever.

A prime cause is the scattering of irrigated farms among dry farms in the area. Not only are organizational service areas scattered, as described above, but pump-irrigated land is similarly interspersed with dry-farmed land over a wide area.<sup>42</sup> This pattern of course multiplies the volume of water that must be sunk underground to support water tables beneath the irrigated acreage, and no doubt this helps to make uneconomical an operation that would, with compact development of irrigation, often be feasible.

Corresponding to inadequate recharge is the problem of excessive withdrawal. The individual pumper feels no constraint to economize on ground water and accordingly treats it as a free good.

#### Inadequate reuse of water

The early diversions from the Kaweah, which today have fixed priorities based on historical use as well as privileged riparian status, were largely made at lower elevations, toward the bottom of the system. Water so applied drains out of the system with less reuse than if it were applied initially on the higher bench lands.

#### Segregation of the Kaweah from small local streams

There are several small intermittent streams nearby the Kaweah, whose flows aggregate some 20 per cent of the Kaweah's. Generally, the smaller a stream the less reliable its flow, so these waters are largely unusable.

It is interesting to note, however, that these intermittent waters could be made usable by integration with the Kaweah, materially augmenting the area's usable water supply. They rise from much lower watersheds than the Kaweah, so their patterns of flow are different, tending to offset each other and the Kaweah. When all the flows are aggregated, in fact, the coefficient of variation of the combined flows is little greater than for the Kaweah alone.<sup>43</sup> This benefit would flow simply from applying the principle of pooling offsetting risks. However, it has not been done. Rather, as we have seen earlier, the

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<sup>41</sup> Preliminary studies by Edward Renshaw at the Giannini Foundation appear to yield comparable figures.

<sup>42</sup> Water Resources of Tulare County . . ., *supra* (Note 13), Map 1; Irvin H. Althouse, *supra* (Note 16), map in back pocket.

<sup>43</sup> .52 for the Kaweah and .54 for the combined flows. The coefficients of variation for the small streams taken individually run around .75 - .80. Computed from data for 1890 - 1940 in Irvin H. Althouse, *op. cit. supra* (Note 16).

contrary: the Kaweah itself is unpooled, split up in such a way as to create more risk, regressing from Nature rather than improving on her.

### Segregation of the Kaweah from the Kings River

Integration of the Kaweah with its larger northern neighbor, the Kings, has been recommended by most students of the area of an engineering or economic orientation. These include Irvin Althouse,<sup>44</sup> a leading engineer of Tulare County; the California Division of Water Resources in its original plans for the Central Valley;<sup>45</sup> and more recently the Bureau of Reclamation.<sup>46</sup> Some of the advantages would be:

1. The Kings River has abundant cheap surface storage (at Pine Flat), which could be used to firm up the Kaweah, thus indirectly helping to regulate the latter.

2. The Kings has a relative water surplus, and its present service area is much cheaper to reach from the north if more supplies are to be imported.

3. The Kings could serve much of the Kaweah delta by gravity, releasing Kaweah water for export southeastward at high elevations into the zone of highest marginal productivity. The Friant-Kern canal could have been shortened into a "Kaweah-south" canal, and its cross-section could have been reduced by utilizing some elevation to increase the very low gradient, presently just six inches per mile. These measures would have greatly reduced its high cost, which was incurred by maintaining elevation through the rough foothills between the San Joaquin and the Kings.<sup>47</sup>

These net gains waited upon getting some flexibility into water allocations. They still wait. Not only was local enterprise blocked, but even when outside benefactors, the state and the nation, offered to cover most of the expenses, the obstacles of water law proved insurmountable.

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<sup>44</sup> Op. cit., supra, (Note 16), p. 97

<sup>45</sup> Paul Bailey, Water Resources of California, State of California, Dept. of Public Works, Division of Engineering and Irrigation, Bul. No. 9 (Sacramento: State Printing Office, 1925), Plate IV facing p. 10.

<sup>46</sup> Central Valley Basin, supra (Note 18), p. 132.

<sup>47</sup> Richard Boke, testimony at Hearings on S. 912 . . ., supra, (Note 14), p. 661

The Role of Water Law in Imposing and Perpetuating Diseconomies<sup>48</sup>

I have several times already alluded to the role of water law in the diseconomies described. The present section spells out this relationship more systematically.

Productivity not the initial basis of water rights

The state has never allocated its valuable waters by putting a rental on their use, neither has it ever sold licenses or titles to the highest bidder. Rather it has followed a mixture of methods whose rationale bears little apparent relationship to marginal productivity.

Riparian rights. Riparian rights are limited, as we all know, to lands fronting on natural channels. The Kaweah Delta with its many distributaries is endowed with more than the usual quota of riparian lands. The Kaweah channels are unusually shallow, as well as absorptive. Ground water gradients, therefore, slope down away from the channels, so that riparian lands in general have the easiest pump lifts and the least need of surface water. Thus riparian rights attach surface waters to the lands that need them least.

Appropriative rights. Appropriative rights, as we all also know, are based on priority of use and ranked by seniority. Rights become appurtenant to lands in the order that they are developed for irrigation.

Now the supersession of lands from less to more intensive uses in our society has almost never proceeded orderly-wise, in compact increments, and irrigation use is no exception. The more diligent early irrigators are sprinkled among dry farmers, and their appropriative rights the same, so that conveyance costs are excessive.

Early appropriative rights are not necessarily biased toward better soils, since dry-farmers on these are under less pressure than those on poor soils to augment their incomes, and are more typically holdouts against innovations like irrigation. Early rights are biased, however, toward soils and locations better suited to quick-development crops, uses like hay or grain. The slower-evolving uses with high per-acre capital requirements, like orchards, tend to join the race too late to get good water, even though they ultimately develop higher marginal productivities than the fast starters. Thus it is that the citrus zone has such inadequate water rights. Not only is land development slow, but extension of ditches to serve these higher lands requires more capital and a longer development period. The earliest pioneers were short on the capital and organization for such projects.

Worst of all, the appropriative system puts a premium on excessive and wasteful diversions. Even before that the "doctrine of relation," which bases priorities on the date of first claim rather than first use, puts a premium on premature and inflated claims, that are a source of enervating uncertainty. But when the chips are down, the courts have generally fallen back on histories of diversion as the ultimate basis for prorating scarce waters. The individual's incentive is, therefore, to divert water whether he needs it or not.

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<sup>48</sup>I am indebted to Thomas Crocker for assistance in research for this section, and to Professor Fred Mann for tolerant legal counsel.

It is the accepted means of staking a claim for the future.

Thereby a cost to society--withdrawing water--is made a revenue to the appropriator. Where water was superabundant, this may once have served some useful function in accelerating development. Now when water has become scarce it would be hard to contrive a more perverse arrangement.

Correlative rights. In California rights to percolating ground water are called "Correlative." They have no statutory basis but are based on court traditions and judgements. Land overlying an aquifer is treated analogously to land riparian to a stream, and correlative rights are limited to these overlying lands. "Surplus" waters may be exported, but the meaning of "surplus" is for a court to decide in each case and on the Kaweah, despite the situations described earlier, the courts have denied permission to export ground water from acres of low to high marginal revenue productivity.

As mentioned above, the prohibition on exporting ground water also stops "foreign" land holders from using underground reservoirs.

The initial pattern is frozen

The initial pattern would be of limited concern if it could be altered to meet changing demands. But under prevailing water laws, water users are insulated from social opportunity costs. The state charges no economic rental for the use of its waters, or indeed any rental at all. The counties hardly tax water rights (unless held by rich outside cities). Nor is there much appreciable implicit opportunity cost felt by the individual because he cannot easily sell surplus waters even if he wants to. The last point bears elaboration.

Allegations of transferability

It is generally recognized that riparian and correlative rights are not transferable, but several writers have alleged that appropriative rights are. S. T. Harding in 1936, seemingly in a glow of optimism over Peabody vs. Vallejo,<sup>49</sup> could write that "economic pressure will eventually result in the available water supplies being used where the greatest return will be secured,"<sup>50</sup> but this was little more than an expression of faith and hope. Several other allegations of transferability ultimately trace back to a citation in Wells Hutchins<sup>51</sup> wherein he discusses some of the possibilities of and obstacles to transfer in various states. But the discussion is purely legalistic with no purport of economic analysis or quantitative evaluation, and certainly should not be asked to bear much weight as a demonstration that any significant volume of our water resources is effectively transferable in response to ordinary economic pressures. To my knowledge there is no such general demonstration, but only a belief in some quarters that one exists.

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<sup>49</sup>2 Calif. (2d) 351, 40 Pac. (2d) 486 (1935)

<sup>50</sup>Sidney T. Harding, Water Rights for Irrigation, supra (Note 4), p.46

<sup>51</sup>Wells Hutchins, Selected Problems in the Law of Water Rights in the West, USDA Misc. Publication No. 418 (Washington: Government Printing Office, 1942), pp. 378 ff.

## Kinds of transfers achieved on the Kaweah

Certain limited kinds of water transfers actually have been effected in the Kaweah system. The most common kind is the sale of shares in mutual water companies. There has been an active and continuing market in these shares, among individuals and areas. In general, the movement has been in economical directions, from north to south. Big buyers have been the Irrigation districts: the Lindsay-Strathmore, Tulare, and Corcoran. Biggest sellers have been shareholders in the Wutchumna Water Company, which had an undoubted surplus.

## Uneconomic aspects of these transfers

Transfer of water company shares has bemused several water economists recently as a means toward that workable water market most of us would postulate as an ultimate goal.<sup>52</sup> Unfortunately, these are drawbacks to this type of transfer that severely narrow its potentiality.

**Fixed point of diversion.** The buyer of mutual water company shares in California must use the selling company's diversion works, however inconvenient. In 1928, Lindsay-Strathmore Irrigation District, having bought shares in several downstream mutual water companies, sought to divert its share of their waters by gravity through Foothill Ditch from a higher diversion point. The courts enjoined this,<sup>53</sup> requiring Lindsay-Strathmore to let the water flow freely downhill to the mutual water companies' diversion works, tap onto the individual ditches below their heads, regather the waters, and then pump them back uphill. These requirements precluded most of the transfers, and imposed extra costs that consumed much of the net benefits from the one such transfer that was consummated (from Wutchumna Water Company).

Tulare Irrigation District, which lies below Wutchumna Water Company, in order to divert its share has had to build the long canal previously described, paralleling the Kaweah Branch and crossing both branches to tap the Wutchumna Ditch near Woodlake.

Thus the Kaweah water distribution system has had to grow physically in a manner analogous to the law itself, with one principle hanging on another back to the ancient and ultimate fountainheads of authority. It is questionable whether circuitous transfers of this sort are desirable at all, even if each individual operation shows a net gain. For as one ditch is tacked on to another, more and more interests become vested in an increasingly absurd tangle, and the hope of rationalization recedes ever further into the realm of unattainable visions.

**Short-run inflexibility.** The flexibility achieved by sale of shares is largely long run. Within some areas there is some leasing, but between companies it would usually be necessary to extend a ditch to effect a transfer.

<sup>52</sup>Raymond L. Anderson, "Operation of the Water Rental Market in the South Platte Basin," 42 JFE (5): 1501-03 (December, 1960).

<sup>53</sup>Consolidated Peoples' Ditch, Co. v. Foothill Ditch Co., 205 Calif. 54, 269 Pac. 915 (1928).

There is lacking a planned excess ditch capacity such as is necessary to allow much flexibility. The process of transfer is slow and sticky, whereas demands fluctuate continually and to a degree unpredictably.

**Deconsolidation of service areas.** Individuals selling shares give little heed to the over-all effect on distribution costs, so the company service areas are shot full of holes, resulting in the pattern of scattered and overlapping service areas noted above.

**Limited area of transfer.** The transferability of mutual water company shares is limited to the Kaweah Delta area. Areas of higher marginal productivity outside the delta cannot get Kaweah water this way (or any other way). This point was decisively settled by the out-of-court treaty closing the "17-years war" against Lindsay-Strathmore. While this one persistent district was finally vouchsafed an interim supply until Central Valley Project water should arrive, there was clearly no hope for other citrus lands, none of whose owners have since found the temerity to try to tap the Kaweah.

#### Kinds of transfers blocked

Other types of voluntary transfer have been blocked almost completely.

**Riparian rights.** Riparian rights in California are "part and parcel" of land and transferable only by extinction. The same holds for mutual water company shares based on riparian rights.

Riparian rights are not good for storage. If a riparian claimant wants to store water he can do so only by filing as a junior appropriator and taking his place at the end of the line. Since the Kaweah is all "claimed up" this would avail him nought, and if he sought to put water at the end of the line by abandoning his riparian claim he would find this water completely swallowed up in the inflated claims of prior applicants.

A riparian, therefore, has little choice but to insist on maintenance of the natural flows he can claim and to use them without any storage regulation. Transfer of these waters to storage is legally impossible, in the normal course of events.

**Correlative rights.** Like riparian rights these are completely nontransferable.

**Appropriative rights.** The basic legal presumption is that appropriative rights are transferable, and sometimes they have been transferred. But there are many hurdles to cross that, in their cumulative effect in the Kaweah area, have the effect of complete prohibition.

**Uncertainty of tenure.** An appropriator does not "own" a water right. He has a permit or a license to use the state's water. Appropriators would like to have these licenses regarded as firm property rights, and in part they have succeeded, but only in part. The law is equivocal, now asserting the state's ownership, now deferring to the licensees' "property" rights, and in the last analysis will no doubt, like Mr. Dooley's Supreme Court, follow the election returns. Meantime, appropriative rights are left hanging in a tenuous limbo, the judicial reflection of public schizophrenia.

The appropriators' position rests on a kind of mystic philosophy that value is entirely created by use, a mystique that will not bear analysis and so must deny much of the rationalism associated with the commercial revolution. This mystique is roughly violated, and the acquiescent public outraged, by the spectacle of licensees "trafficking" in their privileges and measuring them in the balance with something so profane as money.

Some of this attitude rubs off on the licensees themselves, many of whom put water rights in a class with family heirlooms and heap social disapproval on any of their number who would sell, the more so because publicity attending sales at high prices might weaken the already shaky position of licensees generally, expose them to regulation, taxation, or royalty charges, and rouse opposition to their receiving subsidized reservoir services from federal agencies. And so there is a strong bias against commerce in appropriative rights. By its nature the relative strength of this factor is impossible to quantify, but in my observation and judgment it is appreciable.<sup>54</sup> It has some measure in the zeal with which land holders agitate to have federally developed and delivered waters made "appurtenant" to their lands.

Marginal adjustments. Ordinarily an appropriator with surplus water would not want to sell his entire supply, but only the surplus, that is, the part whose marginal productivity falls below its opportunity cost. It is doubtful if a licensee could guarantee the buyer a good title in such a transfer, however, because the validity of the license rests on historical beneficial use, and sale of surplus water could and doubtless would be seized upon by thirsty junior appropriators as evidence that the water never had been used "beneficially" and should revert to them. Thus a licensee cannot sell something as good as what he has because the process of sale weakens the license. A strong bias against change inheres in the system.

Rights held by water-users' organizations. Additional difficulties beset transfers of water rights when these are held by mutual water companies or irrigation districts. Since most water rights on the Kaweah and in California are so held, these special hurdles are of prime importance in any discussion of water right transfers. Curiously, however, I have found little such discussion, so that what follows must be partly the conjecture of a guardhouse lawyer. If it is seriously misleading, I hope it will at least irritate some real lawyer into publishing a definitive correction.

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<sup>54</sup>The "Chicago School" approach of Drs. Hirschleifer, De Haven and Milliman is doomed to frustration, I believe, for failure to acknowledge this aspect of the problem. They argue most persuasively the benefits to flow from removing barriers to transfer of water, their means being to strengthen absolute private property control over water. (Water Supply [Chicago: University of Chicago Press, 1960], pp. 222-54.) But to convert a conditional into an absolute "giveaway" is to clarify the issue of distributive equity to the degree that the public will become aware of it. So long as the licensees are ascendant they are unlikely to tolerate market transfers that risk arousing the public; while if the public were ascendant, it would not likely abandon all interest in its waters without exacting some quid pro quo. We are not likely to achieve the benefits of market allocation of water rights without an unequivocal resolution of this incertitude: the licensees gain full control of the water by buying or (I think preferably) leasing it from the state.



Mutual water companies and irrigation districts hold property and water rights as trustees for the beneficial owners, the served land holders. The land holder is more than an ordinary shareholder in a mutual, or a voter in a district: he is the beneficiary of a trust. The law presumes that the trustees will continue the customary service to the customary beneficiaries in the absence of some new condition that a judge finds compelling and persuasive.

Just what a judge might deem compelling and persuasive is sometimes hard for an economist to fathom. I have found no clear-cut decision authorizing a mutual or district to sell water rights. Nor have I found any instance where one has done so, save to another organization serving the same lands. But there are several instances of conveyances through sale or foreclosure being enjoined.<sup>55</sup> Since there are scores of districts and mutuals with surplus appropriated water they should but do not sell, it seems that judicial interpretation of the trustee relationship has virtually prohibited sale.

The would-be seller is pinched between the devil and the deep, for on one hand he must satisfy the courts that he is not depriving any litigious trust beneficiary of something of much value, and on the other hand that the district or mutual has a valid appropriation to convey, based on beneficial use. An economist might feel he could resolve such a dilemma to the mutual benefit of all parties, but economic concepts are not to be presumed as among the intellectual equipment of jurists, especially in the lower courts. So the trustees play it safe by hanging on to all the water they can for such future use as it may have to them. It is effectively withdrawn from commerce in a mortmain grip as deadly as that fastened on the lands of medieval Europe.

Point of diversion. In transferring an appropriative right one may shift the point of diversion only if no one is damaged. The most economical transfers in the Kaweah area would entail shifting points of diversion, as we have noted. But today one cannot shift any point of diversion without damaging or at least discommoding someone else.<sup>56</sup> One could seek an agreement from him not to press his claim, but his ransom is not necessarily limited to actual damages. No point of diversion has been changed on the Kaweah during the period this study covers most intensively, that is back to 1919; and the general patterns of uneconomic diversions still extant go back at least to 1880, when they were roundly condemned by the California State Engineer.<sup>57</sup>

<sup>55</sup> Copeland et al. v. Fairview Land and Water Co. et al. 165 Cal. 89 (1913); Bent v. Second Extension Water Co. et al. 51 C. A. 648 (1921); Wells Hutchins, Mutual Water Companies in California and Utah, Farm Credit Administration, Cooperative Division, Bulletin No. 8 (Washington: Gov't. Printing Office, 1936), pp. 87-91, 137-38; Tulare Irrigation District v. Collins, 154 Cal. 440 (1908). "An Irrigation District owns no lands in a proprietary sense, and its property is owned by the State and is held only for governmental purposes." -- Allen v. Hussey, 225 Pac. 2d 674, (1950); 101 C. A. 2d 457 (1951).

<sup>56</sup> On the neighboring Kings River a few changes have been possible, but only downstream. (Clarence Smith, Kings River Water Master, in interview, 1958.) The general need, however, is for upstream shifts, and these are blocked by intervening land holders with interests in channel seepage.

<sup>57</sup> Wm. H. Hall, Report of the State Engineer to the Legislature of California, Session of 1880, Part I (1880), pp. 33, 35, 36, 105-17 et passim. Hall's observations applied specifically to the Kings, Tule, and Kern, which border on and overlap the Kaweah service area.

## The Dynamic Evolution Shaped by Water Law

Professor Wantrup has remarked that a system of water law should be judged over time, <sup>58</sup> and the point is well taken. But if this is to imply that the judgment will thereupon become more favorable, it is not.

The effect of water law on economic development is to reinforce other economic and political pressures working toward premature overdevelopment of new lands, a process already past the point of no return today. Let me expand on this perhaps startling asseveration.

### Marginal vs. monumental adjustments

Legal perception of economic values is too crude, as we have seen, to effect or even to permit of marginal adjustments among local waterusers. Yet Justice is not entirely blind. It is more to be likened to the near-sighted Mr. Magoo who does respond, however inappropriately, to the major outlines of things. After the water-seeker has ranged far enough from home, and crossed several underused streams, he ultimately reaches one in which the courts will acknowledge the existence of a "surplus."

He finds the courts little concerned with any monetary comparison of productivity F. O. B. the source. Such comparisons might leave him with a negative or very low net product, after deducting his high conveyance costs. But the law is disposed to count that in his favor as a mark of sincere purpose and acute thirst.

Panglossian philosophers may point to this as evidence that water law is, after all, dynamic. On the Kaweah, it is true water law has attained to a nearly perfect degree of stagnation which the law contemplates with equanimity. But this has not stopped, indeed it has materially accelerated great interregional transfers of dimensions that dwarf the Kaweah.

Thus water law as a whole does not simply resist change. Inexpensive little local economies on the Kaweah meet a stone wall of judicial disapproval, but water law opens up wide avenues for monumental projects to effect grand interregional transfers. <sup>59</sup> Rather than block development, it biases development toward remote sources. This is the dynamic growth pattern imposed by water law. If we wish to criticize the law, it must be on grounds that the type of change it promotes is less desirable than the alternatives.

### Drawbacks of monumental projects

Monumental interregional transfer projects have captured the imaginations of the state's voters and politicians to the extent that they now dominate water development. It is my thesis that this type of development is leading to overexpansion.

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<sup>58</sup>S. V. Wantrup, "Conceptual Problems in Projecting the Demand for Land and water," Giannini Foundation Paper No. 176 (Berkeley: 1959), Mimeo., pp. 14

<sup>59</sup>For a more general criticism of monumental transfer projects see Hirshleifer et al., op. cit. (Note 47)

Size of increment. A remote import must usually be a large one for several reasons. First, to be economical at all it must realize scale economies springing from the fact that canal cross sections increase out of proportion to their cost. Second, it requires strong political support, to secure both water rights and state or federal financing, and for these purposes it must have a large service area. Third, this service area typically has scattered irrigation developments, and to keep project distribution costs within bounds it must plan to serve the included dry lands as well. Likewise, in recharging underground reservoirs, it must import enough to recharge the entire area over which irrigation is scattered. Fourth, the political conjuncture that permits the region to import water is an opportunity to be fully exploited, and the beneficiaries will try to stake claim to as much water as possible.

So a remote import is likely to be a large one, an indivisibility in economic development, in contrast to the continual fine adjustments that would be possible under a more flexible system of water law. In the Kaweah area the increment from the Central Valley Project is in fact several times the local supply. The Friant-Kern Canal with 4,000 second-foot capacity can import most of the San Joaquin River, whose mean annual flow of nearly two million acre-feet is about four times the combined means of the Kaweah and Tule rivers. More, this is regulated water from Millerton Lake. Almost one million acre-feet is to be Class I water delivered on demand. The increment to summer water is much greater than 400 per cent.

The potential impact of this increment has been concealed, among other ways, by the belief that much of it would go to overcome overdraft. But the annual overdraft is of a much smaller order than the San Joaquin imports. Equally important, there is no basis for assuming that irrigated land development will cease when water equilibrium shall have been attained. There are no controls on pumping and nothing (except market collapse) to stop development short of another overdraft. But in fact, before this becomes an issue there will be a question of how to dispose of the waters now used for recharge and soon to be available for other uses as that operation is completed.<sup>60</sup>

In terms of acreage, size of the increment has been concealed by most of its having gone into alfalfa, pasture, and cotton, whereby the impact is absorbed by nationwide markets or government storage. But these uses could never justify the cost of the Central Valley Project. They are lower uses in an area of excellent soils and superlative climate suited for horticulture and winter vegetables. It is only a question of time before these slower-developing, higher-yielding farm enterprises lay claim to much of the new water.

But here the impact will be overwhelming. Three local products of which California produces most of the nation's supply are plums, freestone peaches, and navel oranges. These supplies come from the following acreages: plums,

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<sup>60</sup>In their commendable zeal to maintain the government's bargaining position in drawing up water contracts, Bureau of Reclamation officials have understandably tended to minimize this eventuality. See, for example, Hearings on S. 912 . . . , supra (Note 14), pp. 710 et passim. Whether their prognostications of continued high demand are correct is a question of fact that I am content to leave to the verdict of events. The current drought forestalls the emergence of a surplus, but on the other hand helps stimulate more new water supply developments that in the long run may aggravate the oversupply.

21,000; freestones, 36,000; navels, 65,000.<sup>61</sup> In the last five years, new non-bearing acres of these (and other) tree fruits have turned up sharply, reversing long declines. The potential acreage increments of 10 per cent or 20 per cent have aroused considerable anxiety, as well they might, the more so because they are more intensively planted than the old and with better stock. But they are as nothing compared to the eligible acres now newly supplied with water from Friant-Kern. The increment of almost one million acre-feet per year of Class I water, and additional Class II of variable water, could support 300,000 or 400,000 new acres, far more than markets could absorb in the foreseeable future. This one project has brought water supply to so much potential fruit land that fruit land as such is hardly any longer a scarce economic good. Scarcity today attaches only to producing groves, and tomorrow perhaps not even to them. Only this relationship is not yet reflected in land prices, whose inflated levels lend a specious plausibility to the project still.

Slow response to changing demands. Another serious drawback of remote imports is the long lag between stimulus and response. Lindsay-Strathmore's wells began striking boron in 1913. Friant-Kern water reached them in 1951, 38 years later. Meantime the area's high potential citrus development was arrested completely, and other regions filled the gap. The scale economies of monumental projects are to be considerably discounted because of their ponderous immaneuverability. They are slow a-building, and once built they are slower to liquidate. They cannot be rolled up when obsolete, and they pay out slowly if at all.

A cycle of overdevelopment. A response which is both slow and excessive is the basic element in a cycle of overdevelopment along the lines of the classic cobweb theorem (corn-hog cycle). Only with land and water development the period is much longer, the mistakes irreversible, and the excesses much greater for several reasons I will mention.

Lag of private land improvement behind public works. To increase public water supplies rarely results in commensurate increases in the products of irrigated land until long after, because private improvement of the lands made irrigable lags many years, decades in fact, behind the public works.<sup>62</sup> Thus, the price effects and capital requirements of the incremental land supply are

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<sup>61</sup> Gerald W. Dean, and Chester O. McCorkle, Trends for Major California Fruit Crops, California A. E. S. Extension Service Circular 448, 1960.

Sherwood W. Shear of the Giannini Foundation has been more than gracious in supplying acreage and production data. Neither of the above is implicated in the use of the data here.

<sup>62</sup> Ray P. Teele, The Economics of Land Reclamation (Chicago: A. W. Shaw Co., 1927), pp. 99-100.

\_\_\_\_\_, Land Reclamation Policies in the United States, U. S. Dept. of Agri. Bulletin No. 1257 (Washington: Government Printing Office, 1924). p. 15.

Roy Huffman, Irrigation Development & Public Water Policy (New York: The Ronald Press, 1953), pp. 61-62, 81.

deferred and concealed until the project and its several features are committed past the point of no return. The long developmental period of tree fruits lends itself to its own cycle of overexpansion anyway. When this is combined with the lag in building large water supply systems, the lags and accompanying perils of overexpansion are multiplied.

#### Incitement of other projects

The price umbrella. Lagging private development of project-served lands holds a price umbrella that entices more starts than markets can ultimately absorb and for which capital can be found at feasible cost. The high prices bring on competitive starts of several kinds. Private lands in older irrigated areas are intensified, for which the sloppy developments of the past leave considerable scope--in fact, if lands served by pre-Central Valley Project water supplies were developed to capacity, there would be little need for new public water supplies. Lands in the new project area are planted at high standards of intensity based on high land values that do not accurately reflect the impending abundance of raw land.

Most striking of all, entirely new water supply projects are begun. To a degree this is simply analogous to what has happened in land cycles of every kind throughout our history. But water law is responsible for amplifying the cycle in ways besides those already mentioned.

Racing for water rights. When one region goes foraging about the whole state for "surplus" waters, this naturally awakens anxieties in others lest they lose out. They seek to nail down claims that others cannot jump. The surest means to this end is to begin developing waters to establish a history of use. It takes little imagination to anticipate the result, which today one observes throughout California: premature interest in developing water ahead of need.

Logrolling. Monumental interregional transfers are usually too costly for local finances. They are undertaken with state and federal subsidies. This incurs political debts to be repaid in kind, less on a basis of economic productivity than of political bargaining power. There must be something for everyone, or at least for enough legislators to constitute a working majority. And most projects need to be started before any is completed, lest late starters lose their bargaining power. This process clearly lends itself to the cycle of overexpansion, too: the impact of the first project is suppressed by noncompletion until the later ones are well underway. This is the sort of process by which Indiana went bankrupt in another kind of canal boom that busted in 1836.

#### Current overexpansion of water-supply projects

J. K. Galbraith has won wide support for his thesis that we put too small a portion of our resources into the public sector. While this may be true in comparing tail fins vs. school rooms, it can be very misleading in comparing private vs. public contributions to land and water development. Public water supply works stand ready to serve far more land than private capital has improved to use the water.

This is not a new phenomenon. David Weeks and Charles West documented it extensively in 1927 in their classic The Problem of Securing Closer

Relationship Between Agricultural Development and Irrigation Construction. They noted that capital flowed into public water supply works much easier than into corresponding private farm improvement, with a resulting lag, serious imbalance, and ultimate overdevelopment of irrigated land. Their judgment was abundantly confirmed in the ensuing collapse of land values.

The premature excessive public works they observed were the product of local enterprise almost entirely. To redress the balance would seem to have called for diversion of capital from public works to individual land improvement. Yet, instead, the last 25 years have witnessed the opposite, and on a scale hitherto undreamed of.

First, the value of the tax-exempt feature of local bonds has risen along with personal income tax rates. In the 1920's these bonds often sold at big discounts; today at handsome premia.

Second, local water enterprises receive new state and federal subsidies, under the Small Projects Act, the Davis-Grunsky Act, and interest-free loans from the Bureau of Reclamation.

Third, irrigation districts and private power companies have cemented an effective working alliance whereby the power company borrows the irrigation district's immunity from local property taxes and pays for it with free water. This is a big factor in the estimated one billion dollars worth of local projects now underway in California.<sup>64</sup>

Fourth, the Army Engineers have gotten into water supply under guise of flood control, especially since the Flood Control Act of 1944, and are planting federal projects in hitherto neglected sites all over the state, including Terminus on the Kaweah, and Success and Pine Flat on its neighbors, the Tule and Kings.

Fifth, the Bureau of Reclamation, once a negligible force in California, has contributed the Central Valley Project and its slowly proliferating appendages.

Sixth, if all this were not enough, we add now the Feather River Project, whose \$1.75 billion bond issue is conceived as only a beginning on an over-all California Water Plan.

Finally, seventh, Secretary of Interior Udall announces that the U. S. has shirked its duties and will increase its contributions to water supply development.

There has been no commensurate stimulus to the flow of capital into improving private farm lands. On the contrary, higher personal income tax rates, in conjunction with the various capital gains loopholes, have encouraged much more land buying to reap price increments without land improvement, a type of behavior that has previously played a central role in creating this

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<sup>63</sup> Univ. of Calif. College of Agriculture, Agri. Expt. Sta., Bulletin 435 (Berkeley: Univ. of Calif. Printing Office, 1927).

<sup>64</sup> Western Water News, October, 1960

problem even without such added stimulus. Indeed it is only in the last five years or so that bearing acreages of most of California's distinctive specialty crops have ceased contracting.<sup>65</sup> Here is the bottleneck that has held back output and sustained the prices on which the whole mammoth structure of public works is premised. Modest increases of a few thousand bearing acres, soon finally to be forthcoming, are adequate to meet the market demands that ultimately must justify investments in water supply.

Irrigation is new enough in American history that it has figured in only two major land collapses, 1893 and 1929. But in those two it figured prominently, through excessive expansion of water supply works for undeveloped lands. "Too much, too late" has characterized the denouement of each cycle. There is evidence that we have moved too far on the same course again.

In this cycle, water law, while not solely responsible, plays an important role. It is water law that blocks the economical use of the best waters, compelling recourse to marginal sources, gigantic projects, and state and federal financing with consequent logrolling. It is water law that sets region racing against region, and agency against agency to establish use rights ahead of need.

And so when we view water law in the dynamics of development the view is more illuminating, but not more complimentary. How serious the defects, again I am willing to leave to the verdict of events.

### Conclusion

In this paper I have sought to expound the conclusion I have reached from observation of water use in the Kaweah area, that water use is grossly uneconomical. I have laid the blame where I believe it belongs, on the doorstep of water law. I have gone on to show how water law contributes to the cycle of overexpansion that has run so far along today.

I have not suggested, save by indirection, alternative policies, nor will I impose further on your patience by doing so now. But assuredly, if it be established that present policies are intolerable, the moulding of new is the greatest challenge facing our profession.

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<sup>65</sup>Dean and McCorkle, op. cit. (Note 53).







## PRICING PUBLICLY OWNED RANGE AND WATER RESOURCES

M. F. Brewer<sup>1</sup>

Virtually all sciences today are confronted with problems of prolific taxonomy. Single syllable terms formerly used to convey a recognizable area of concern have begotten swarming families of scientific argot. There can be little doubt that the term, "price," has parented one of the largest kinship groups within economics, affording a wide range of interpretations of the assigned topic. As a guard against the hazard of jumping from one such interpretation to another, I choose at the outset to qualify the meaning of public pricing and develop the structure of my argument within this definition. For problems of policy, such semantic specifications constrain<sup>2</sup> relevant analysis, much as technical coefficients of productions do in problems in production economics.

Public Policy and Pricing Practices

Policy is taken to mean a set of decisions motivated by common objectives--or more simply, as a line of actions. These action systems, or policy programs, are evolutionary processes, representing the interaction between perceived objectives and past actions.

As social scientists, we may be interested in at least two kinds of public policy evaluation. The first is in terms of the stated or implied objectives.<sup>3</sup> Thus, a policy program may be judged as consistent or complete inter se. The second type of evaluation uses criteria not necessarily included in objectives. Two types of criteria frequently are relevant: those relating to particular functions of a policy, and those relating to social welfare. Thus, we can evaluate how well price policy functions as source of revenue, as a tool for resource management, or as an allocator of a particular resource. We also may assess the extent to which a particular price practice affects the size and incidence of state or national income.

Frequently the functions of a line of public action are not immediately apparent, but are revealed through historical perspective. In this sense, the past performance of public agencies, their legislative basis, and the role accorded them by the community are important sources of insight into the func-

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<sup>2</sup> For a discussion of this problem in terms of symbolic logic, see: Andreas G. Papandreou, Economics as a Science (New York: J. B. Lippincott, Co., 1958), especially pp. 121-146.

<sup>3</sup> An objective, or goal, is not synonymous with an evaluatory criterion for assessing particular policy measures. However, an operationally valid objective to public policy is so specified that one can deduce analytically useful criteria for such an evaluation. Such criteria may permit an ordinal ranking of alternative tools on the basis of their degree of satisfaction of that objective. Frequently, objectives are so indefinite that criteria deduced therefrom are not capable of differentiating finely between policy tool alternatives.

tional role of particular policies.<sup>4</sup> The empirical relevance of this type of research uniquely depends upon the proper identification and specification of observed parameters. Frequently errors of this type are more significant than a lack of precision in quantitative measurement.

Price policies are action systems through which proprietary interests are exchanged. Properly articulated, they indicate sufficient or necessary conditions of payments and tenure under which exchange occurs. A policy for price thus consists of a basic set of objectives and a sequence of decisions that collectively accomplishes a tenure transaction. The size of payments involved, their form, timing, and type of proprietary interests involved all are part of such a policy and must be identified for it to be described completely.

This general, if awkward, expression of "public pricing" is used purposely because too frequently we think of the concept in the partial and static sense of a readily identifiable unit cost. Although relevant for certain categories of manufactured goods sold on well-defined, competitive markets, it is limited with respect to many natural resources, and particularly range and water. Three characteristics are especially important in explaining the inapplicability of the partial and static concept: product uniformity, ownership institutions, and forms of payment.

#### Product uniformity

Economic goods may be classified by various criteria. Frequently in economics an arbitrarily specified level of demand cross-elasticity is used to group-related products or goods. Analysis customarily assumes each such group homogeneous in delineating market structure, performance, or the familiar functional relationships.

The deduction and measurement of market demand and supply functions imply that each unit of good is, in fact, replicated in a firm's inventory. Such an assumption is especially heroic for natural resources. Water, for example, presents a broad quantitative spectrum--from sewer effluent to a chemical distillate--and its classification for purposes of transaction embodies broad criteria. Class I and II water are specified by the Bureau of Reclamation on the basis of probability of annual delivery, whereas the Metropolitan Water District of Southern California differentiates on a "treated" or "untreated" basis. Similar broad categories are used to indicate range resources.

Three consequences can be drawn from the lack of uniformity in range and water resources. First, the cost of using a given physical quantity may vary over both time and space. Thus, the "user cost" of water varies with quality; it also varies for public range, depending upon the extent of fencing and improvements required. Pricing systems often have been related functionally to such costs, thus departing from a single constant unit price.

A related derivative is the variation in average value product of range and water resources. Concern with "unjust enrichment" from using public water--and with excessive federal subsidy in public range--sometimes has

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<sup>4</sup> For an example of such an analytical synthesis, see: Stephen C. Smith, The Public District in Integrating Ground and Surface Water Management: A Case Study in Santa Clara County (manuscript to be published), 177p.

made payments responsive to such variation,<sup>5</sup> necessitating departure from single unit prices.

The third consequence of resource heterogeneity is tied to the flow nature of both range and water. The dependency of resource quality and quantity on types and rates of previous use makes possible programs of resource management. Price has been found an effective management tool and substantial differences exist between management units. The use of assessment by local water districts is particularly important in this regard.

#### Ownership institutions

A wide variety of ownership equities is used in the sale or transactions of natural resources, requiring broad interpretation of price. Fee-simple ownership, assumed for most consumer goods, has been fractioned for range and water. Public "sales" entail conditional grazing rights and limited circumstances under which privately "purchased" water can be withdrawn from public canals. When a price is announced for water or range, the particular ownership equity involved, or service provided, must be identified before analysis can have pragmatic relevance. The extent to which they remain ambiguous in the pricing process influences the use to which they are subject and is analytically important.

#### Payment Form

Payment form is a third area of difference that warrants observation. Payment authorities for many natural resources are governmental bodies, often authorized to specify and enforce several forms of Payment in addition to a charge per unit "bought." For present purposes, ad valorem taxation is the most important variant form. This has been used widely as a component of the "price" of public water.

Thus, we see range and water characterized by physical and temporal heterogeneity, a large variety of types of ownership equity, and exchanged under institutional conditions often entailing several forms of payment.

Two methodological implications derive from these attributes of range and water pricing. The evolutionary nature of the policy "process" suggests that the social forces motivating policy effectively can be observed by historical study; and those institutions through which a policy functions must enter directly into the analysis, not merely be discussed as constraints.

Relevant analytical method, thus, must identify the basic institutions involved and the role of price for each. Interpretation of the analysis--and associated prescriptive suggestion--must recognize that price policy changes in response to these institutions and the role accorded price by them.

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<sup>5</sup>This type of surcharge has been adopted as state policy for pricing irrigation water from the proposed California Water Plan. See: California Department of Water Resources, Contracting Principles for Water Service Contract Under the California Water Resources Development System (Sacramento, 1960). Processed.

The Role of Price in the Public Development  
of Range and Water Resources

Broad differences in the organization and methods used for pricing range and water resources initially may suggest their lack of comparability. On the other hand, the direct and rather parallel relationship of each to western development in the United States, their physical interdependence, and the increasing demand to which both are subject indicate comparable exposition would be fruitful. The prices of both resources have constituted vehicles for general economic development, a means to stimulate investment in resource development, and devices for allocating the resources themselves over time between uses and among users.

### Range

The price of public range has played and continues to play two important, related roles in the development and use of this resource. The first is to foster general development of regional economies based on livestock production. The particular role of price has been to facilitate private use of and investment in the public domain. Indeed, the widespread practice of a zero price--manifest in trespass and the illegal use of federal range during the early 1900's--appears to have been sanctioned by the United States government. Since passage of the Taylor Grazing Act in 1934, public range resources have been made available to private livestock producers at a fee generally held<sup>6</sup> to be below private rental fees for similar quality range.

The current diversification of our western economy, the availability of credit institutions, and developments in the technology of livestock production collectively have weakened the past dependency of western economic growth upon range pricing policies favorable to private producers. The historical trend, alluded to as "underpricing," nonetheless persists. It is questionable whether additional development actually is stimulated by these practices. Evidence indicates that net private benefits of these leasing arrangements have been capitalized into the base property to which a grazing permit is virtually appurtenant.<sup>7</sup> Such practices, however, tend to perpetuate a fixed pattern of income distribution (or capital asset distribution).

The western development objective for public pricing of range resources still may be argued as applicable. If so, the concept logically must be broadened to include regional products of all types. If complementary relationships exist between grazing and other regional activities, temporary subsidization within the region may be indicated in the interests of regional efficiency.

The second role of price pertains to range as a factor of livestock production. In a formal sense, range is a capital good capable of forage production. As a limiting case, we may consider forage a stock resource. A public

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<sup>6</sup> Delworth B. Gardner, "Price Policies and the Changing West," Proceedings, Western Farm Economics Association: The West in a Growing Economy (Utah, 1959), pp. 228-243.

<sup>7</sup> This is a consequence of the priority criterion used to issue licenses when applicants request leases in excess of available range. Both the Bureau of Land Management and the Forest Service employ this criterion.

pricing agency then is faced with the problem of allocating this stock. Under these circumstances, the traditional, microstatic value-of-marginal product criterion for efficient allocation alone is adequate.

On the other hand, if forage inputs are considered from the standpoint of polyperiodic production, changes over time are important. The extent and condition of public range determines the quality and quantity of forage it produces. For present purposes the quantity of federal land--or our public land inventory--may be taken as depending on other public policies, and then fixed from the standpoint of pricing.

Range quality, however, appears related to federal management measures, to private inputs associated with private use such as fences, structures, etc., and, finally, to the rate and extent of grazing by a particular user. To the extent that price affects these variables, one of its functions becomes the determination of range quality. Investment in range management by several federal agencies is related to price through a percentage of total fee receipts earmarked for range improvement. As price is a partial determinant of total fee receipts, it is similarly related to the range improvement budget for a particular year.<sup>8</sup>

Federal price policy also may have important bearing on the extent to which private investment in public range improvement is required or encouraged and actually undertaken. Thus, to the extent that private investment is specified by contract, or influenced by reducing uncertainty of contract renewal, or changing individual time preference, it affects the ability of range to produce forage. Finally, contractual lease arrangements often include specific limitations upon the rate and intensity of grazing in particular years or months.

So long as price is a determinant of both public investment in range improvement as well as an influence on private investment and use, a problem of optimal investment arises. An "efficient" investment vector is thwarted so long as there is a discrepancy between the time preference rates of the public investor and private range users. As the range itself remains a public asset, the public time preference appears as the most relevant for ascertaining "efficient" investment levels. If price policy tends to induce a pattern of private investment similar to what it would be were private time preference equal to public time preference, such a price may be said to be filling its investment role effectively.

## Water

The role of price in public water development and use differs from that for range in several respects. Water development is linked more closely to price through agency practice; and price exerts a strong influence on local organizations that participate in public development and undertake local programs of water management.

The quantity of water available for use ultimately is determined by precipitation and ground water deposits, but more immediately on the extent of developmental facilities, or projects. Public investment in water development

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<sup>8</sup> Obviously, price may increase this budget only if it exceeds its marginal value product in private use.

as manifest in federal practice must satisfy two basic criteria, or tests: economic justification and financial feasibility. The former purports to yield an indication of total project benefits in relation to total project costs. The latter indicates the "workability" of a project under conditions laid down by legislation or agency policy. Such conditions specify reimbursable components of total capital outlay that must be returned within stipulated repayment periods, interest rates to obtain, etc. Price is related to both tests. As an important source of revenue, it is relevant to financial feasibility. Constituting a basic condition for private use of the project product, price has direct bearing on the type and extent of activities that will result from a project and, consequently, the benefits that reasonably may be anticipated from a particular water project. Prices in excess of water costs from alternative sources (such as pumped ground water) may result in curtailed water use and benefits accordingly.

Another role of price relates to the organizational arrangement through which water development, management, allocation, and use occur. As already implied, water development often entails many publics. Physically tracing water from the point of initial impoundment to eventual consumptive use usually involves a chain of organizations through which water rights and/or service commitments are transferred. Federal agencies, districts of districts, counties, and local water districts are common links in this chain. We are concerned with the economic consequences of pricing by the dominant developing agency--which I assume to be the initial link. These consequences devolve upon the functions of the entire organizational sequence and the eventual allocation of water among uses and users.

When publicly developed water is supplemental to other sources, its price often affects the cost structure of the entire water system of an area. By using both fixed and variable cost charges in pricing water from a particular source, price becomes a tool frequently used for water management by local districts.

The extent to which public price at the wholesale level leaves local districts economic and legal autonomy in their retailing functions is important from the standpoint of water allocation. If retail pricing is constrained, the local district's ability to engage in water management and local economic planning is limited accordingly. The extent to which the local district may shift the cost incidence among its members is especially important. Such flexibility permits local districts to induce desired patterns of water use and compensate when the management plan requires higher costs for particular groups. The organizational role of public price at the wholesale level is manifest in the consequent flexibility afforded local water organization.

### The Economic Analysis of Pricing Methods

The extent to which actual pricing methods perform these roles, or functions, efficiently may be analyzed. "Pricing methods" are general formulations of price. By themselves they do not establish a numerical price; however, they do identify the major variables in a price function and are susceptible to comparative evaluation. Those discussed represent the principal methods actually used or proposed for use in pricing public range and water resources.

## Range

Administrative Cost Pricing. Grazing fees are established under this method so that annual sales or rental receipts equal those components of total cost to the managing federal agency termed "administrative." It was used by the Grazing Service and the Bureau of Land Management until 1957. Secretary Ickes spelled out this pricing method in congressional hearings prior to the establishment of a Federal Grazing Service.<sup>9</sup> General wording in the Taylor Grazing Act instructs the Secretary to set "reasonable fees"--which has been interpreted in this light. The method further was specified by amendatory legislation in 1947 and has been accepted in principle by the National Advisory Board Council until 1954.<sup>10</sup> Fees were five cents per cow-unit-month and one cent per sheep-unit-month, excluding animals under six months, which were grazed free, until 1947 when they were raised to eight cents and 1 3/5 cents respectively. In its application, this method appears to have resulted in fixed low fees with little reference to actual costs of program administration.

It has been argued that this type of pricing results in a price below the marginal value product of the lands leased (imputed from private land leases), that there is no assurance of efficient utilization because the permit priority freezes the allocation, and that net social product suffers thereby.<sup>11</sup> In short, the classical case for misallocation.

Whether or not actual transfer of range between lessee and nonlessee occurs depends upon the tenure aspect of price policy. If livestock of any brand may be run on public range, it may be "subleased" by a permittee who grazes the stock of others. More efficient operators than the permittee presumably would respond to profit stimuli and initiate such transfers. The current permittee is then in a position of having secured a federal "concession" at advantageous cost, which redistributes income in a fashion favorable to himself. There still may be social objection to this, but the issue is one of income distribution rather than efficiency.

This precise argument often is articulated with righteous indignation when a windfall gain occurs from a generally single purpose public investment, the cost of which has not been incident upon and repaid in full by primary (private) beneficiaries. Thus, the farmer whose south 40 will border the planned superhighway has good fortune when his alkali becomes prime business frontage; yet, the Kern County Land Company in California is unjustly enriched as the result of a state water plan not containing the 160-acre restrictions of Federal Reclamation Law.

The extent to which such subleasing practices are interpreted as a violation of use diligence obviously will determine the relevance of this argument. However, the apparent lack of a central body designated to adjudicate such

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<sup>9</sup>U. S. Congress, House, Committee on Public Lands, Hearings, on H. R. 2835, 73rd Cong., 1st Sess., 1933, p. 16.

<sup>10</sup>In August, 1954, the National Advisory Board Council agreed on a fee system based on the combined prices of cattle and sheep in the markets of the 11 western states. Philip O. Foss, Politics and Grass (Seattle: University of Washington Press, 1960), p. 192.

<sup>11</sup>Gardner, op. cit.



matters implies that the practicality of such subleasing arrangements would be determined of the district grazers. If such transfers are not possible, the case for there being classical misallocation is strengthened.

Several other consequences of administrative cost pricing deserve attention. The allegation long has been made that the Taylor Grazing District permits are capitalized into the base property of the permittee. An argument based on this premise, contending that any change in fee would result in double payment, led to a 1939 Nevada court injunction restraining the regional grazer from interfering with the free use of public range.<sup>12</sup> If this allegation is accepted--I have not yet seen convincing empirical proof, but it appears intuitively valid--two "side-effects" may be noted. One is the effect of this capitalization on the tax structure of grazing communities; the second is the impact on farm income fluctuation.

Prevailing methods of property valuation for local assessment purposes frequently employ an average value per acre that is applied to the entire community. If this is so, capitalization of a permit's net private benefit into base property results in an upward bias on assessed values of nonpermittee property. This is particularly significant, as many of the early grazing priorities were obtained by old ranching establishments of larger-than-average size. Such a change in tax incidence is especially regressive with respect to credit availability, as the permit value may be used as loan security.<sup>13</sup>

The second result of such capitalization relates to the general problems of extensive agriculture--namely, the relatively high proportion of total production costs that are fixed. Repayment of mortgages on enhanced value base property increases fixed costs, tending to accentuate the fluctuation in net farm returns and aggravate the general problem of industry supply response.

It seems to me that the charge of "inefficiency" for administration-cost pricing can be supported on the basis of its secular consequences.

**Livestock Base Pricing.** This pricing method has two variants. The first is represented by U. S. Forest Service practices. Grazing fees are computed from a base fee, for each National Forest, weighted by the previous year's price index for cattle and sheep. The base price was determined in a 1930 Forest Service study purporting to represent the average rental fee for range of a quality comparable to that within the boundaries of National Forests. The 1930 figure averaged 14.5 and 4.5 cents per cow and sheep U. M. respectively. Under this price method, the formula averaged 50.75 and 15.75 cents for 1960.

A number of purely statistical drawbacks to this method might be mentioned--the price index may not be representative of prices actually received by an individual permittee. This may result from a nonrepresentative cattle-sheep mix or to regional variation within the 11 western states.

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<sup>12</sup>Dewar v. Brooks, 60 Nev. 129; 106 p. 2d 755.

<sup>13</sup>See U. S. Department of Interior, Federal Range Code for Grazing Districts, January, 1956, Washington, D. C. Section 161.18, "Pledge of Licenses and Permits for Loans."

The consequence of this pricing method on farm income stability--and, hence, on one important source of private investment uncertainty--will, of course, depend on the accuracy of the price index and on the manner of lease administration. If the permit fee is fixed, once issued, regardless of whether the permittee grazes to the authorized intensity, the increase in average fixed cost during the upswing of the beef cycle will be larger than the reduction in average fixed cost on the downswing of the cycle.<sup>14</sup> This creates periods of different susceptibility to operating loss. It is problematical whether this increase in uncertainty is outweighed by the reduction resulting from linking the fee to previous years' prices.

The second variant of livestock base pricing currently is used by the B. L. M. on public range. The fee is set at the previous year's price per pound of sheep and cattle. This version avoids assumptions of constant relative range quality invoked by using an historical base. It still may suffer from regional price differences. Aside from these problems, the method is easy to apply and reduces operators' time preference to the extent that farm income is proportional to beef prices.

Equity and capitalization problems arise with both variants of the method to the extent that a net permit benefit is capitalized into the base property.

## Water

Now let us consider several price methods used for water. An important physical characteristic of water explains a principal difference in pricing methods from those used for public range. Water is mobile, and its placement costs constitute a large portion of total development costs, which has led to suggested price methods that establish a price varying systematically for purchasers in different locations. The first method considered, however, is more simple.

Postage Stamp Pricing. The principal exponent of postage stamp pricing for water is the U. S. Bureau of Reclamation. Within a given reclamation project, the same price is charged agricultural customers for water from any point on the distribution system.

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<sup>14</sup>James H. Lorie, Causes of Fluctuation in the Production of Livestock and Livestock Products (Chicago: University of Chicago Press, 1947).

Establishing a single price for a public service raises the problem of how the charge is to be determined. Marginal and average cost pricing is possible under this method, and the substantial literature<sup>15</sup> on public utility rate structures is directly relevant. Federal reclamation practice entails a price designed to return sufficient water sales revenues over the project's life to cover that portion of allocated project costs termed "reimbursable."

The delivery cost of a given amount of water increases as it is brought further from its place of impoundment or "production" locus. If water is purchased, or contracts are signed, at a constant fixed cost, the marginal value product to the consumer presumably exceeds this magnitude. If postage stamp pricing is employed and related to total aqueduct costs,<sup>16</sup> there is no indication when the marginal cost of the distribution facility is in excess of the marginal value product at outlying locations and, thus, there is no safeguard against overexpansion of the facility.

If there exists a gradient of net farm returns, increasing away from the point of water impoundage due to site conditions<sup>17</sup> or locational market advantages, equity problems may arise with postage stamp pricing. Assuming such a gradient to run from north to south, a northern irrigator may have his consumers' surplus confiscated in greater degree than his more southerly counterpart. In fact, the northern irrigator may be paying in excess of the marginal cost of providing water to his region, while southern farmers experience a marginal value product less than the marginal cost of water supply. Under these circumstances, efficient production would require an expansion of northern production and a contraction of more southerly irrigated acreages.

From an operational standpoint, postage stamp pricing offers few problems. Requirements for its application are delivery data and the water use categories represented by contracting districts.

<sup>15</sup>R. W. Clemens, "Rate of Return for Public Utility Some Aspects of the Rate of Return Problem," Land Economics, Vol. XXX, No. 1, February, 1954, pp. 32-43.

Harold Hotelling, "The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates," Econometrica, Vol. 6, No. 3, July, 1938, pp. 242-269.

Emery Troxel, "Discussion of Paper by Bonbright, James C. -- Two Partly Conflicting Standards of Reasonable Public Utility Rates," American Economic Review, Vol. XLVII, No. 2, May, 1957, pp. 403-405.

Troxel, "Incremental Cost Determination of Utility Prices," Journal of Land and Public Utility Economics, Vol. XVII, No. 4, November, 1942, Part I, pp. 458-467; Vol. XIX, No. 1, February, 1943, Part II, pp. 28-39.

<sup>16</sup>These frequently are the largest components of reimbursable cost. In the proposed California Water Plan, for example, 64 per cent of estimated total outlay on capital facilities is for distribution system. Charles T. Main, Inc. General Evaluation of the Proposed Program for Financing and Constructing the State Water Resources Development System of the State of California Department of Water Resources, October, 1960, p. 2-4. Processed.

<sup>17</sup>Often topographic features result in such a gradient. Reservoir sites tend to be located in deeply incised terrain. Whereas, the alluvial soil and gentle slope of valley floors are particularly well suited for irrigated cultivation.

Zonal Price Differentiation. In contrast to a single, constant price, let us consider zonal price differentiation. A series of zoned water prices has been adopted in principle by the state of California in connection with the California Water Plan. Although any of a number of zonal cost allocation methods may be used, the proportional-use-of-facilities method has been adopted for the Southern California Aqueduct System.<sup>18</sup> Federal agencies generally have used the separable-cost-remaining-benefits method<sup>19</sup> for cost allocation between different project functions of multipurpose projects. Its use in connection with zonal pricing appears relevant, as intrazonal deliveries may be considered individual purposes of a "multipurpose" aqueduct system.

It is possible to infer the major difference between these two methods of cost allocation. In the California example, the separable-cost-remaining-benefits method would result in higher water charges to California than does the proportional-use-of-facilities method. This is due to two attributes of the regions. First, the temporal bunching of irrigation demand, the dominant water use in the Central Valley, requires a larger capacity structure per acre-foot delivered annually than the constant demand of municipal and industrial water that comprises a high proportion of anticipated Southern California demand. Second, the relatively larger share of total benefits accruing to Southern California does not tend to decrease the portion of the aqueduct's total joint benefits accruing to Southern California under the proportionate-use-of-facilities method.

If zonal price differentiation is combined with preconstruction contract guarantees,<sup>20</sup> the incremental costs of southern water diversion will be covered by revenues from water sales, eliminating the possibility for facility over-expansion. A number of technical problems, however, accompany this proposal. If a zone north of the most southerly zone fails to contract sufficiently to assure receipts to the regional authority equivalent to zonal construction costs, does this influence the size of contract payments to the more southerly zone? Will their costs be adjusted to cover the delinquent zones' excess costs? Are these excess costs to be amortized over all other potentially "solvent" zones along the distribution system?

In the case of the California Water Plan, this eventuality appears distinctly possible, especially if a differentiation of price among different uses is made by local agencies. The Southern California Metropolitan Water District already has existing mechanisms for such a differentiation, effectively shifting cost incidence to urban or industrial areas by ad valorem property assessment. Although public districts in the Central Valley also have this power, their limited urban tax base prohibits as extensive an intrazonal price differentiation by use as that possible for the Southern California coastal plain. Such a reduction of agricultural water costs might alter the current interregional patterns of agricultural production within the state.

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<sup>18</sup>This system extends south from the Sacramento River Delta, through the San Joaquin Valley, and into the Southern California coastal basin.

<sup>19</sup>See Inter-Agency Committee on Water Resources, Proposed Practices for Economic Analysis of River Basin Projects, Washington, 1950.

<sup>20</sup>The state of California requires that 75 per cent of reimbursable costs be secured by signed delivery contracts prior to construction of each aqueduct unit. See California Department of Water Resources, Contracting Principles, op. cit.

Conceivably, such a regional production shift may be economically efficient. This would be true if the value of marginal product of agricultural water in Southern California exceeded that for the San Joaquin Valley. If we accept the thesis<sup>21</sup> of an urban center surrounded by, and dependent upon, an agricultural hinterland, the intraregional shift of water cost incidence from agriculture to municipalities and industry would not impair the efficiency of agricultural production. The urban area (comprising mainly municipal and industrial water users) is considered an integral part of regional agricultural production. If this thesis does not hold, the postulated shift would represent a net loss of state real income. Whether this thesis is appropriate for Southern California is open to question. If the industrial-urban concentration of the south coastal plain represents a self-contained economic unit whose functions are independent of an agricultural hinterland, the postulated shift in agricultural production would not satisfy efficiency criteria.

This admittedly is a static interpretation of efficiency. The willingness of Southern California municipal and industrial water users to bear part of the cost of agricultural water reflects their desire to establish current use of this water, which will be available to the region in the future, when a substitution of urban water uses for previous irrigation use may be anticipated. The longer run marginal value product of water to this portion of the state, thus, is adequate to warrant a current underwriting of agricultural costs by municipal and industrial water uses. This still does not assure an efficient economic allocation from the state's standpoint. The organization of water agencies through the Metropolitan Water District permits a longer time horizon for the conception and estimation of a value of marginal product of water than is afforded local districts in the San Joaquin Valley. Productive efficiency would require comparable planning horizons on the part of organizations in both parts of the state.

### Conclusion

After examining and appraising in a functional sense actual pricing practices for both range and water, it is useful to address a broader problem-- whether the role currently played by "price" for these resources is appropriate.

With respect to range, present leasing arrangements imply a type of investment partnership between the Federal Government and permittee. The fixed percentage of grazing receipts earmarked for range improvement, its tendency to be appurtenant to base property, automatic renewal, and a rental fee that is low relative to value all stimulate private investment in range. Is this relationship appropriate, or should it be replaced by a pricing policy based solely on the sale of forage?

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<sup>21</sup> This thesis maintains the organic unity of urban centers and the agricultural area immediately adjacent thereto as units of social organization. Although primarily employed for purposes of sociological analysis, economic derivatives of the thesis have been used in the analysis of communities in the San Joaquin Valley of California. See: W. R. Goldschmidt, "Social Structure of a California Rural Community" (unpublished Ph. D. dissertation, Department of Anthropology, University of California, 1942).

Pricing practices of the Department of Defense tend in this direction. Its grazing contracts spell out in detail the type and intensity of grazing to be permitted as well as a list of specifications on all improvements for which the permittee is responsible. These contracts are let for three- to five-year periods on a competitive sealed bid basis.<sup>22</sup> The contract in essence represents a certain quantity of forage, administratively determined, that is put up for bid. Under the circumstances, sealed-bid competition is an efficient pricing method in terms of resource allocation.

Two reasons suggest themselves why this type of contract and sales policy might be appropriate for the other federal range leasing agencies. First, no compelling reason for local community investment and management activity is apparent. Federal forage merely is made available to individuals within the community under favorable pricing conditions.

The second reason why such a shift in range pricing policy may be warranted relates to the problem of management objectives. Under joint public-private investment arrangements promoted by current practices, conflicting objectives may lead to a lack of coordination of management measures undertaken by each agent. This problem would appear to be especially acute<sup>23</sup> with respect to portions of national forests that are being managed for recreation and timber as well as for forage. One readily could predict opposition to such a change in range lease concept. Divorcing the range improvement budget from fee receipts, for example, would doubtless meet with initial congressional opposition. Grazing service and B. L. M. appropriations traditionally have been criticized as unwarranted western subsidization.<sup>24</sup> The shift in management investment responsibility to the Federal Government would imply a less prominent role for the N. A. B. C. in program administration--a suggestion not likely to receive the industry's unrestrained approval. Finally, the redistribution of income at the local level accompanying such a change would be skeptically viewed by present permit holders.

For water the situation is distinctly different. Here there are strong motivations for and available organization with which to implement an investment partnership between the Federal Government and local community.

The problem of pricing method, however, remains an acute one. Because of the unique institutional aspects of public water development, it appears feasible to adopt a method of pricing based on benefits received. Being a "wholesale" price, these are benefits to a community from participation in a program of public water development.

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<sup>22</sup> Form of contract, price, and administration of Department of Defense licenses currently is under study at the University of California by Robert Leonard and Dr. Stephen C. Smith.

<sup>23</sup> Here the problem of different time preference rates is aggravated by single purpose-multipurpose conflicts.

<sup>24</sup> See Foss, op. cit., especially Chapter 8.

Conceptually this implies knowledge about the community demand function for water, and in application the method entails prices resembling those of a perfectly discriminating monopolist. So long as the demand functions of separate local districts are not equally elastic with respect to price, sales receipts are maximized by this pricing method.

This method would localize charges on beneficiaries. Payments would tend to be proportionate to real benefits received. A district approach that considers the district to be a production unit, imputing to it a unit water benefit, appears to be the most feasible manner in which the principle could be rendered effective. This would provide the basis of the size of payments for individual district contracts and would leave the district its present flexibility in using its present variety of payment forms for internal pricing arrangements. Approximative procedures using the cost to particular organizations of alternative supplies as a confining limit to these benefits suggest the district as the logical unit for analysis as well as administration of such a pricing method.

The value of benefits may be taken as a weighted average of benefits or marginal value product to individual water uses and users occurring within its boundaries. Technically each district would have a different average, but in practice ranges could be established into which recipient organizations could be grouped. The geographical configuration of actual payments resulting from this price tool may parallel that derived from zonal price differentiation. For example, in the case of the California Water Plan, each of these methods would result in average acre-foot payments increasing to the south. In one case, this results from the allocation of aqueduct system cost; in the other from the increasing limitation on alternative water supplies and superior site conditions in that direction.

A further advantage from the district standpoint of such a pricing method is that the direct link with benefits implies an automatic price adjustment geared to the particular phase of the business cycle prevailing at a given time. It would provide protection against the wholesale foreclosing experienced by many water districts during the national depression when payments were not adjusted accordingly.

Perhaps the overriding consideration in price policies for both resources is recognition that the future may see a wider acceptance of planning. Price is a powerful tool in the process of allocating public resources, or their product. It is desirable, therefore, that price policies be maintained which admit future price change--and that the administration of a particular price policy does not preclude future organizational mutations. If it does, our latitude for reallocating these important resources is limited, and thus their potential contribution to regional and national development.

PRICING PUBLICLY OWNED RANGE AND WATER RESOURCES<sup>1</sup>B. Delworth Gardner<sup>2</sup>

Dr. Brewer has presented us with a broad and yet penetrating discussion and appraisal of pricing policy related to range and water allocation. This was a difficult assignment, but Brewer was equal to the task. The paper is particularly stimulating in suggesting hypotheses that might be tested by other scientists. There are both positive and normative elements in any policy evaluation. In many cases a scientist may be on safe ice when it comes to "what is," but if he tries to say much about "what ought to be" the ice may become precariously thin and he may even fall through. Personally, I don't like icy baths so am content to stay in the positive area, and it is here that I have some reservations about Dr. Brewer's discussion. It isn't that I disagree with either his analyses or the validity of the conclusions that he reaches. Rather, with most of these I give hearty concurrence. However, I don't think he pushes far enough in his criticisms of present pricing policies, particularly as related to: (1) "efficiency" of resource use between uses and also between users of the same use, and (2) the "optimum" level of investment in public resources.

Essentially "underpricing" in both the range and water areas has necessitated the improvisation of noneconomic criteria that have been used to allocate resources. These pricing procedures and the accompanying rationing methods tend to tie public resources to certain private resources in an inflexible manner. There is evidence to suggest that the public resources are prevented from being employed in their "highest" economic use, and therefore the product taken from these resources is diminished.

In Dr. Brewer's opening section he presents a justification for the wide diversity of policies that are used to price public resources. He attributes this diversity to the fact that "natural resources are characterized by physical and temporal heterogeneity, a large variety of types of ownership equity, and are exchanged under institutional conditions that entail several forms of payment." All this seems to be true, and implies an important corollary. Most of the specific policies that we have today came out of political and legal controversy and represent compromises that were required to get any policy at all. Economic considerations related to efficiency played only a minor role, while equity or wealth considerations played a major role. This, no doubt, explains why efficiency comes off so badly in the analysis, and perhaps the most crucial thing is that when compromise does lead to policy, it is not easily changed thereafter. If efficiency criteria have no role initially, and you try to introduce them later, the apple cart of equity considerations is upset and "efficiency" progress is most difficult to achieve.

In Dr. Brewer's second section he discusses the various roles in public development of resources. He indicates that "price" has been a vehicle for general economic development, a means of stimulating investment in natural resources development, and a method of allocating range and water resources.

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<sup>1</sup> A Discussion of the paper by M. F. Brewer.

<sup>2</sup> Department of Agricultural Economics, Brigham Young University



However, except for the latter consideration, his evaluation of price policies in the following section is disappointing. I would like to have seen him elaborate more on the effects of the various pricing procedures on general economic development and investment stimulation in natural resources development.

Dr. Brewer indicates that in range pricing the particular role of price has been to facilitate the establishment and maintenance of viable local economies based on livestock production. I wonder if he means that public range has been intentionally underpriced so that a subsidy could be extended to the industry. He implies that a zero price on the public domain prior to 1934 was also part of this intentional policy. My interpretation is different from this explanation. I would argue that there was simply an absence of policy of any kind on the public domain until the period of the Taylor Grazing Act, when it became apparent that management of the public lands was necessary for perpetuation and development of the range resources. At that time, pricing at the full value of the marginal product was politically impossible. Stockmen were accustomed to the zero price of the "no-policy" period. Secretary Ickes did succeed in getting a "nominal" fee that presumably would cover cost of administration, but it was far below the value of the grazing.

Brewer seems to feel that it is questionable whether additional economic development is stimulated by continuing "underpricing." I fully agree. In my view the underpricing has resulted in a windfall gain to original permit recipients, because of the capitalization into permit values of much of the differential between the value of the marginal product of the grazing and the permit fee. I doubt that underpricing has resulted in much net gain to the livestock industry in the long run, and, therefore, it is hard to see how economic development has been increased materially over time. In fact, underpricing may have had a considerable deleterious effect on development. If the prerequisites for holding permits have, in reality, inflexibly tied the permits to certain ranches (ranchers) and have accordingly prevented the resources from passing into their highest economic use, then it seems probable that these procedures have diminished total product and have impeded economic development. At least I expect this is the case a priori. Admittedly, empirical tests of these hypotheses are needed.

Brewer believes that underpricing may increase the private share in public investment. Again, this may or may not be true; evidence would be helpful. However, since the Bureau of Land Management uses a given proportion of the fees to develop the range, it seems certain that underpricing has decreased the federal investment commitment. Be this as it may, in this area of investment pricing considerations are probably of minor importance compared to tenure and allotment considerations. Ranchers cannot be expected to invest in the development of public resources if their tenure is not certain or if they must share an allotment with several other ranchers who will not participate in the development but who will share in the benefits of the investment. The tenure consideration is most critical on the forests where permits have been drastically reduced. Over-all, I suspect that there may be "underinvestment" from the private side in public range improvement practices. I have some data that

indicate that internal rates of return to range reseeding averaged 15 per cent on private lands in Colorado which are comparable in range quality to many nearby public lands.<sup>3</sup>

Brewer discusses the classical case for misallocation. He correctly indicates that the extent of the misallocation depends upon transfer possibilities of range permits. He states that if a rancher under permit is able to graze cattle of any brand, then misallocation may be avoided. I agree. However, the Forest Service Manual explicitly requires the ownership of livestock by the permittee. I can't find an explicit requirement of ownership in the Federal Reserve Code, which is the B. L. M. 's guide. However, several passages imply ownership by speaking of the permittee and his stock. How rigidly these rules are adhered to in actual practice, I can't say. However, in my experience with this question, I know of no cases where a permittee has been permitted to graze another's stock. Transfer of permits seems to be rather limited unless the stock or the base properties is transferred also.

When speaking of livestock base pricing of the Forest Service, Brewer makes a technical error that might produce the wrong inference. He states that the 1930 base fee, from which all more recent fees are derived on the basis of livestock price changes, purports to represent the average rental fee for comparable private range. It might be inferred from this that the forest livestock-base-pricing method may not give rise to "underpricing" if livestock prices and values of marginal product have moved together over time.

As a matter of fact, the 14.5 base fee per AUM in 1930 did not represent the private rental fee. The Casement study of 1923 came up with an average private rental of 24.6¢ per AUM. When Casement, a livestock breeder, made his report in 1926 he advocated a compromise fee of 14.5¢. The current forest fee was 10.4¢, and Casement adds "my belief that social and economic principles have been and should continue to be applied in the administration of forest grazing leads me to recommend that precise recognition of these principles be given by a general reduction in the proposed fees" (the private rentals).<sup>4</sup> Both this evidence and many other factors demonstrate that "underpricing" has occurred in forest grazing as well as in B. L. M. grazing, and therefore is subject to all the same difficulties.

Brewer argues that if the differential in value of marginal product and the fee gets capitalized into base properties or permit values, then this involves double payment when fees are raised. As to the question of capitalization of the net differential into permit values, my own studies reveal that in the case of the Forest Service permits most of the differential is capitalized, while in the Bureau of Land Management case most is not.<sup>5</sup> The reason is that in the Bureau of Land Management case the permits are more inflexibly tied to given base-properties, while in the Forest Service case there are added transfer

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<sup>3</sup>B. Delworth Gardner, Costs and Returns of Range Improvement in Colorado, unpublished bulletin manuscript submitted to Experiment Station, Colorado State University, p. 3.

<sup>4</sup>W. F. Dutton, History of Forest Service Grazing Fees, pp. 4, 5. Mimeo. publication of USDA.

<sup>5</sup>B. Delworth Gardner, "Price Policy and the Changing West," The West in a Growing Economy, Proceedings of WFEA, Logan, Utah, 1959, pp. 236-238.

possibilities by selling the permit with the livestock. The greater transferability has the effect of increasing the demand price for the permits and results in greater permit values. Still because in both cases some capitalization does occur, the effect on assessment for tax purposes is as Brewer claims. But I am not convinced that increased capitalization due to a low fee increases fixed costs over what they would be if fees were higher and capitalization less. This would be true only if fees can be regarded as a variable cost. My opinion is that fees are a fixed cost and are so regarded by stockmen. They are an unavoidable cost of using the range, and are committed, even if not paid, as far as 10 years in advance.

I am much less familiar with water pricing than with range pricing. However, one factor that is readily apparent to even the novice is that water payments are determined almost entirely on the supply side and are related in no obvious way to the value of the marginal product of the water. This means that the water pricing methods are subject to the same kinds of criticisms that have been levied against forage pricing. Before we can really be very sure that economic "efficiency" prevails, water prices must be determined by interaction of supply and demand forces.

In conclusion, it is easy to criticize present pricing procedures using "efficiency" criteria. It is more difficult to settle on a "just" and "efficient" action to improve the situation. New policies that would improve efficiency might require sharp changes in income distribution. It may be impossible to identify the gainers and losers if the policy were changed and would be even more difficult to quantify the amounts of gains and losses. Recommended policy changes always have political and legal facets that cause friction. But even if no changes are made, we should be aware of the "costs" of procedures presently in use to allocate resources. The challenge that lies ahead for us is to make the policy makers aware of the costs and returns of doing the job in various ways.

## MEASURING RANGE PRODUCTION

H. G. Reynolds<sup>1</sup>The Range Complex

Rangeland consists of a complex association of vegetation that is subject to utilization by livestock. Under proper management, rangelands yield a sustained forage crop. The annual forage crop is converted by grazing livestock to meat and other animal products that have market value. Range vegetation is the result of interactions of climate, soil, and plants occurring with time. These basic interactions, together with relation to the grazing animal, are coordinated in the concept of range condition.

Range condition is a production concept. In general, it refers to the character, amount, and stability of the forage crop, and the amount and quality of livestock products relative to what can be achieved under the best possible management. Range condition is maintained largely through attention to proper utilization--the way in which the forage crop is harvested annually.

Except for the occasional drought year, foliage is produced by range plants in excess of needs for maintenance of range condition. This is the annual forage crop. Proper range utilization specifies the amount, season, and system for grazing the annual forage crop so as to maintain range condition or production. Production may be measured as animal units or forage units.

Animal Production

Livestock production varies with many factors, including: breed, inheritance, previous condition, sex, stage of maturity, pregnancy, or fattening. Animal production is thus relative to kind and class of livestock. Production is also relative to kind and level of livestock management.

Where differential production is desired--e. g., between ranges in different condition--variability can be controlled by using uniform animals with the same manager. To control variability in space, resulting from differences in site productivity, relief, and distributional controls, a replicated experimental design may be employed.

In brief: Animal production is relative to: (1) the class of animals grazed, (2) kind and level of livestock management in effect, and (3) the system of grazing employed for maintenance of range condition. Variability in outcome where differential effects are desired can be evaluated by using (1) as uniform livestock as possible from one operator, and (2) statistical design for controlling variability in space.

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<sup>1</sup> Rocky Mountain Forest and Range Experimental Station, Forest Service, U. S. Department of Agriculture; central headquarters maintained at Fort Collins, Colorado, in cooperation with Colorado State University. Author stationed at Tempe, Arizona, in cooperation with Arizona State University.

### Forage Production

Forage production can be used as an indirect measure of range production. Animals require a certain amount of forage for maintenance, growth, reproduction, and fattening. If specific animal needs are known, forage values can often be converted to animal units.

Measures of forage production are useful where differences in production are desired. If response of vegetation is in the same kind of forage material, relative increases or decreases in forage production, and hence range production, can be measured.

Forage sampling problems. Forage production of an entire range unit is usually too expensive to measure. This necessitates sampling, which must provide for: (1) an unbiased sample wherein each unit has an independent opportunity for selection, and (2) an estimate of sampling error. Both of these provisions are satisfied by random sampling.

Other problems are also involved in sampling. These include: (1) selection of the unit of vegetation for measurement, (2) the kind of sampling unit to be employed, and (3) control of the sampling error.

Sampling error. Sampling error measures the reliability of the sample for estimating population characteristics. It depends on the amount of variation in the population and the number of units in the sample. Sampling error is controlled by conventional statistical methods.

Actual measurement of a sufficient number of sample units to meet acceptable sampling errors is often too expensive--particularly when sampling for weight. Accordingly, estimating may be substituted in whole or in part for actual measurement. The usual procedure is to train in estimating prior to field application. The entire sample may then be estimated, or by double-sampling, a correction can be made for the estimating error.

In brief: Forage production is an indirect measure of range production. Where animal consumption rates are known, forage production can often be converted to animal units. Forage production is subject to sampling errors that may be controlled statistically. Forage production is most useful for measuring differences in production resulting from range improvement practices.

### Range Improvement

Rangeland production can be increased by a number of improvement practices. Among the more important practices are: (1) improved range condition, (2) noxious plant control, (3) range reseeding, (4) improved utilization, and (5) range fertilization. Each of these improvement practices may require an input of material, labor, or equipment. Output is measured as forage or animal production. On small units, forage production is most commonly measured. On larger units, where livestock can be controlled, output is measured in terms of (1) live-weight increase per unit of time per unit area, and (2) animal unit days of grazing per unit of time per unit area.

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## TIMBER PRODUCTS

Philip N. Knorr<sup>1</sup>

Mr. Chairman and gentlemen, yesterday's program was of great interest to all of us who are engaged in the various aspects of wildland management. Economics has always been important in forestry, and since World War II there has been a resurgence of interest in this fundamental discipline. The moderator, Dr. Kelso, has asked me to speak on timber products and has warned me not to stray too far from the subject. The warning was in order because, as some but not all of you know, an American forester is trained primarily as a wildland manager. Few foresters in the United States are engaged exclusively in the management of timber stands. I shall do my best to confine my talk to the subject of timber crops. However, I shall be forced to depart occasionally from timber forestry in discussing sawtimber in Arizona where multiple use is common sense as well as good economics.

In order to get Arizona timber in its proper perspective, we should look at the national scene first. The United States Forest Service published in January, 1958, The Timber Resources Review. Most of the data presented here are from that source. Trees are grown to some extent in every state in the Union, but the most efficient (highest annual yields) areas for growth are the South and the Pacific Northwest. The potential quality of Arizona timber is excellent because it is mostly ponderosa pine, a multipurpose wood that is soft, uniform, and workable. Ponderosa pine can be used for pulp, construction, or cabinet work. However, in Arizona, the pine grows above the level of 6,000 feet where the growing season is short, the soil not generally deep, and the rain scant as judged by tree growth requirements. From growth and yield tables we can estimate Arizona ponderosa pine as growing from one-third to one-fifth as many board feet per acre per year as the commercial Douglas fir lands of western Washington and Oregon. The commercial timber lands of Arizona cover about two-thirds of one per cent of the commercial timber lands of the first forty-eight states. Although the quality is excellent, timber products from Arizona constitute a small part of the national production.

The United States Forest Service's Timber Resources Review, a 713-page publication, is described in the opening sentences as a "State-of-the-Union" message of the Forest Service on our national timber supplies. Two sentences can briefly define the purpose and scope:

The chief purpose of the Timber Resource Review is to provide a stock-taking of the current timber situation in the United States and look into the future with respect to prospective timber supplies and needs. Because forestry is a long-time undertaking the current situation in timber carries perhaps more than the usual implications as to future supplies.

In the Timber Resources Review, three estimates of the nation's timber demand were projected. The medium projected demand indicates increases of 32 per cent for 1975 and 83 per cent for the year 2000 as compared to 1952

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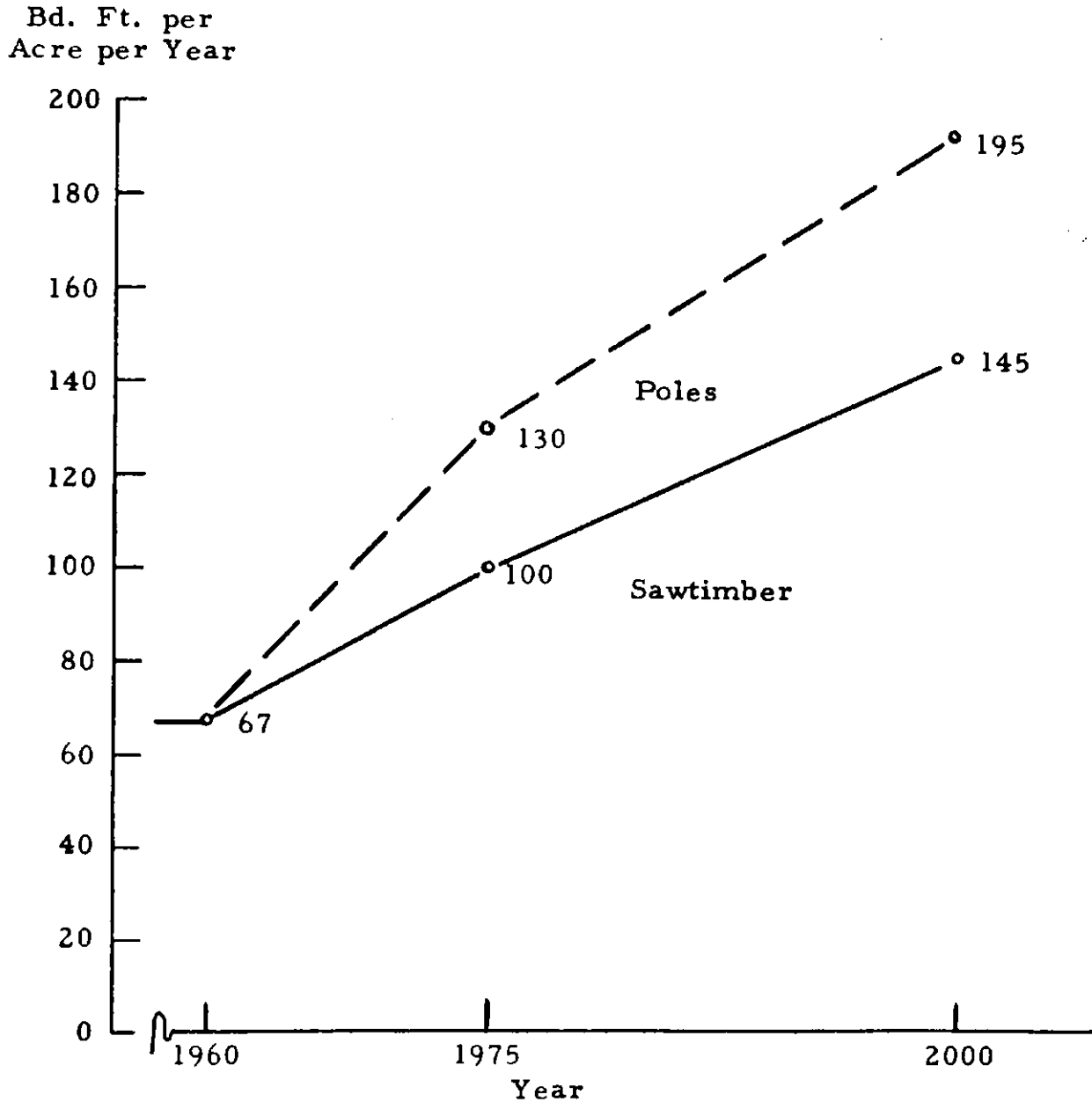
consumption. The authors note that "The large upswing in total timber demands over 1952 are attributable largely to expected growth in the population rather than to increases in per capita demand." Parenthetically, at this point, to a group of economists, it must be noted that several prominent forest economists, including Bob Gregory of the University of Michigan and Henry Vaux and John Zivnuska of the University of California, have taken issue with the projections of the Forest Service economists.

With the above background, let us now turn to the forests of Arizona. The Timber Resources Review gives 22 per cent of the area of Arizona as non-commercial forest land. Inasmuch as this talk deals with timber land, we will be concerned solely with the 4.4 per cent of the state designated as commercial forest land (roughly one twenty-third of the state area). Of this timber land, 95 per cent is in federal ownership and Indian lands and one per cent in state ownership. Ponderosa pine comprises 88 per cent of the sawtimber and Douglas fir 7 per cent. To be less precise, but simpler, the commercial timber situation in Arizona can be summarized thus: Owners, the federal government and Indians; one species, ponderosa pine covering 4.4 per cent of the state or 3,180,000 acres.

After projecting demand for timber products into the future, the Forest Service planned how the goals would be met. At the October 27, 1960, meeting of the Society of American Foresters at Show Low, Arizona, Dahl Kirkpatrick from the Regional Office of the Forest Service in Albuquerque gave figures on what was anticipated from the Forest Service commercial timber lands in this region. As you can see in the accompanying chart, it is anticipated that sawtimber production will be raised from a past growth rate of 67 board feet per acre per year to 130 board feet per acre per year in 1975 and 145 board feet per acre per year by the year 2000. In addition, smaller-than-sawlog sizes referred to as poles on the chart would be grown on the same land at the equivalent rate of 30 board feet per acre per year by 1975 and 48 board feet per acre per year by 2000 for the pole-treating plant at Prescott and the pulp mill now under construction at Snowflake.

At the same Society of American Foresters' Meeting, mentioned earlier, Ed Groesbeck of the Regional Office of the Forest Service spoke about cutting the virgin stands lightly and quickly in order to harvest the overmature trees before they deteriorate further or die; this would also allow residual trees to add more increment. He explained that earlier working plans would probably be followed, and gave as an example ponderosa pine stands on a 180-year rotation with a 20-year cutting cycle. This means that, although there will be thinning in the younger age classes, the final crop trees will be removed every 20 years at which time most of them will be close to 180 years old. More knowledge is needed as to the optimum growing stock for such management in Arizona, but at this time the Forest Service foresters believe that cutting back the residual stand every 20 years to a basal area of 80 square feet per acre is the best answer to their problem of increasing the growth in order to meet the goals set for the years 1975 and 2000. Basal area in this case can be defined as the total area of the cross section of trees four and one-half feet above the ground on an acre. Foresters like to use basal areas because diameters and, from them, basal areas can be quickly and accurately determined and can be correlated with more expensive, time-consuming volume determinations.

Figure 1. Forest Service Growth Goals For Southwestern Forests

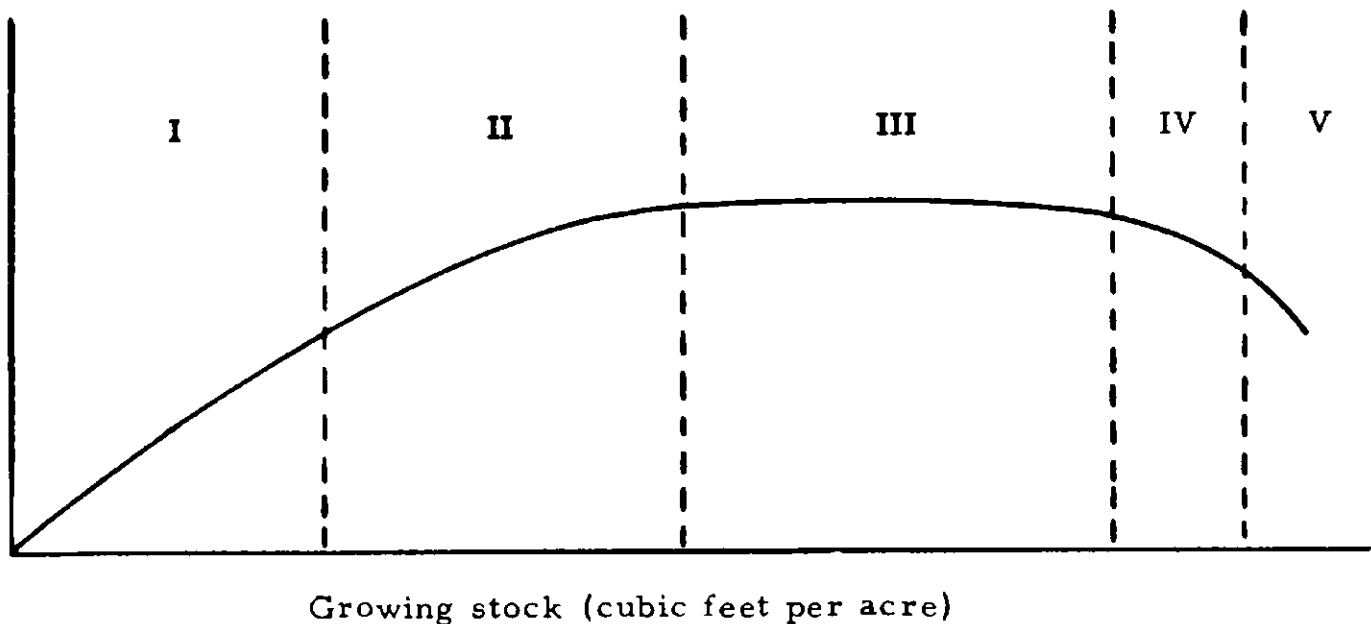


At this point you might ask, "Why cut back the basal area to 80 square feet?" The answer is that in a well-regulated forest you can make intermediate harvests with little effect on timber growth. In other words, the remaining trees grow more rapidly so that volume growth per unit of area is about the same as before but is concentrated on fewer large trees. This can be illustrated by graph (Hawley and Smith, 1954) which shows this hypothesis as given by Langsaeter.

Note that the "total production of cubic volume by a stand of a given composition on a given site is, for all practical purposes, constant and optimum for a wide range of density and stocking." This curve apparently holds true if all the wood in the boles of all the trees is counted. The curve will vary if board feet or basal area or larger diameters only are included, but the same general shape of the curve, and hence the same principle, holds. In practice in this region, it would mean the thinning of the stand back to the point between

Figure 2. The Relationship Between Density of Stocking and Growth

Growth  
(Cubic feet per  
acre per year)



(Adapted from Hawley and Smith, 1954, p. 355)

II and III on the graph at the time of intermediate cuts. This thinning would allow timber-producing foresters to concentrate approximately the same growth on fewer more select stems. Therefore, the final timber harvest would have the same volume, but concentrated in larger trees of better quality than in unthinned stands.

After much reading and consideration Ed Gaines (1954) set the figure at 80 square feet for ponderosa pine stands of the Southwest as the hypothetical point between II and III on the graph. It is of interest at this point to note that R. R. Reynolds (1950) found that for mixed pine and hardwood forests in Arkansas that "from the standpoint of maximum quality board foot volume and growth" the basal area should be about 75 square feet per acre. The agreement is close.

The economy of northern Arizona is based to a great extent upon the forest products industries, and the pulp and paper mill being built near Snowflake will be a welcome addition. For 1960, Dr. Seltzer's latest value for timber and other forest products for Arizona is \$21,200,000. Of course, pulp and paper plants take a lower-grade tree than a sawmill, and there is a great deal more added value in manufacturing. I have estimated from its capacity that when the new pulp and paper mill comes into full production the total forest products value for the state should approximately double (that is, total about \$40,000,000).

For the forester engaged in growing trees, the flexibility introduced by thinnings for pulpwood for the Snowflake mill, which may allow cutting down to six-inch diameters, means a stand can be kept in a thriftier growing

condition. Proper spacing of stems is an especially important part of increasing timber growth. In this regard the Forest Service with foresight and courage made a series of thinnings in pine stands in the Beaver Creek area.

Regional Forester Kennedy stated:

One specific aim in our treatment was to reduce the density of stands in the 100,000 acres of ponderosa pine by several different methods and degrees of reduction; determining the effects of these removals on water yields, soil movement, and timber growth. On one of these trial areas, for example, the goal was to reduce stand density to 80 square feet of tree trunk per acre--considered to be optimum stocking level for good timber production in ponderosa pine.

I have read the above to point out that in the very small, but highly important, commercial pine zone the largest land manager is interested in finding the optimum residual of growing stock for increased timber production.

Cutting back the stand to 80 square feet would probably be considered a moderate to heavy thinning, and both timber foresters and watershed management foresters probably would not expect water yields to be greatly affected. It is commendable from a research standpoint to have a range of cuts of residual basal areas in ponderosa pine stands to see how timber growth and water yield are affected by changes in stand density on specific sites. With such data, the economist can work. In vegetative manipulation of this sort, the continuing inputs to maintain an unnatural vegetative cover must be weighed against outputs in addition to the original cost of heavy thinning or clearing.

If the Forest Service and other timber operators can get their growing stock regulated on the commercial timberlands of Arizona to the extent indicated in their plans, the aesthetic quality of the forest will remain. In places, or according to the individual's taste, the beauty may be enhanced by a better distribution of tree age classes and by less dead snags and down logs. Near roads there will be the long clean-boled trees as a result of earlier pruning by fire crews keeping fit by timber stand improvement between forest fires. Inevitably there will be conflicting interests in the multiple use of our wildlands, but in the commercial timber areas, forests can be maintained for maximum timber production and still retain that aesthetic appearance that will appeal to the citizens of Arizona and to visitors from other states.

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IDENTIFYING AND MEASURING THE INPUTS AND OUTPUTS OF  
WATERSHED TREATMENT AS RELATED TO WILDLIFE AND RECREATIONClay Y. McCulloch<sup>1</sup>

For our purposes, the inputs and outputs of watershed treatment are the changes that treatment brings about in the game-producing capacity of the area. Most of the treated watersheds are essentially big game areas, and our studies are centered on big game effects of treatment. I would like to beg off discussing recreation, except for that which stems directly from pursuit of wild animals. We realize that Arizona watersheds provide much recreation other than the kind involving hunting and fishing. Our investigations are simply not set up to try to measure effects on those other kinds of recreation, important as they are.

One of our big problems of measurement results from the fact that the experimental treatments have sometimes preceded any wildlife research on the areas. There is little in the way of records of game populations or of vegetation important to them on certain areas prior to treatment. This is especially true in the case of the Beaver Creek Project, and also in most of the juniper eradication projects. The difficulty is not quite so marked on the Three Bar watersheds. There, we did have a short period of pretreatment records before a wildfire burn speeded up the schedule and caused some drastic changes in the proposed treatments. And we are still ahead of the experimental treatments on the Willow Creek, Mingus Mountain, and Whitespar watersheds. On the latter areas, we hope that we can observe fluctuations in game populations for several years, through at least one apparent cycle of wet and dry years. This sort of calibration period is as important to wildlife studies as to the water-yield studies.

Where we lack the before-and-after treatment records, our techniques are limited to comparisons of existing treated areas with untreated control areas, and of one kind of treated area with another. With this method, it is difficult to find areas that seemed to be strictly comparable in vegetation, topography, and other ecological factors which affected wildlife.

There are two main approaches for trying to detect differences or changes in treated areas as they affect wildlife. One is to try to compare population densities of the animals on the experimental areas. The other is to sample for differences in vegetation important to the wildlife as food, cover, shelter, and other needs of life.

Our efforts to detect animal population differences are indirect. They consist simply of sampling the areas to determine abundance of animal droppings. The problems involved are similar to those of other kinds of sampling of areas for ecological characteristics, complicated by animal mobility and behavior. For example, it may be necessary to allow for animals' tendencies to spend more time near one plant species than another. Direct methods of determining animal populations are generally too costly for use with the species present on most of the experimental watersheds. These methods would involve

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<sup>1</sup>Biologist, Arizona Game and Fish Department.

year-round intensive observations of animals on each area, preferably with live-trapping, marking, and releasing of many individuals. Direct counts from aircraft are not effective in the cover types present on most Arizona watersheds.

There are additional problems in estimating population densities either directly or indirectly. One is that in size the treated areas may be only a fraction of the area of home range typical of individuals of big game species. The experimental units are not big enough to support individuals, let alone a population, of animals which do not range onto adjacent areas that are treated differently. Game species are seldom confined to a single vegetation type, regardless of its size. On the other hand, watershed treatments are usually done by vegetation type. More knowledge is needed about individual home ranges of game species in each specific area, seasonal movements of groups of animals, and their seasonal use of the experimental areas.

Some of the important game species normally occur in rather sparse populations. In the case of elk, turkey, and javelina, for example, it is very costly to sample adequately for population densities, even with the indirect methods. Attempts to compare population differences of areas are practically confined to deer.

The other principal approach which I mentioned also has its problems. Through observations of effects of watershed treatment on vegetation, we may predict treatment effects on game. In order to do this more effectively, however, we need more knowledge as to what plant species are much used by wildlife in each treated area. Apparent food preferences of game species do vary somewhat from place to place. A browse species that appears to be relished by deer on one area may be little used by deer on another. Also involved in this vegetation approach is the need for techniques less costly than some now available for sampling wildlife forage production, preferably in absolute terms such as pounds per acre.

In addition to these problems involving only the plants directly important to game, it would be well if we had more thorough understanding of the whole community of a watershed. Treatment effects on rodents, insects, and plants not actually used by game could have indirect but important effects on the larger animals. Replacement of natural plant communities with man-made ones has often resulted in population buildups of rodents, for example, or insects. We do not know how or how much such possibilities might affect food plants of game species.

This briefly covers what I think are the major problems of identifying and measuring wildlife inputs and outputs of watershed treatments. Some of the most important may not be problems of technique so much as lack of basic information.

Before I conclude, I would like to call attention to one more problem. It is probably common to all phases of watershed research, but it may hamper wildlife investigations more than it does the others. I presume that it will be possible to state estimated inputs and results eventually in mathematical terms that are easily understood. I mean that we may read in dollars and cents what a watershed treatment indicates in board-feet of lumber, pounds of beef, and acre-feet of water. Wildlife represents some special kinds of value. We hate to put a price tag on them, but it seems almost necessary to do so in the game of deciding who gets what. In 1956, the Arizona Game and Fish Department

completed a survey aimed at estimating the dollar value of game to hunters. Another study is now being started to provide some more thorough and up-to-date estimates. These will undoubtedly be useful in expressing the wildlife inputs and outputs of watershed treatments.





## WATERSHED MANAGEMENT HYDROLOGY

P. B. Rowe<sup>1</sup>

Watershed management means different things to different people. In order that we may think in the same terms, I would like to start this discussion by presenting my concept. This is, that land consisting of the plant cover, soil, and rock mantle is a reservoir that receives, stores, and discharges water. This reservoir supplies water for on-site as well as for downstream uses. Moreover, it is subject to change and to regulation through land use and treatment.

Watershed management has multiple goals. First, it must develop and maintain watershed conditions that produce and put to beneficial use the maximum amount of water. Second, it must do this in such a manner as to assure satisfactory control of flood runoff and erosion. Third, these objectives must be integrated with programs providing for the optimum and most economic use of the land. To achieve successfully these goals the watershed manager must: (1) know what can be done to accomplish desired objectives, and (2) be able to predict the quantitative effects of actions he may take on the hydrologic regime of the watershed--floods, soil erosion, and water yield.

What is the status and what are some of the problems of watershed management in Arizona? People living in this thirsty state, particularly the old timers, have always been water conscious. Hence, it is but logical that some of the earliest watershed management research of this country was started and carried out here. Over the years, as demands for water have increased, this interest has grown and today is reflected by the large number of intensive watershed management research and action programs throughout the state.

What then are the possibilities of increasing yields of usable water from local sources? Average annual precipitation in Arizona is about 13 inches, and varies from less than 4 inches in some of the lower-elevation desert areas to over 35 inches in some of the high-elevation forest areas. Roughly 45 per cent of the state receives 13 inches or more precipitation during an average year. Many of these areas of above-average precipitation offer important opportunities for increasing water yield through the application of selected watershed management practices.

Results of recent studies indicate that control of the heavy water using woodland-riparian vegetation, growing along water courses and in wet places, can result in large increases in water yield each year--two to three acre-feet per acre treated. Other treatments, such as deadening of heavy chaparral-brush vegetation growing on deep soils of side slopes, have also resulted in increased water yield, particularly during years when annual rainfall was in excess of consumptive use. Such increases in yield, however, do not necessarily mean enough water or cheap water, and in certain areas may be obtained only at a cost of increased flood and erosion damages.

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<sup>1</sup>Department of Watershed Management, University of Arizona.

Past and current research and action programs, carried out here and elsewhere, have contributed much to our knowledge of the hydrologic processes, and of the relative influences of the watershed variables of climate, topography, soil, geology, vegetation, and land use on these processes. They have also provided valuable guidelines for present and future research, and for watershed management and land use practices.

But although we may recognize the more important processes of the hydrologic cycle, we need much additional information concerning (1) the quantities and rates involved in each of them, and (2) the effects of watershed variables and of planned land treatments on these values. However, no two watersheds are alike, nor are the land conditions within individual watersheds homogenous. Because of this, we can reason that watershed management is like spot farming. To be effective and economically feasible it must be limited to areas where conditions of the environment are adequate to yield the desired results. Hence, watershed management research, to have more than limited and uncertain application, must be aimed at determining the source and magnitude of the benefits that can be obtained, not only in relation to treatments applied, but also to the physical conditions within the treated watershed.

Lack of adequate data on the physical characteristics of watershed lands is a serious handicap to the planning and carrying out of watershed management research and operational programs in Arizona. Thus, one of the prime needs for the development of an effective statewide watershed management program is a reliable inventory of the hydrologic characteristics of our wild lands. This would include data concerning the topography, geology, soils, vegetation, and present land use. Along with this inventory is a need for additional measurements of precipitation and streamflow. Also needed are realistic forecasts as to what the future pressures and economic demands on these watershed lands may be.

In closing, I would like to point out still another important need in watershed management. This is for a greater number of watershed management specialists--specialists trained in various of the many disciplines involved in watershed management, such as climatology, geology, soils, engineering, forestry, hydrology, and economics.

## MULTIPLE USE - INTERACTIONS AND PROBLEMS OF MEASUREMENT

A. L. McComb<sup>1</sup>

Following Mr. Arnold's slides, the four panel members preceding me have dealt with the five major products and services coming from the wild-lands--water, forage, timber, wildlife, and recreation. In summation I want to talk about some of the interactions involved in simultaneously managing wildlands for multiple products and some of the problems arising from these interactions, including problems of measurement. I want to say right now that the confidence levels regarding some of the statements I shall make are not known, and some may be rather lower than I should like.

To focus attention on the problems of interactions in multiple-use management, I want to make an analogy between a multiple-use wildland watershed and a biological organism. Zoologists use the word homeostasis to indicate the maintenance of balance and steady state in an organism through regulation and coordination of physiological processes. Each organism is made up of a number of tissue and glandular systems that individually play important roles in the life of the whole organism. In contributing to the life of the whole, each tissue (or let us say gland) functions at a level below the maximum possible for it. If one gland is functioning at too high or too low a level the functioning of the organism as a whole is altered abnormally. The level of activity of the different glandular and tissue systems is regulated in such a way to permit the organism as a whole to function in a way that has had high survival value and which we call "normal."

In searching for a way to illustrate the concept of homeostasis, I remembered Julian Huxley's little poem, "Song of the Glands." Huxley lightheartedly writes:

We are the glands of the old brigade  
 We'll show you how a self is made:  
 We squirt into his blood, and he  
 Turns into what we made him be.  
     Squirt, squirt, squirt - he's fat and placid.  
     Squirt you there - he's growing acid.  
     This one squirts, and he's a giant.  
     That one - he becomes defiant.  
     You dry up - he's feeling sick;  
     You now - and his speech comes thick.  
 Squirt and now he knows the use  
 of the pancreatic juice.  
     - - - - -  
 Ah and you, sweet gland of glands  
 Who gives the heart its fond commands.

I won't quote more because after all we are concerned here with multiple use on watersheds. Now to get back to the analogy. We are interested in obtaining a satisfactory balance among all the multiple uses of the wildlands.

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<sup>1</sup>Department of Watershed Management, University of Arizona.

The fabric of a watershed is a mosaic of different complexes of vegetable and animal life with their climatic and soil controls. These complexes exist together and may both help and hinder each other. On a forested watershed trees make up the dominant vegetation. Beneath the tree layer may be layers of shrubs and grasses and other herbaceous plants. Various animals live and find food and shelter in the different layers above and below ground. There is constant competition and there are many complementary actions. Our job is to understand the interrelations well enough to determine the degree of competition and the nature and extent of the complementary actions.

In the management of these biological complexes we can favor any one of them, the extreme of which is single-use management; or we may decide on multiple use. Most wildlands are managed on a multiple-use basis because the returns probably are greater than from any single use.

For any given tract of wildland we must decide (to use the zoological analogy) the level at which each vegetation-environmental complex or system will be allowed to function. These complexes yield various combinations of products. So we search for answers to a number of questions. At what level do we want the water yielding-environmental complex to function; the forest products-environmental complex; the forage-producing complex; the wildlife and recreational complexes? What combinations of levels of these are possible, and which will give the highest return? These are the basic economic decisions that rest in the last analysis on the value judgments of people. Finding the answers is difficult because of the many competitive and complementary relationships. Nevertheless, there is considerable information available from the several sciences that, if assembled and correlated, would represent a good start.

In the Southwest water is king and every city, industry, and agricultural enterprise is deeply concerned with water problems. Our watershed problems are very complex. This is so in part because water is not only a separate product of the watersheds and of watershed management, but it is also a most important ingredient of the other products and services of the wildlands. Thus, there are posed the questions of how to manage watersheds for maximum yields of water and how to determine the value of water for each of the wildland products and services and, where there is multiple-use management, to determine within the limits possible, the proportion of water going to each use.

What are some of the more important interactions among the product-producing complexes of the wildland watersheds? I want to discuss some of these in terms of water. Professor Rowe has indicated that water yielded as streamflow can be increased by watershed management methods. Clearcutting forests in humid and superhumid climates has resulted in streamflow increases of between 25 and 50 per cent. Keep in mind, however, that this is not forest management but rather forest conversion. If one assumes sustained yield management of a forest operated on a 100-year rotation, no more than 1/100th of the whole area can be clearcut in any one year, and the total water yield increase would be expected to be proportional to the percentage of the total area cut and bare of vegetation.

If one decides that timber growing is desirable then what about water yields in relation to the density of the stands and to thinning? If stands are thinned, will more water be available for other uses and if so, how much? With reference to timber yields and stand density, Professor Knorr has pointed out the general relationships as developed by forest scientists in Denmark

and Germany and corroborated by work in this country. The salient points of this relationship are:

1. There is little decrease in total wood yield between maximum density and about 50 per cent of the maximum, because the volume of leaves and of absorbing roots is changed only very temporarily by thinning. However, yields of larger-sized products may be increased as density is decreased.

2. Below 50 per cent of maximum density, unoccupied crown and root space increases, some of the growth factors are not completely utilized, and wood yields decrease.

With reference to the question of water yields and thinning, the following generalizations seem warranted by our present knowledge.

1. Water is the principal factor limiting timber yields in Arizona (and in fact in most temperate forest regions).

2. A great increase in timber yields and yields of other vegetation could be obtained if more water were available. Conversely, decreasing available water will decrease yields.

3. Appreciably increased water yields would not be expected in the forest density range 50 per cent to 100 per cent of maximum density<sup>2</sup> because there is no decrease in timber yields and water is the principal limiting factor.

4. Below about 50 per cent density, water yields will increase with decreasing density and probably in proportion to the decrease in yield of timber and other vegetation.

5. What is said about forest stand density and water yields probably applies also to forage and browse plant density and water yield.

Since increased water yields will probably be at the expense of decreased yields of timber, grass, and shrubs, one of the problems needing solution is the determination of the value of water used in place on the watersheds for production of these products. It is estimated roughly that if precipitation or available water were double, yields of ponderosa pine sawtimber might be expected to quadruple. Forage yields probably would show a similar increase.

An illustration of a simple calculation serving as a base to compute the approximate value of water in terms of wood produced and to point to needed research might be as follows. (Admittedly, the confidence level of this computation is low.)

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<sup>2</sup>For concepts and density definitions see: Möller, Carl. Mar. 1954. Grundflächenzuwachs und Massenzuwachs mit verschiedenen Definitionen. Forstwiss. Centralblatt 73: 350-354.

Precipitation	=	23" per year
Streamflow	=	3" per year (10 to 15 per cent of precipitation in ponderosa pine type)

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Total evapotranspiration	=	20" per year
Evaporation (50% of total)	=	10" per year (Based on agricultural studies in the Midwest)
Transpiration (50% of total)	=	10" per year (and on lysimeter studies)
75% used by trees	=	7½" per year
25% used by forage and browse plants	=	2½" per year

7.5 inches of transpiration water produces 150 bd. ft. /acre/year

1.0 inch of water produces 20 bd. ft. /acre/year

1.0 acre-foot of water produces 240 bd. ft. /acre/year

The weakest points in the above calculations and those urgently needing more research are (1) determination of the amount of water used in transpiration and in evaporation in stands on different sites, and the effect of changes in stand composition and density on each loss or use; and (2) division of the total water transpired by vegetation among trees, forage, and browse plants.

To get the total value of the water used in place on the watershed, the value of water transpired by grasses, forbs, and shrubs and converted to livestock products, wildlife, and recreation must be added to the value of water used in timber production. What this total on-site value of the water will be we do not know. Values of this kind are needed so they can be compared with off-site uses of the same water.

A related density of vegetation-water yield question concerns the effect of forest thinning on non-tree vegetation and on water yields. Grasses, shrubs, and tree seedlings grow very poorly under dense stands of trees because of competition that results in supplies of light, water, and nutrients that are inadequate for best growth. If the timber stands are heavily thinned, then usually there will be increased growth of the subdominant grasses and shrubs; forage, livestock, and wildlife yields will increase. This increase will be related to the use of part or all of the increased water made available by the tree thinning. To get the full increase in water yield possible from forest thinnings, the density and growth of subdominant plants should not increase. Since it will be difficult and costly to prevent this increase, the question that then arises is how valuable is the extra water, stemming from the thinning, in terms of the increased yields of livestock and wildlife. Secondly, to what extent should the forage-producing complex be favored in relation to the timber complex and to the water-producing complex?

If the forest were completely removed and the area converted to grasses, what would happen? Would the grasses use the same amount of water as the trees? If not, how much would they use? For the water used, how much forage, livestock, and wildlife would be produced? What is the value of

this production and the value of the water in terms of the yields of these products? On what sites could you expect increased water yielded as streamflow? (Research to date suggests that increased water yields depend upon having soils deeper than root penetration and precipitation sufficient to wet the soil below the roots.) What then is the total value of the products of the forage-water-yielding complex in comparison to the timber-water-forage complex?

What has been said with reference to forage, timber, and browse suggests that we need to have more data from which to calculate the efficiency of water use in terms of usable products of various kinds. We also need to be concerned with the best place or places on a watershed to use the water that falls, i. e., with the place or places of most efficient use. As an example, forage and livestock production probably could be materially increased by measures designed to spread and retain surface runoff waters on the areas of better soils. If this were done, downstream water yields would be decreased somewhat. What is the value of the water used on site for forage and livestock production in comparison to its use downstream for agricultural, municipal, or industrial purposes? Perhaps this answer is known to some of you.

Another facet of this problem concerns the effect of stream transmission losses in relation to the point of most efficient use of water. On the San Simon drainage of southeastern Arizona, Mr. Dorrah of the Soil Conservation Service has shown that only 20 per cent of the water measured on site upstream reached the stream mouth. Part of this lost water went to the ground water recharge, but part went to uneconomic phreatophytes. For most of our streams we do not know the magnitude of the channel loss, let alone what part of it is potentially recoverable. The magnitude of these unrecoverable stream losses and the cost of preventing part of them affect not only the cost of delivering additional water downstream but also the point of most efficient use of water.

One could continue for hours talking of the many interactions among water, forests, forage, wildlife, and recreation. I haven't said much about either wildlife or recreation. I suspect the water-forage-wildlife complex is similar in many ways to the water-forage-livestock complex. Recreation, one of the most important products of wildlands and one which is becoming more important each year, was completely omitted. Before I started thinking of some of these interactions I used to feel sorry for economists, the complex questions they had to deal with, and how difficult it was to get accurate information on the multitude of interrelated factors needed to solve the problems with which they were faced. Now, I think we in watershed management need your sympathy and certainly all the help we can get.





## OBJECTIVES AND METHODS OF ECONOMIC EVALUATION ON THE BEAVER CREEK WATERSHED PROJECT

David P. Worley<sup>1</sup>

### The Broad Problem

Even though Arizona receives only 11 inches of precipitation a year, the state's population is increasing at an unprecedented rate. Urban population in 1954, for example, amounted to 600,000 and is expected to increase to 3,900,000 in the year 2000. Currently, the factor most likely to limit population growth is water for home use, for industry, and for agriculture.

A major statewide problem is to determine ways and means of getting the water to supply this expected growth. In the Salt River Valley and in Phoenix in particular, water supply problems are even more serious. The Phoenix area receives about seven inches of precipitation a year; and the Salt River Basin, which furnishes water to Phoenix, includes as maximum water potential areas relatively small acreages where precipitation is 25 to 35 inches a year. Census figures and median projection figures show the following populations by decades in Phoenix from 1940 to 2000: 190,000; 330,000, 590,000; 860,000; 1,220,000; 1,590,000; and 2,000,000.

**Proposed Actions and Some Implications.** To increase water yields, action programs have been recommended, some of which consider sweeping modifications of the plant cover on lands where increased water yields might be expected. Some of the finite recommendations could jeopardize other land values. Some are irrevocable in that they can be made easily, but if they turn out to be mistakes, they can't be undone except through long years of treatment and at great expense.

Specifically. The implications of these treatments are of particular importance to the United States Forest Service, since this agency administers much of the land in the Salt River Basin, including some of the better potential water-yielding areas. In light of its national and regional responsibilities, the Forest Service must proceed in its land management programs from a sound basis in fact. Some pertinent facts have already been developed through earlier research. In order to consolidate them, a 275,000-acre watershed was set aside as a pilot area to try out the recommended practices.

The problem in evaluation, then, is to determine the advantages and disadvantages of the alternative programs of land management designed to increase water yield. These must be set forth so that treatment effects on the other resources and on the direct and indirect benefits from the land can be compared, thus providing a basis for deciding on the best course of management on different classes of land.

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<sup>1</sup>Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, with headquarters at Colorado State University in Fort Collins, Colorado.

## The Beaver Creek Area

The Beaver Creek watershed area is part of the Coconino National Forest. It is tributary to the Verde River, which flows into the Salt River near Fort McDowell. It includes within its boundaries ponderosa pine-land, alligator juniper land, Utah juniper land, and semi-desert land. These cover types occur in different precipitation zones and are associated with different water yield potentials. The project area contributes water to the problem area and includes land with different water-producing potentials.

It is naturally divided into two large drainages of 126,000 acres and 149,000 acres. Four internal intermediate-sized watersheds between 12,000 and 16,000 acres are designated for special study. They include a complex of cover conditions. A further subdivision of 14 small watersheds from 100 acres to 2,000 acres completes the areas segregated for special study. Each of these is covered by a single vegetative type. Three of them are located in each juniper type, and eight are located in the pine type. Stream gages have already been built on most of these so as to measure water outputs before and after treatment. The gaging program will be completed this year.

### Stage Evaluation

It is proposed to tackle the evaluation problem in two stages. The first-stage evaluation is to be made on the small watersheds, each composed of a single vegetative type. These will be used to test results of treatment on water yield and on other products from the land. Results of these tests are to be fortified by studies outside watershed areas to determine functional relations between products, and by other studies to determine treatment costs and returns from products.

Second-stage evaluations will be made on intermediate and large watersheds covered by several vegetative types. Here, products such as wildlife and recreation will be studied to determine if the effects of treatment as determined in the first-stage tests are additive. Data on water delivery from headwater areas to larger channels will also be collected.

### Treatments to be Evaluated

Essentially, the treatments are reductions in woody plant cover. In the juniper areas, complete juniper removal will be compared with no removal. In the pine areas some of the pine and associated overstory trees will be removed so as to leave different amounts of residual timber standing. This will extend from complete removal of pine and conversion to grass on some watersheds to untreated control conditions on others, and will include cutting and burning as different methods of reducing the overstory.

Several serious problems in evaluation present themselves here. Answers must be found for these questions. How shall we define the treatments? What management intensity should be included in treatment or should follow treatment? How shall we determine the cost of treatment? These problems are particularly acute in the pine area. We do not have enough small watersheds to test a great array of treatments combined with different posttreatment intensities.

Results of a literature search now underway will be adapted and sifted to obtain rational functional relations between potential treatments and product yields. These will be validated in the field by making limited tests outside gaged watersheds. Once validated or adjusted, they will be used in conjunction with factor analysis to define treatments and establish levels of posttreatment management intensity to be evaluated on the watershed.

### Treatment Costs

Estimates of direct treatment costs will also be obtained from the literature search. These are being validated and adjusted from cost records of the Coconino National Forests where large-scale trials of various treatments have been made. Eventually, when treatments on the other small and intermediate watersheds are made to determine streamflow changes due to treatment, physical inputs such as labor time, equipment time, supervision time, and material quantities will be collected. Later, these will be multiplied by appropriate unit costs to give the investment costs for each treatment over and above past management costs.

Once a treatment has been made, the land should be kept in the same general condition prescribed by the treatment. This will require periodic maintenance costs, that will first be estimated and later validated on the watersheds themselves. Such estimated future costs will be discounted to the time of treatment and added to the treatment costs to give a total investment committed by treatment.

### Products to be Valued

The National Forests are managed by the multiple-use principle, which implies a recognition of the responsibility to manage for the variety of products produced from the land. Undue emphasis on one product may impair or destroy actual and potential yields of other products.

The products to be evaluated in the Beaver Creek Project are water, soil, timber, recreation, and range for livestock and game. Each of the treatments imposed on pilot watersheds to increase water yield can be expected to affect the yields of other products either favorably or adversely. In order to measure the effect of treatment in economic terms, it is necessary to determine the changes in physical product yields due to treatment and to determine what they are worth.

This requires two kinds of studies: valuation studies and physical studies to produce data needed for making a decision as to the best treatment for the various kinds of land. It is vital in this regard that valuation procedures for each product be thought out first so that the physical studies yield the data required. Technical experts, on the other hand, designing the physical studies should not be restricted narrowly to the immediate valuation objectives, but should be encouraged to develop further functional relations that will enable the results to be used elsewhere.

### What Are We Doing To Value These Products ?

In deciding what to do, it is important to decide first on the form of the answer sought. Here we are setting up as a design target, accounting type answers for all products. It is well to reiterate that this is a design target.

In the present case, some of the products such as water, timber, and livestock are tangible commodities paid for in some kind of market. Other products such as various forms of recreation are often considered intangibles. However, any serious change in the soil values caused by recreation is likely to incur additional costs for both upstream corrective measures and downstream maintenance. Hewing the line to an inflexible monetary accounting could very easily get us into a position of adding apples, oranges, and peaches, and coming out with a sum of lemons. Although a strict accounting is the design target, it is clearly realized that some of the products may ultimately be expressed in physical bonus units after the other products are accounted for. It is important to emphasize here, too, that the stated methods and principles to be discussed presently are based on preliminary ideas partly determined by work already done or committed.

With this in mind, let me list the products to be valued, state the valuation principle to be used to obtain direct unit values, then get right into what we are doing and anticipate what we intend to do on the watershed area to get the necessary physical data to combine with direct unit values so as to evaluate alternative treatments.

### Water

#### Valuation Principles:

1. For water going downstream - base watershed water value on alternative costs for obtaining equivalent water elsewhere by deducting costs to transport watershed water downstream from costs of alternative means.
2. For water remaining on the watersheds - include in other watershed values.

#### Physical Evaluation Studies on the Pilot Watersheds:

1. Determine precipitation over the area with a network of precipitation gages to determine water input.
2. Determine streamflow by gaging small, intermediate, and large watersheds so as to compare actual posttreatment flow with predicted flow based on pretreatment yields. Significant differences are attributed to treatment. This constitutes watershed output.
3. Determine the water regime of upstream impoundments before and after treatment by making repeated hydrologic inventories on the watersheds. This will also supplement the statistical streamflow analysis and help determine channel losses in delivering water from small watersheds to the large watershed gages.

### Soil

#### Valuation Principles:

1. For sediment going downstream - since sediment may clog channels and fill reservoirs, the costs thus incurred due to treatment will be determined, discounted to treatment date, and added to treatment costs.

2. For sediment remaining on the watershed and erosion on the watershed - erosion control costs and upstream impoundment maintenance costs will be treated as for downstream costs. Reduced productivity will be evident in other product yields.

Physical Evaluation Studies on the Pilot Watersheds:

1. Measure sediment discharge at gaging stations.

2. From the hydrologic inventory, determine the rate of sediment accumulations in upstream impoundments and locate erosion severe enough to require rehabilitation.

Timber

Valuation Principle:

1. Determine unit stumpage values by (a) studying competitive stumpage prices, and (b) calculating residual stumpage values by deducting all costs from the value of wood products in a market situation.

2. The value of timber removed in treatment is deducted from treatment costs as is the discounted value of estimated future yields.

Physical Evaluation Studies on Pilot Watersheds:

1. Determine estimated growth before treatment by studying increment cores taken from trees on permanent sample plots and estimating posttreatment growth by periodic remeasurement. Permanent sample plots are to be located to sample different sites, stand sizes, and stand densities so that the yield of a normal forest resulting from treatments can be determined.

2. Inventory all watersheds before, immediately after, and periodically after treatment, using a design to conform to conditions sampled on the permanent sample plots. The inventory should include data on insect and disease problems, on wildlife damage, and on fuel accumulations, as well as normal cruising data. Maintain a continuous record of posttreatment yield.

Range for Livestock

Valuation Principles:

1. Determine unit range values by (a) analyzing competitive range rentals, and (B) calculating residual range value by deducting all costs from the value of livestock transactions.

2. The values produced need to be related to weight of beef produced per acre or acres per animal unit month. Estimated future values are discounted to the treatment date to develop the value of treatment for range.

Physical Evaluation Studies on Pilot Watersheds:

1. Measure pertinent range factors as forage variables and water availability before and after treatment on treated watersheds.

2. Study existing local data to determine local valid relations between weight gain and animal unit months and between range factors and acres per animal unit month.

3. Pasture trials to measure cattle weight gains and range factors will be made on pastures treated like the watersheds.

### Recreation and Wildlife

#### Valuation Principles:

1. Most valuations of these products that have been made in the past are based on secondary values as expenditures made by vacationists and hunters in pursuit of recreation. These have been criticized from the economic standpoint, as confusing inputs and outputs and yielding no estimate of economic efficiency. Such valuations, too, are not helpful in deciding the physical studies required on the watershed to determine the effects of treatment on recreational and wildlife values. Therefore, physical studies for the present are directed toward determining the effects of treatment on wildlife populations and on recreation sites.

2. A reasonable beginning in valuation, though, seems to be to examine investments made for wildlife and recreation facilities in particular cases so as to find criteria for those that have worn well in the judgment of experienced administrators and to determine the cost in terms of other product yields foregone.

#### Physical Studies on Pilot Watersheds:

1. Wildlife - estimate game populations before and after treatment by making repeated seasonal pellet counts and by a record of systematized sightings. Determine food availability from forage production plots expanded to include browse. Determine food preference by analyzing stomach contents. From these data we should know how much game we have, where it spends its time and what it eats.

2. Recreation - inventory recreation sites for various uses before treatment and after treatment to determine effects of treatment on these sites.

### Putting the Results Together

The importance of setting up a target design is that it helps develop the requirements for input-output studies as well as setting the stage for economic studies. The accounting type answer to maximize value yield to the land imposes as requirements the data needed for other analytical methods. It implies determining net values associated with the treatments. As a result, it is expected that a concrete type of analytical model can be developed so that periodic redeterminations which include new management intensities and new values can be made so as to inventory the direction and rate that management programs are taking or should take.

Other analytical objectives that can be accommodated with the physical data collected include most of those discussed at this meeting. A benefit-cost analysis can be developed for the various treatments. An analysis of

opportunity costs to produce more water can be made either to impute water values before a programmed answer or as additional costs based on a programmed answer. These can, of course, be expressed so as to determine the least cost of obtaining a given quantity of water in light of the multiple-use principle on which National Forest Administration is based.





## THE NEED FOR WATER IN CENTRAL ARIZONA

W. S. Gookin<sup>1</sup>

It is a pleasure to be with you today, and to have the opportunity to discuss the water problems of Central Arizona. There is no area in the nation where water is so important to the economy, and there is no area in the nation where the water problems are as serious as in Central Arizona.

Those of you who have been in the Phoenix area for any appreciable period of time have heard the slogan, "Arizona Grows Where Water Flows." Those of us who have lived here for any period of time know how very true this slogan is.

The development of Arizona has always followed closely upon the development of the water resources of the state. Without such development the state is virtually uninhabitable. With such development it blossoms into one of the most thriving areas of the nation.

The Central Arizona area is a nebulous area, and is frequently defined to include all or virtually all of the irrigated lands in the Gila River Drainage Basin. However, for the purposes of this discussion, it would be better to confine our consideration to the irrigated acreages in Maricopa and Pinal counties. This is not to say that these acreages are more important than the other irrigated areas. However, in combination these two counties contain approximately two-thirds of the total irrigated acreage of the state, and generally speaking the problems of the two counties are essentially the same.

The map that you see on the wall will serve to illustrate the general configuration of the area we are considering and the location of the irrigated lands. This particular drawing was prepared as an exhibit in the case of Arizona v. California et. al. in 1956.

Basically the problem of the two counties may be simply stated: There just is not enough water available to sustain the present rate of water utilization.

A total irrigated acreage of slightly more than 810,000 acres is located in this area, and approximately 720,000 people reside in the two counties.

Virtually all of the surface water supplies of the area are fully developed. The Verde River is controlled by the Horseshoe and Bartlett Dams, the Salt River is controlled by the Roosevelt, Horse Mesa, Morman Flat, and Stewart Mountain Dams, the Gila River is controlled by the Coolidge Dam, and the Agua Fria River by the Lake Pleasant Dam. Experience over the years has demonstrated that even with this high degree of control, the surface supplies of the area can only be depended upon to furnish 875,000 acre-feet yearly at the Granite Reef Dam, which is the main diversion structure located on the Salt River below the mouth of the Verde River in Maricopa County. The Agua Fria has demonstrated a dependable yield of 25,000 acre-feet at Lake Pleasant, and the Gila has shown that it can only be depended upon to yield an average of 200,000 acre-feet at Ashurst-Hayden, which is the main diversion dam on the Gila

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<sup>1</sup> Consulting Engineer, Phoenix, Arizona.

River proper. These yields, together with other miscellaneous surface diversions, combine to indicate a total dependable surface supply for the area of about 1, 150, 000 acre-feet annually.

Obviously this surface water is not sufficient to supply the requirements of the 810, 000 acres of irrigated land, to say nothing of the requirements of the 720, 000 people who reside in the area.

To meet this deficiency the people of the two counties have turned to the groundwater basins, and have developed a tremendous system of wells and pumps. In 1959 these pumps withdrew a total of more than 3 1/2 million acre-feet from the groundwater reservoirs to supply that portion of the water demands of the two county area that could not be supplied by surface diversions.

Thus the surface diversions and groundwater withdrawals in Maricopa and Pinal counties total approximately 4, 700, 000 acre-feet of water. With this diversion and withdrawal, much of the irrigated area was forced to operate with an inadequate supply.

The alarming thing about the water supply situation in these two counties is that even though we are not now getting as much water as we need we find that the present rate of pumping is lowering the groundwater tables at a spectacular rate.

In order to illustrate this point I have borrowed another of the exhibits that was used in the recent lawsuit between Arizona and California. On this exhibit are depicted in graphic form the surface diversions, the withdrawals from groundwater, and the cumulative net changes in groundwater level in the so-called "Phoenix Area." I might say at this point that the so-called Phoenix Area is for all practical purposes identical to the two-county area of which I speak. Because this chart was prepared for the Arizona v. California litigation, it is not up to date nor are the data whereby it may be updated readily available. However, for discussion purposes it is recent enough to illustrate our problem.

You will note that during the five-year period from 1952 to 1956 inclusive, with diversions and withdrawals averaging about 4 1/3 million acre-feet, there was an average decline in the water table of about eight feet per year. While we do not have specific data we know that since 1956 this same general situation has prevailed.

Rapid as is the drawdown rate as indicated on the chart, the increase in pumping lift is even more rapid. Let me illustrate by example. Under the Salt River Project, which is one of the most favorably located areas in the state, during the period from 1950 to 1960 inclusive the static level of the groundwater table declined from 79 to 140 feet, or a total of 61 feet. During this same period the average pumping lift in the wells operated by the Salt River Project has increased from 125 feet to 250 feet, or a total of 125 feet. In short, the increase in pump lift has been more than twice the decline in water table. This is indicative of the fact that as the water table declines the aquifers from which we must pump are tighter and yield less water per foot of drawdown in the well.

Our groundwater levels are declining at an alarming rate, and ultimately there can be but one answer. Our withdrawals of groundwater must decrease, and unless some alternative source of supply is developed to replace this diminution, our total water supply will diminish and our economy will suffer.

There has at various times been considerable technical controversy over the extent of the overdrafts we are making on our groundwater basins. To evaluate this overdraft in specific terms necessitates a determination of the safe annual yield of our basins. There was a time when I would have been extremely hesitant to make an estimate of the safe annual yield of the groundwater basins in this area. However, no less an authority than Harold E. Thomas of the United States Geological Survey in his book, The Conservation of Ground Water, has defined "safe yield" as "an Alice-in-Wonderland term which means whatever its user chooses." Within the framework of this definition I can evaluate the safe-annual yield of the two-county area with considerably more confidence.

I feel that it is reasonable to assume that ultimately, unless new water supplies are developed from some source not now utilized, it will be necessary for the pumps in the two-county area to reduce withdrawals by almost three million acre-feet per year.

Such a reduction will not come this year or the year after next, nor will it come suddenly. It will be a gradual process occurring over a period of years, and it will come in varying rates in various parts of the area. I would not attempt to predict when this diminution in withdrawal will be experienced, because it depends not only upon physical factors which while constant are to a certain extent undetermined at this time, but in addition depends upon economic factors. Were I able to predict those economic factors, I would now be in a position to finance remedial measures from my personal funds. However, this much is certain, with water levels declining at a rate now approaching 10 feet per year, at some time in the future the groundwater will either be exhausted or will have declined to a depth where it is no longer financially feasible to pump it.

I have not discussed the problem of quality of water, nor does time permit an exploration of this problem and all of its ramifications. It is worthwhile to mention that in this arid region the streams that enter the two-county area carry with them salts in relatively large quantities. It has been estimated that almost 3/4 of a million tons of salt is dissolved in the water that is diverted to the two-county area. This diversion of salt greatly exceeds that which leaves the area. Most of the balance is accumulated in the soils and groundwaters. As the result of this and other factors, the quality of the water we pump is deteriorating. In some areas, wells that were once usable have already deteriorated to the point where the water can no longer be utilized. In other areas, this will prove to be a limitation before the limitations of availability and economics become effective.

So we find that in the central part of the state of Arizona we are mining water to meet our day-to-day requirements. We are in fact mining about half of what we are using. Unless some remedial steps are taken we face a serious decline in the economy of this flourishing area. I am convinced that there is no one solution to this problem. We must search every avenue of solution and develop every source of supply to its ultimate. We must utilize our Colorado River water, we must develop our watershed, we must proceed with evaporation control and phreatophyte control, and we must continue with our efforts to modify our weather and to demineralize our saline waters. We must intensify our efforts to reduce canal losses, and we must continue to improve our irrigation practices. All of these methods of water conservation must be diligently prosecuted if we are to avert the economic disaster that faces our area.



THE ECONOMIC MEASUREMENT OF WATERSHED TREATMENTS  
IN THE FACE OF INADEQUATE TECHNICAL DATAM. L. Upchurch<sup>1</sup>

It is a very real pleasure for me to meet with you today. After listening to the past one and three-fourths days of fine papers, I feel that I have arrived "lastest with the leastest." The very nature of the topic assigned to me doesn't suggest any formal treatment, so I shall not try to treat it formally or rigorously.

The difficulties of economic analysis with inadequate data have been with us for a very long time. Many economists have complained of the limitations this imposes. I suppose there never has been an economic analyst who was entirely satisfied with the scope and accuracy of his data. So the problem as posed in the context of today's discussion is unique in degree rather than kind.

Few problems, however, present as many gaps in data as those relating to resource development. The physical and biological relationships involved in flood control, irrigation development, watershed management, and many other types of resource-oriented projects are very imperfectly known despite much research and experience, especially in the past 25 years. We know relatively little about the relationships between plant cover and runoff, management practices and erosion, response of vegetation to specified treatment practices, and many others. Precise economic analysis is handicapped by these gaps in information.

Moreover, we do not know what economic values to place on many of the products involved in resource development projects. For example, we do not know the value of water used for boating, the value of forage grazed by deer, the value of woods shading the campground.

Despite inadequacies of data and standards of measurement, economic decisions about resource developments are being made. And they must be made, whether or not trained economists have the data and tools for precise analysis. Professional economists can either retire behind academic walls and concern themselves with theory and methods or they can participate in the decision-making process, using their training and ingenuity as best they can; or they can do some of each.

I strongly support both courses of action. We need academicians who can help develop the most sophisticated tools of analysis it is possible to get. We need also practicing economists who will do the best they can with what they have at hand, despite limitations of methodological tools and data. Perhaps the greatest need is for generalists who can deal effectively with both theory and practical application.

My remarks today are directed chiefly to the practicing economists. They are the people who must calculate the benefit-cost ratios on proposed flood control and reclamation projects, or struggle with the output-input relationships of land management practices. Their assignment requires specific estimates, not academic abstractions. Whatever their handicaps of training,

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<sup>1</sup> Assistant Director, Farm Economics Research Division, Agricultural Research Service, U. S. Department of Agriculture.

abilities, time, money, personnel, or data, they must stand and do their job. They cannot be idle simply because they do not have all the facts or all the accuracy in their data that they would prefer.

My advice to these people boils down to a sentence of one-syllable words: Do the best you can with what you have or can get.

This advice certainly needs to be elaborated, if it is to help anyone, so the following suggestions are offered as guides.

1. Specify your needs for data in terms of things you need data on, degree of accuracy required, scope of coverage, time dimensions, and techniques of analysis you expect to use. Frequently, economic analysis of resource development projects begins with a general sweeping together of "all relevant data." When a project evaluation proposal says that all relevant data will be assemble, it often means that the project leaders don't know what they need, so they gather everything in sight. Too often time and money are wasted gathering data that are either not relevant or are excessive in quantity and coverage for the job in hand. When minimum requirements for data are specified as precisely as possible, you may find that you are not as badly off as you thought you were.

Degree of accuracy needed in data is another factor to watch. We sometimes worry about accuracy when fairly wide margins of error would not affect our final answer. For example, we may try to quantify precisely the output from a land management practice when any output above \$10 an acre would make the practice profitable. Why struggle needlessly to determine whether the output is \$14 or \$16 an acre?

Don't misunderstand me; I am not advocating slipshod work. I am suggesting, however, that in a practical, pragmatic, problem-solving job, we frequently can answer our questions well enough for the purpose without time-consuming pursuit of excessive accuracy. The law of diminishing returns applies to economic inquiry as well as to other endeavors.

The techniques of analysis we expect to use materially affect the kind and degree of accuracy needed in data. This idea is illustrated by the differences between farm budgeting and "activity analysis" or linear programming in problems of farm organization. In the first, the analyst has opportunity throughout the analysis to exercise judgment and to spot nonsense relationships. The latter, being more formal and more mechanical, does not provide this opportunity, so we need to be especially careful of the data used with this technique. As we increase our use of activity analysis on resource development problems, our needs for more precise data will increase.

2. With your needs for data well in mind, you can sometimes initiate experiments to provide needed information. Experiments have been initiated as a part of the Arizona Watershed Program, as we have heard earlier today. Those responsible for initiating and carrying out these experiments are to be congratulated. But remember, experiments to determine physical and biological relationships among plants, animals, and soils are slow and costly, especially in a semi-arid or arid country. You may need economic answers of some kind long before definitive data can be developed this way. This does not mean that the experiments should not be continued and broadened, for I am sure that the data they develop will be needed 25 or 50 years from now. Had we started 25 years ago to conduct more experiments of the type now being done, we would not have to do so much guessing now.

When experiments are made to develop data for use in economic analysis, make sure that they do. Care should be taken to assure that the relevant variables are measured, that the range of variables is adequate to establish a response surface, and that proper records are kept. Often, the results of experiments tell us how to kill brush, for example, but they don't tell us whether we would want to.

Usually, physical or biological experiments are not conducted by economists. Others trained in the natural sciences know better how to experiment. But if you expect to obtain data from such experiments that will be used in economic analysis, economists should help design the experiments and keep the records that will be relevant for their purposes.

3. You can initiate surveys to provide some of the data needed for economic analysis of resource development projects. Unfortunately, too many economists feel that a survey is the only method for getting data, so they start planning a survey as a first step in their analysis. At best, a survey can only supplement other sources of information, and, even then, it must be carefully planned and conducted to produce valid data efficiently.

In making a survey, you assume that someone has information you need, so you ask him for it. You can ask a farmer how many bales of cotton he raised last year and he can tell you with a high degree of accuracy. You can ask a rancher how many tons of forage grew on his Forest Service grazing allotment, but he cannot tell you for he does not know. He has no measure for it. My point simply is that you waste time and money trying to get information from respondents by the survey method when they do not have the information you seek.

When surveys are made be sure that the population to be surveyed and the design of your sample are appropriate for your purpose. Frequently, we think of random sampling as synonymous with the survey method. Actually, a random sample may be very inefficient. For example, if we want to know the organization of farms in an area proposed for a supplemental water supply, we may find that some farmers in the area already have adequate water while others are quite short on water. A stratified sample of each group may tell us much more than a random sample of all, and it may give us the data we need at much less cost.

Collecting data by the survey method is costly, and, I believe, should be used only when necessary. Many weary miles have been pulled under the wheels of automobiles, and many man-years of time spent in getting numbers from respondents. Survey schedules often cost \$20 to \$30 each, not counting costs of supervision and analysis. These prices require us to use surveys sparingly and with intelligence.

4. You can initiate record keeping on resource development projects to provide data for economic analysis later. As with experiments, record keeping may be a slow way of providing data, but we should do more of it. If good records had been kept on the large number of projects undertaken in the past 25 years, we would not now be so concerned over our shortage of data. If we don't start keeping some records now, we will still be concerned 25 years from now.

In view of the huge sums spent of reclamation, flood control, conservation, and other types of projects, especially since 1933, it is amazing that we



know so little about the results of this work. The Soil Conservation Service is taking steps now partially to remedy this situation by recording the results of conservation practices on a sample basis. Work has started in some districts in five states, I hope the results warrant more recordkeeping on a wider basis.

One problem of keeping records is that the agencies carrying out the project are often not the ones most concerned with economic analysis of the results. Reclamation project supervisors, forest supervisors, managers of grazing districts, district conservationists, and others are busy people carrying out their major tasks. They have little time, and often little enthusiasm, for records that some unknown economist at some for-off time may find useful for analytical purposes.

I'm glad to hear that records are being kept on work done under the auspices of the Arizona Watershed Program. I hope the proper data are being recorded in a form that will permit rigorous economic evaluation.

5. In the absence of, or as a supplement to, data from experiments, surveys, and records, you can supply some of your needs for data by the use of established principles and criterion. Some principles of cause-effect relationships have been established and generally accepted. Use of them may provide estimates of magnitudes that are good enough for rough economic analysis. An example of this is the Blaney-Criddle method of determining water requirements for irrigation. Despite its questionable applicability in specific situations, it can be used to determine water requirements accurately enough for most purposes in project planning and evaluation.

Many other principles can be used and are used to good effect for economic analysis. But experienced judgment must accompany their use in specific situations, because sometimes the principle may result in odd answers. For example, the usual generalizations about the relationship between rainfall, altitude, and soils and timber species and growth do not explain the lousy stand of ponderosa pine found on the Hualapai Reservation, nor do they explain the invasion of brush on former grass or timber land.

6. You can supply some of your needs for data by the use of analogies. By this, I mean that you often may find data developed for different purposes and in different areas that you can transpose for your use in a specific economic evaluation problem. For example, if you must appraise the effect of a range improvement practice on a given watershed, perhaps you can find data relating to the practices that have been developed elsewhere. With modifications by judgment, they may serve your purpose.

The danger in using analogies lies in the extent to which the two situations are in fact analogous. Some good data have been developed in California showing the relationship between plant cover on a watershed and water yield. Can these data be used to show this relationship in Arizona? In this instance, differences in amount and seasonal distribution of rainfall, differences in type and density of vegetation, and differences in other factors may make an analogy invalid. Nevertheless, similarities can often be found and used for purposes of economic analysis.

7. At times, you may also use "the expert guess" to supply items of data essential for answering economic questions. As a matter of fact, the expert guess is used more often than we realize for making economic decisions. In the private business world this usually substitutes for verified facts and rigorous appraisal.

The expert guess should not be dismissed lightly even by the most sophisticated analyst. Estimates based on experienced judgment often prove to be highly accurate, perhaps accurate enough for your purpose. You will not have statistical measures of reliability, but you may have confidence. Sometimes the expert guess can be obtained with relatively little cost, whereas the experiments or surveys needed to verify the estimate or to improve on it may be quite costly in time and money. Let us not forget the law of diminishing returns as applied to our own efforts.

Occasionally your confidence in the expert guess can be improved by relying on a team of experts rather than one. Several people experienced in a given subject may together make a better estimate than one. If the experts can agree, your confidence in the estimate is enhanced. If they disagree, you'd better search elsewhere for verification.

8. Another device to provide data often used in economic analysis is the "rule of thumb." I claim no scientific basis for it and neither will you, but again many economic decisions are based on just such evidence. Bankers often have rules of thumb to guide them in making loans, and real estate brokers have a rule regarding the ratio of your income to the price of a house you can afford. Usually these rules are based on experience and serve, in the absence of better information, a good purpose in economic decision making.

Analysts who struggle with resource development problems also have rules of thumb. An established relationship between depth and duration of flooding and flood damage is often used. The handbooks used by the Soil Conservation Service, the Forest Service, and the Bureau of Land Management--to name only a few--contain many rules of thumb, some explicit, some implied. One rule of thumb we sometimes see is the 1 to 3 ratio between direct and induced benefits of reclamation projects. These rules are not necessarily wrong or bad. They can be and are used in the absence of better information. But they should be used with judgment and should be verified whenever possible.

9. Sometimes you can use the simple "opportunity cost" principle of economics to supply estimates of magnitudes not available in any other way. You may not know how much water is worth in a given use, but you may have an estimate of its worth in an alternative use. If so, you have at least a measure of worth needed for it to be devoted to the use in question. You may not know what a deer is worth, but if you know how many sheep have to be foregone in order to have the deer, you at least have some basis for estimating the cost of the deer. Some ingenuity in the application of this principle can help supply many estimates useful for economic analysis that are not easily obtained in any other way.

10. You may have occasion to get some of the data you need for economic analysis by contract. This may be dubbed the let-George-do-it principle. I mention this one only because it is used often when time presses, and it does have certain advantages. If you need, for example, estimates of future crop yields in a given area, perhaps you can contract with the state experiment station to supply them. This is just what the Southwest River Basin Commission has done. In this instance, a contract with the Texas Agricultural Experiment Station supplied the estimates needed. Not only did the experiment station have a variety of experts to draw on for making estimates, but the results carried an aura of objectivity that enhanced their acceptability.

After you have specified your needs for data and exhausted these devices and others to obtain them, how do you know when you have data that are adequate for purposes of economic analysis? Certainly you must first use the ordinary statistical tests whenever they are applicable. Even the crude tests of the "range" and "average deviation" about a mean are useful measures that are too often neglected in our economic evaluation of resource development projects. Even they provide some basis for judging the adequacy of data.

Frequently, the data we obtain by the expert guess or from other sources are not subject to any statistical test of adequacy. These must be subjected to other tests. One is the test of consistency. For example, if you have data showing yields of different crops in a given situation, inspection will reveal whether they are consistent with one another. If one is out of line, you cannot conclude immediately that it is wrong, but you can do some further checking. This may lead to a new datum that appears consistent with the others or to an explanation of the apparent inconsistency. The test of consistency is so obvious that it should need no stress before a group of professional people, but you would be surprised how often glaring inconsistencies appear even in carefully done research reports.

Another test, also obvious, I shall call the "test of absurdity." In dealing with natural phenomena, we know that certain data simply cannot go beyond given ranges. We know that a range steer will not gain five pounds a day, although I once reviewed a report that said he would, if you divided the total gain claimed by the number of steer-days of grazing (in this instance, the number of steers was erroneously reported). We know that the acreage flooded cannot exceed the total acreage in the flood plain, but this error too has been made (by blowing up results of a sample survey).

Absurdities are occasionally committed in methods or techniques as well as in data. To calculate usable forage yields from data obtained from rodent-proof enclosures is somewhat absurd. To measure the value of game by the retail price of goods and services bought by hunters is equally so. It is also absurd to measure the value of water by imputing to it the net values of all the associated inputs, yet we see this done frequently.

Watch out for absurdities both in data and methods. They are easier to commit and harder to detect than you might think.

Up to this point I have been talking chiefly about ways to improvise when you must make economic analyses with inadequate technical data. Even without data, or with scanty data, there are other things you can do as economists that will help make rational economic decisions.

One, we can explain or point out the economic principles involved in the decision. We can pose the questions in relevant economic terms so that those who do make decisions can more easily fill in with their own data or can at least know the extent of the gaps in information.

Two, we can, through partial analysis, set the limits within which unknown data must fall if the decision is to be rational in economic terms. For example, in a recent study of the costs and benefits of juniper control in Central Arizona, we found that we could not adequately measure the quantity and value of forage produced. We could, however, quantify the costs of control. From this we know that the value of the forage produced must be above specified amounts, if ranchers are to make any profit from the practice. Although we cannot say that juniper control is profitable to the rancher, we can say what

it is likely to cost and what he must make if he is to finance the control alone. This is very useful information, but it is not the final answer.

Three, we can point directions of desirable economic change without necessarily knowing the ultimate extent of change. This can be illustrated by a simple farm management problem. If feeding hogs is more profitable than feeding steers, a farmer can increase his profit by feeding more hogs and fewer steers, even though he does not know precisely how many hogs and how many steers give him the maximum profit. The "maximum profit" combination of the uses of resources is very difficult to ascertain, particularly in a complex resource development problem. It is much easier to learn what will improve economic productivity than to determine what is maximum economic productivity. Economic analysis can point the direction to go without specifying the distance to travel.

Finally, let me repeat that economic analysis with inadequate data should not frighten us too much. Perfect knowledge like the perfect vacuum is an ideal never fully achieved. Our problems of economic analysis of resource development projects differ from others only in degree. We can exploit the data we have more fully. We can use our ingenuity to "make do" with what we have or with what we can get within the limits of time and resources. Even without much data, we can do a useful service by pointing to the directions of change and to the economic principles involved in decision making. These things we must do because economic decisions do not wait for perfect knowledge.

In the meantime we can strive to improve our data and our tools of analysis, for we will need them next year and for many years after that. The work of pioneers of thought in this field like Ciriacy-Wantrup, Margolis, Kelso, Eckstein, Krutilla, Castle, and others are worthy of the most careful study. We are now much better equipped with data and tools than ever before. I hope we continue to improve, and I believe we will.