POTENTIAL ECONOMIC EFFECTS OF UPSTREAM FLOOD CONTROL AND IRRIGATION DEVELOPMENT: BOGGY CREEK WATERSHED, OKLAHOMA

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CHAPTER I

INTRODUCTION

The Watershed Protection and Flood Prevention Act of 1954[1] (and subsequent amendments thereto) permits locally organized watershed associations to sponsor the construction of improvements for (1) flood prevention, (2) drainage, (3) irrigation, (4) recreation, (5) wildlife and (6) providing water for municipal and industrial purposes. These watershed improvements create a potential to increase agricultural output through reduction in flood damage to crops. The reduced flooding hazard also creates opportunities for farmers to increase efficiency by making adjustments in land use, capital investment, and farming practices. These opportunities to adjust arise from possibilities

[1]This act followed 18 years of upstream flood prevention activity by the Federal Government, which began with the Omnibus Flood Control Act in 1936. The Flood Control Act of 1944, which authorized flood control improvements in 11 watersheds of the United States, included Oklahoma's Washita River. Congress authorized 60 pilot watershed projects during the fiscal year 1954. Public Law 1018 of 1956 which amended Public Law 566 (1) included non-agricultural water measures, (2) authorized federal credit assistance, (3) revised the work plan approval procedure and (4) authorized the Federal Government to bear the entire cost of the flood prevention purposes. A further amendment (Public Law 85-865) in 1958 provided federal technical assistance and cost sharing for fish and wildlife development.

to (1) use flood plain land more intensively as flood risk is reduced, and (2) to irrigate with the water impounded by the water retarding dams.[2]

Currently, Oklahoma has about 30 percent of its total land area involved in watershed development in some one of several stages from applications received to complete construction.

For various reasons, farmers of a given watershed may be unable, or unwilling, to make the adjustments necessary to realize the full potential for increasing their net incomes made possible by a watershed improvement project. They may be unable to acquire the additional capital, unwilling to put forth the extra labor, or they may simply lack information as to the economic consequences of the newly created alternatives now facing them.

Farmers generally lack information needed for achieving the potential increases in net returns made possible by flood protection, but this is not as crucial as the need for more knowledge of the irrigation potential. Because structures for flood control purposes are almost completely financed by the Federal Government, farmers with flood plain land have little difficulty in deciding for the project. But since a decision to add increments to dams for

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[2]These dams are generally called "structures" by those who work with the flood control program. The terms may be used interchangeably in this dissertation.

irrigation requires capital outlays by the farmers, they are more reluctant to agree to irrigation development.

A further obstacle is presented by the necessity to make the decision to invest for irrigation at the time the structure is being planned by the engineers. Lack of information at this stage is probably reflected in the few structures planned for irrigation. Of 209 plans in the United States as of January, 1960, only 10 had included irrigation water storage.

This study is limited to one watershed, Boggy Creek, which is located in Washita County in Southwest Oklahoma. The area is between Clinton and Cordell, with the stream passing just south of the small town of Bessie. The head of Boggy Creek is near Burns Flat. From here, it flows in an easterly direction for 18 miles where it empties into the Washita River about six miles east of Cordell. The topography is rolling, with the elevation varying from about 1400 feet to 1870 feet above mean sea level. The soils range from fine to medium textured with very shallow to deep profiles. The slowly permeable clay soils developed mostly from the Cloud Chief shales. The permeable deep sandy soils are from the Elk City sandstone and the shallow soils developed from the Doxey silt stone formations.

For the purpose of this study, the land is classified by upland and bottomland. The upland is sub-divided into native grassland and cropland, and the bottomland is divided between flood plain and non-flood plain land. The assumed homogeneity of yields in these classes appears justified from an examination of the USDA soil survey of Washita County.[3] The results of the soil survey indicate that the principal soils of the bottomland are Reinach Very Fine Sandy Loam, Portland Silty Clay Loam, Yahola Silty Clay Loam, and Yahola soils undifferentiated. The upland soils are chiefly Tillman Silt Loam, Vernon Silt Loam, with small areas of rough broken land. The bottomland soils are described as productive, and there is not a great variation in the yields as between soil types. The Tillman Silt Loam of the uplands is described as an "agriculturally important soil occupying large smoothly undulating areas in the central part of the County."[4] The Vernon Silt Loam is shallower, with steeper slopes than the Tillman. Much of it has never been cultivated, and it supports a cover of native buffalo grass, grama, and blue stem.

The study is limited to the 64 farms in the watershed containing flood plain land. These farms in the watershed emphasize the production of wheat, cotton, barley, grain sorghum, and beef cattle. The general problem is to analyze the potential effects of the federal small watershed project upon production and income for these farms.

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[3]A. W. Goke, C. A. Hollopeter, and C. F. Fisher, Soil Survey of Washita County, Oklahoma, United States Department of Agriculture, Bureau of Chemistry and Soils, Soils Survey Division, and Oklahoma Agricultural Experiment Station, Series 1935, No. 17, (Washington, D. C., March, 1941).

[4]Ibid., p. 11.

The study divides into two phases: flood control and irrigation. The main effects of the flood protection provided by a watershed project are (1) reduced flood damages to crops presently being produced on the land, and (2) changes in use of the land to more intensive crops accompanied by other farm organization changes. The main effects of providing and using irrigation water are increased capital and labor requirements, and greater output per acre. Net returns to farmers may or may not be increased by irrigation.

Some specific questions considered in the flood control phase were: What are the potential changes in use of flood plain land? What are the relative magnitudes of the two component economic effects: changed land use and reduction in flood damages? What are the flood protection effects on use of lands other than the flood plain which may be operated by the same farmer? How do sizes of farm units, relative amounts of bottomland and upland, and sizes of acreage allotments affect land use adjustments? How do net returns to the farms change with different levels of flood protection? Some specific questions considered in the irrigation phase of the study were: What is the value for irrigation of water supplied by the structures as designed for flood protection alone? How much can farmers afford to pay per acre foot of water stored under cost-sharing agreements? How much per acre foot would such storage capacity cost?

Although the potential flood protection and irrigation benefits to farmers within the watershed comprise a high portion of total benefits to watershed development, important effects not considered in this study include reduction in damage to farm and public property, and the creation of additional potential for recreation and wildlife.

A major hypothesis of the study is that the potential effects of watershed development vary significantly among farmers in the watershed with different resource situations. If this hypothesis is true, the results of the study will have implications for methodology of watershed evaluation as well as for adjustment by individual farmers. More specifically, the results of the study could support a "whole farm" approach in watershed planning, which, currently, is not the practice of project planners. The distinguishing feature of the methodology of this study is the "whole farm" approach. How this methodology differs from current practice in watershed planning and from other proposals warrants a brief explanation.

Alternative Approaches to Watershed Evaluation

The approach to watershed evaluation now employed by the Soil Conservation Service is an effort to estimate a benefit-cost ratio for a project by considering only the flood plain land, with and without flood protection. This does not adequately take into account the differences in individual farmers' adjustments which are due to their total resource situations and their differing farm organizations. An alternative approach is to consider the whole watershed as an entity for planning.[5]

The purpose of this section is to briefly describe and point out deficiencies in each of these two approaches, and then to defend the methodology used in this study as a possible remedy for these deficiencies.

The Soil Conservation Service calculates benefits and costs for a specific project by considering the watershed "with" and "without" the project services. Project planners are provided with detailed instructions for estimating the damages of flood-water to crops and pastures, roads, bridges, etc. Surveys of farmers in the area are made for the purpose of getting basic information needed for calculating the damages from flooding. Farmers are asked how flood plain land is being used prior to protection and what use is anticipated after protection. Then by budgeting the aggregate values of these uses, with and without the project, the benefits from reduction in flood damage to pastures and crops are calculated. Generally, agricultural

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[5]For examples, see John F. Timmons, "Economic Framework for Watershed Development," Journal of Farm Economics, XXXVI, Dec., 1954, pp. 1170-1183; Fletcher E. Riggs, "The Watershed as an Entity for Planning," Economics of Watershed Planning, ed. G. S. Tolley and F. E. Riggs (Ames, 1961), pp. 59-67; and George E. Pavelis et al., Methodology of Programming Small Watershed Development, Iowa State Agricultural Experiment Research Bulletin No. 493 (Ames, April, 1961).

benefits are ascribed to (1) reduction in flood damage to crops and (2) the added value of crops from more intensive use of the flood plain land made possible by the project.

The defect in this method is that farmers living in a watershed ordinarily have only a portion of their farm units occupying flood plain land. Possible effects of the project upon land use and income of the non-flood plain portions of the farm units are not considered by the method.

The concept of a watershed as a firm has gained some acceptance in the literature since its first explicit statement by Timmons and others.

Technically, these ideas concerning the watershed as a firm do not violate the definition of a firm as a decision making unit if we limit the scope of decision making to the watershed association. But because the association can only make certain limited decisions -- mainly with respect to whether or not a project should be sponsored and federal assistance requested -- the concept of a watershed firm has serious limitations if applied to estimating the impact of a project on a particular watershed.

The reason for these deficiencies is not hard to find. The management of lands in a watershed does not depend on the decisions of group action, but is the result of the decisions of many individual farmers. Because these individual farmers operate very diverse units with respect to land, labor, and capital resources, they will vary greatly in their susceptibility to being affected by a watershed project. This was recognized by Timmons in his original development of the watershed firm concept:

> The watershed firm differs from the farm firm in that it is made up of many farm firms (at least two) and other participants with varying (often times conflicting) objectives of the entrepreneurs, different situations in which to achieve their objectives and varying costs and benefits incident to the development of the watershed as a whole.[6]

This seems to indicate that any attempt to estimate the effects of a watershed project by considering lands and resources in the aggregate as if under one management is likely to result in very different estimates than if an account is taken of the diverse management and resource situations.

The "whole farm" approach permits measurements of effects of the project on upland use as well as the effects on the flood plain. For example, if a more intensive crop moves into the flood plain as a result of flood risk reduction, the "flood plain only" approach may over estimate the "benefits" by failing to subtract the reduced net returns on the upland from the increased net returns on the bottomland. Such an adjustment is made by the methodology used in this study. In addition, the "whole farm" approach removes the deficiencies associated with the "whole watershed" approach by taking into account the diverse resource situations of individual firms which make up the watershed.

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[6]Timmons, p. 1172.

Specific Objectives and Plan of Study

The first objective was to estimate the changes in land use and in net returns, and the components of income changes (i.e., that due to changed land use and that due to reduced flood damage) for typical farm resource situations as the intensity of flood protection increased. The following levels of flood protection were used in the study: (1) present condition (no flood control), (2) land treatment only, and land treatment with, (3) ten structures, (4) twenty structures, (5) thirty-six structures, and (6) complete flood protection.

The second objective was to estimate the changes in resource requirements, land use, and net returns for "typical" farm resource situations at the following levels of irrigation: (1) none, (2) enough water to irrigate the cotton allotment, (3) an intermediate level of irrigation water between levels (2) and (4), and (4) enough irrigation water to irrigate all the bottomland.

The third objective was to estimate the storage water available for irrigation in sediment pools of the structures and the cost to farmers for developing additional storage for irrigation from ten structures judged to be the most suitable for this purpose.

In Chapter II, a conceptual model of the effects of a small watershed project in terms of flood control and irrigation is presented, and the empirical methods are described.

Chapter III contains results of the flood control phase, and Chapter IV contains results of the irrigation phase of the study. The summary and conclusions are presented in Chapter V.

CHAPTER II

THEORETICAL MODELS AND EMPIRICAL METHODS

The purpose of this chapter is to (1) present a conceptual model of the effects of a small watershed project on the agriculture within a watershed and (2) describe the empirical methods used for quantifying the relevant variables of the model and for estimating the economic impact of the proposed project.

Preliminary Assumptions and Definitions

The watershed is so small that the entire analysis may be made within the framework of the assumptions of pure competition. That is, the aggregate of all the firms in the watershed faces perfectly elastic supply and demand curves. The products (cotton, wheat, small grains, beef, etc.) are homogeneous with the products of large areas, and the watershed neither buys enough of the production factors, nor sells enough products to affect prices paid or received.

The method of analysis is that of comparative statics, which has been defined by Samuelson as follows:

> This in brief is the method of comparative statics, meaning by this the investigation of changes in a system from one position of equilibrium to another without regard to the transitional process involved in the adjustment.[1]

In this study, an initial static position is assumed and defined; the disturbance is introduced, and after adjustment is fully reached, a new equilibrium position is achieved. The difference between the magnitudes of the relevant variables in the two positions is used as a measure of the effects of the disturbance.

Equilibrium

There are a variety of notions of kinds of equilibrium: stationary, stable, unstable, dynamic, etc. The definition of equilibrium as used in static analysis

> ...indicates a set of prices and quantities, etc., i. e., solutions with regard to the dependent variables of the system, which if once realized, have no tendency to disappear as long as the system is not influenced by changes in data.[2]

Marshall writes concerning stable equilibrium: "Such an equilibrium, is stable; that is, the price, if displaced a little from it, will tend to return, as a pendulum oscillates about its lowest point."[3] Boulding asserts that "a

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[1]Paul Samuelson, Foundations of Economic Analysis, (Cambridge, 1948), p. 8.

[2]F. Zeuthen, Economic Theory and Method, (Cambridge, 1955), p. 33.

[3]Alfred Marshall, Principles of Economics, (8th ed., London, 1959), p. 287.

firm is in equilibrium when there is no opportunity to act so as to increase its profits, and no incentive to act so as to lower them."[4] Samuelson points out that

> In cases where the equilibrium values of our variables can be regarded as the solution of an extremum (maximum or minimum) problem, it is often possible regardless of the number of variables involved to determine unambiguously the qualitative behavior of one solution values in respect to changes in parameters.[5]

In this study, equilibrium of the firm is used in the sense of the above quotations from Boulding and Samuelson. The firm is in such a position that it cannot act to increase its profits, has no incentive to lower them, and this position coincides with the solution of an extremum (maximum profit) problem.

An Economic Model

There are various definitions of an economic model depending on the method of analysis and the particular aims of the economist. For example, according to Joan Robinson:

> The model consists in a highly simplified mental picture, exhibiting the behavior of people in a social and physical environment, which eliminates what is inessential to the problem in hand so as to focus attention on what is essential.[6]

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[4]Kenneth E. Boulding, Economic Analysis, (3rd ed., New York, 1955), p. 287.

[5]Samuelson, p. 8.

[6]Joan Robinson, Exercises in Economic Analysis, (London, 1960), p. xvi.

The econometric definition is more concise:

> In Econometrics one views economic life as explainable by a set of mathematical equations. These equations express the relationships among economic magnitudes which guide economic behavior. A model, then, is a complete system of mathematical equations, and the system may be as broad or as narrow as the problems being studied.[7]

In this study, a model is viewed as a somewhat simplified set of relationships which helps to explain economic phenomena for purposes of verbal exposition, and as a set of mathematical equations for purposes of an algebraical statement.

In the sense that a model is composed of a set of mathematical equations, which may be as narrow or as broad as the problem under consideration, it is well to note that the variables connected by the equations may be either (1) endogenous or (2) exogenous. Whether or not variables are viewed as endogenous or exogenous depends on the scope of the problem under investigation:

> Endogenous variables are those explained by the model; exogenous variables are not explained by the model, but rather are determined by some forces outside the scope of the model. How comprehensive or broad the model is depends on how many economic variables one wishes to include in the category of endogenous variables. The more variables that are endogenous to the model--the more variables that are explained by the model--the greater is the scope or inclusiveness of the model.[8]

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[7]Michael J. Brennan, Jr., Preface to Econometrics, (Cincinnati, 1960), p. 10.

[8]Ibid., p. 204.

For example, if we select an individual farm as the unit of analysis, we may consider the degree of flood protection as exogenous to the model, whereas if we select the entire watershed as the unit of analysis we may count the degree of flood protection as determined by the watershed model, or that is, as an endogenous variable.

Parameters are the constants of a system of equations. As long as the parameters do not change, the equilibrium values of the variables in the system remain the same. In this study, this conception of parameters is applied to production functions in building the general model for an analysis of the effects of changing the levels of flood protection and irrigation. At any one level of flood protection, the coefficient relating flood plain land as an input to the output of some commodity is a parameter which depends on an exogenous variable (the level of flood protection) for its value. Generally, it is by introducing a change in at least one parameter that displacement of equilibrium of a model is achieved. In this study, a change in equilibrium is accomplished by changing the level of flood protection or the level of irrigation, as the case may be.

The Firm in Equilibrium--A General Model

As pointed out in Chapter I, the appropriate unit of analysis is taken to be the individual farm firm instead of the entire watershed or the flood plain land only. Before isolating the variables which are relevant in assessing the impact of flood control and irrigation on the watershed, it will be helpful to state the framework of the equilibrium of the firm in general mathematical notation.

Let us suppose that a watershed firm (farm) is initially operating with n resources and producing m products:

$$Y_1 = f(X_{11}, \ldots, X_{1n})$$

$$\vdots$$

$$Y_m = f(X_{m1}, \ldots, X_{mn}) \quad .$$

There is a price for each product and for each resource, which under assumptions of pure competition are fixed to the firms. The assumed objective of the firm is to maximize its profit function:

$$\text{Max.} \quad \pi = \sum_{i=1}^{m} P_{yi} Y_i - \sum_{i=1}^{m} \sum_{j=1}^{n} X_{ij} P_{xj} \ .$$

For the ith product, there are n partial derivatives equated to zero:

$$\frac{\partial Y_i}{\partial X_{i1}} = 0, \ \ldots, \ \frac{\partial Y_i}{\partial X_{in}} = 0.$$

If the m functions could be quantified, the X_{ij} magnitudes which coincide with the equilibrium of the firm at maximum profit could be found by solving the m sets of partial derivatives, each equated to zero.

If the firm is in equilibrium:

$$\frac{\frac{\partial Y_1}{\partial X_{11}} P_{Y1}}{P_{X_{11}}} = \frac{\frac{\partial Y_1}{\partial X_{12}} P_{Y1}}{P_{X_{12}}} = \ldots = \frac{\frac{\partial Y_1}{\partial X_{1n}} P_{Y1}}{P_{X_{1n}}} =$$

$$\frac{\frac{\partial Y_2}{\partial X_{21}} P_{Y2}}{P_{X_{21}}} = \frac{\frac{\partial Y_2}{\partial X_{22}} P_{Y2}}{P_{X_{22}}} = \ldots = \frac{\frac{\partial Y_2}{\partial X_{2n}} P_{Y2}}{P_{X_{2n}}} =$$

$$\ldots = \frac{\frac{\partial Y_m}{\partial X_{m1}} P_{Ym}}{P_{X_{m1}}} = \frac{\frac{\partial Y_m}{\partial X_{m2}} P_{Ym}}{P_{X_{m2}}} = \ldots = \frac{\frac{\partial Y_m}{\partial X_{mn}} P_{Ym}}{P_{X_{mn}}} .$$

That is for any product, the ratio of the marginal value product of any resource service to its price is equal to the ratio of the marginal value product of any other resource used by the firm to its price.

Associated with each X_j in the above system of production functions, there is a parameter α_{ij} which is the coefficient relating the particular X_j to the ith product, Y_i. A change in one or more of the α_{ij}'s will displace the equilibrium of the entire system.

Assume that one of the X_j's is the service from flood plain land, say X_1, and that the α_{i1}'s are the parameters or coefficients relating X_1 to the various Y_i's. The firm is initially in equilibrium. Now, if the level of flood protection is an exogenous variable which, when raised to another level, causes a rise in the productivity of the flood plain land, then the α_{i1}'s are all changed to a greater magnitude. The changes in these parameters set off a chain of adjustments which culminates in a new equilibrium position for the firm.

After the disturbance, i.e., an increase in the level of flood protection, the ratios of the

$$\frac{\frac{\partial Y_i}{\partial X_{i1}} P_{Y_i}}{P_{X_1}} \text{'s}$$

become greater than any other

$$\frac{\frac{\partial Y_i}{\partial X_{ij}} P_{Y_i}}{P_{X_j}},$$

therefore, in general, the services of flood plain land will be used more intensively until the equality of the ratios is again established. If there is a limitation on resource use, such as acreage restrictions, the services of flood plain land will be substituted for the services of other resources until the firm is in equilibrium.[9] This may result in more intensive use of flood plain land

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[9]Cf. Sune Carlson, A Study on the Pure Theory of Production, (New York, 1956), pp. 69-70.

accompanied by less intensive use of upland. But if there are no such restrictions on resources (or products) the firm may simply expand its total output by applying more non-land inputs to the flood plain land while its use of upland remains the same.

Graphical Representation of Flood Control Model

Resource development has been defined as investment for increasing the economic supply of land.[10] Examples of resource development as applied to agricultural land include investments in flood control and irrigation. Here, an increase in the economic supply of land refers to an increase in its productivity, where land is thought of as consisting of two components: its natural attributes and man made amendments thereto. The effect of flood protection on flood plain land use may be shown graphically.[11] Let the Y axis of Figure 1 represent units of output of a particular crop and the X axis represent a composite of all non-land inputs on flood plain land. AB is the production function before flood protection and A'B' is the function

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[10] W. B. Back, "Some Distributional Effects of Programs of Resource Development and Conservation of Agricultural Land," Oklahoma Agricultural Experiment Station, (Mimeo., 1961), p. 5.

[11] This graph is taken from the above cited manuscript by W. B. Back, who adapted it from the theory of the firm as presented by J. R. Hicks, Value and Capital, (London, 1946), Ch. VI.

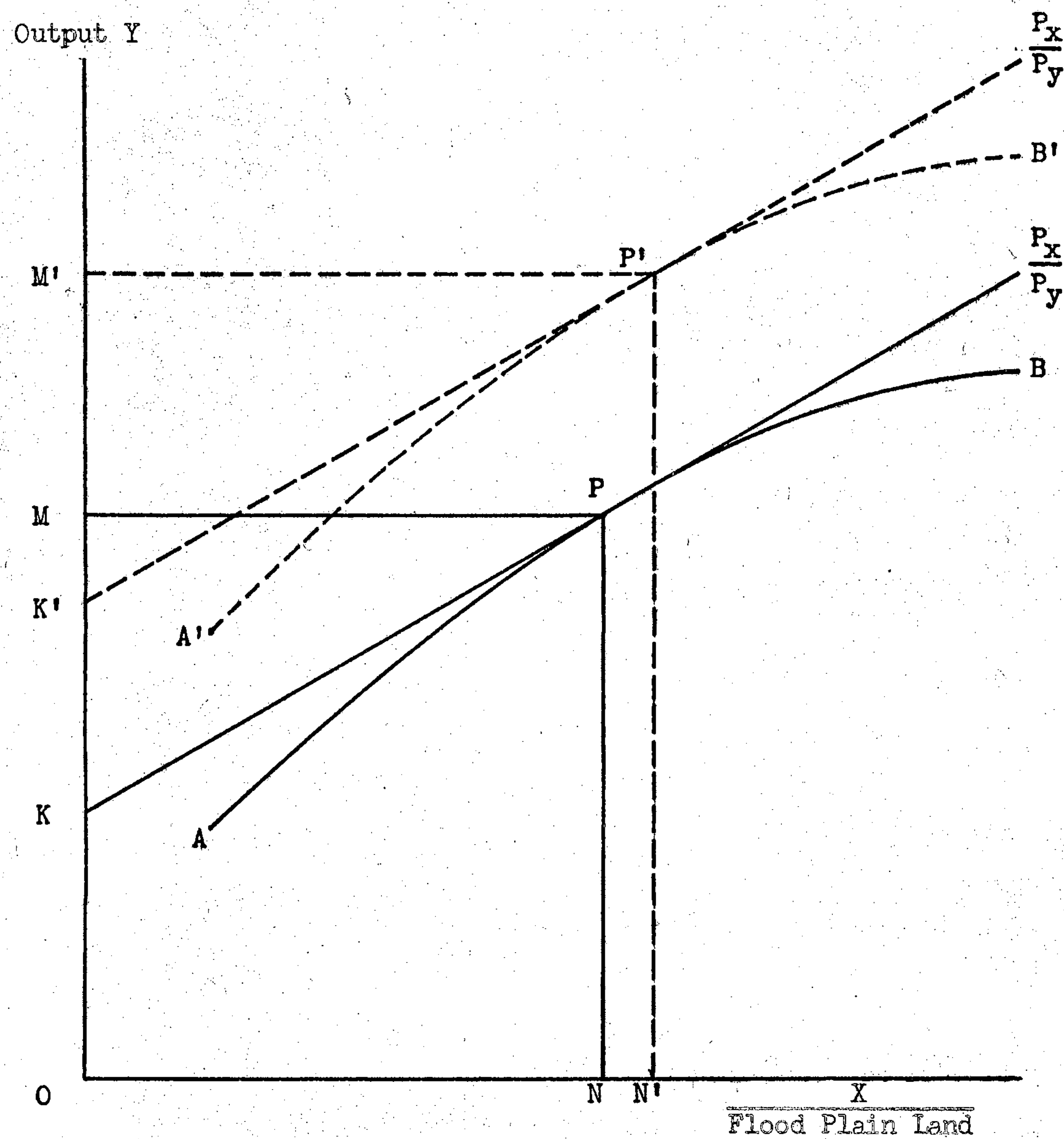

Figure 1. General Effects of Flood Control

after protection. The lines PK and P'K' represent the ratio of prices of inputs to prices of output. Maximum returns to land initially is obtained by applying ON units of non-land factors determined by dropping a perpendicular from the point of tangency of PK with the curve AB to the X axis. The distance OK represents the returns to land and MK the returns to non-land factors before flood prevention structures are installed. Corresponding elements in the new equilibrium after flood protection are the new production function A'B' and the new price line P'K'. Use of non-land factors increase from ON to ON'. Returns above cost of non-land factors increase from OK to OK', or by the increment KK'.

This illustration demonstrates the principal effects of increasing flood protection on flood-risk land with no change in land use: (1) a shift upward in the production function, (2) an increase in returns to land (or in the economic supply of land) and (3) an increase in intensity of use of non-land factors of production per acre of flood plain land.[12]

Levels of Flood Protection

Figure 2 is an extension of Figure 1 to illustrate

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[12]While (3) is probably the usual case, it is not necessarily so. Whether ON' > ON depends on the relative production elasticities of the two curves tracing out the respective productive relationships of non-land inputs to land at the two equilibrium positions.

six levels of flood protection. Y is output from any particular crop which can be produced on flood plain land. The production relationship curves A_1B_1 ... A_6B_6 are drawn progressively closer together to illustrate the hypothesis that diminishing returns can be expected at increasing levels of flood control intensity. This is also reflected in the decreasing increments to returns to land, $(OK_2 - OK_1) > (OK_3 - OK_2)$ ... etc. ON_1 is the magnitude of non-land inputs at the initial equilibrium and the successively larger values of ON at progressively higher equilibrium values illustrate the opportunity for intensifying the use of a given acreage of land as flood risk is reduced. This will also result in increased total returns to the non-land components of the production factors. An increase in the technical efficiency of a fixed factor (flood plain land in this case) can be expected to cause the output of non-fixed factors to rise:

> An increase in the technical efficiency of a variable productive service means an increase in its marginal productivity and a decrease in its cost-productivity ratio. ...... When it is a fixed service that has increased or decreased in efficiency the result will be very much the same. A more efficient plant will cause the output of a variable service to rise, which for a given volume of production means a lower total cost and an increased rate of return. It will also -- at least for a certain range of outputs -- cause the marginal productivity of the variable services to increase.[13]

[13]Carlson, pp. 69-70.

While the foregoing discussion was made by holding Y constant as returns from a particular crop, we can conclude that similar results will be experienced for any crop, and that there are differences between crops as to the magnitude of increases in the OK values, and the opportunities to intensify use of land. This is precisely what stimulates the shifting of land use within the farm in order to reach equilibrium at different levels of flood protection.

Effects of Flood Protection

With the foregoing general analysis of a watershed firm in equilibrium, the probable effects of flood protection can be isolated and discussed more specifically.

Assuming that initially the use of the flood plain land remains the same, the first effect of flood protection will be to raise the output per unit of input. This will raise the net returns to the farmer to the extent that the crops presently occupying the land are being damaged. This is because a greater total revenue is obtained from the increased output with no extra cost to the farmer.

A second effect can be isolated by reflecting that the reduction in flood risk not only raises flood plain productivity for the crops presently being planted on the flood plain, but also for all other crops that might be planted on flood plain land. It is likely that cash crops, or those crops upon which the farmer depends the most for his income, have not been planted on land subject to high flood risk, even though this land is more fertile than the uplands of the watershed. The percent increase in productivity of flood plain land will vary among the crops. The absolute potential increases in net returns from the higher value crops as measured in dollars may be much greater than corresponding increases in net returns from the lower value crops. This is because flooding tends to destroy similar proportions of the physical outputs of different crops on an acre basis. Since the dollar values of these proportions destroyed vary considerably as between high and low value crops, reduction in flood risk may increase the potential net returns much more for a high than for a low value crop. This difference in effects of flood protection among crops creates an imbalance in optimum use of the various classes of land making up the farm unit when protection is introduced. The effect of flood protection spreads to the other lands as the farm operator substitutes more intensive crops from the uplands to the flood plain, and replaces these crops on the uplands with less intensive crops. This substitution will end when the ratios of the marginal value products of each of the resources to their respective prices again become equal and a new equilibrium position is thus attained.

As has been pointed out above, it is not necessary that such substitution between different intensities of crops on upland and flood plain actually take place. As an alternative, the farmer might increase his acreages of intensive crops on flood plain land without reducing the intensive use of upland. But there are two limitations to this alternative. In the first place, acreage restrictions on more valuable crops will prevent expanding total acreages of these crops, and the substitution of less intensive crops on upland will necessarily follow if an intensive crop is moved to the flood plain. And, secondly, restrictions in the supply of labor or capital may also prevent a straight forward expansion of intensive crops on flood plain without a reduction in the intensity of use of upland.

For example, acreage allotments may have different effects on the changes in land use on two different farms.[14] Suppose a small farm has a cotton acreage allotment large enough to be an important source of income. Prior to flood protection, a part of the allotment is planted on upland because there is insufficient other bottom free from flood risk. If flood protection causes cotton to be more profitable on flood plain than on upland, and at the same time the increase in net returns on flood plain for cotton is greater than the increases from any alternative crop, cotton will be shifted to the flood plain. The vacated upland acres will then be occupied with less intensive crops simply because there is no other alternative. Expansion in

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[14]While it is true that acreage allotments present a special case, their influence is rather important on Boggy Creek and many other watersheds.

cotton acreage cannot take place because of the acreage restrictions.

On the other hand, if a large farm has a relatively small acreage allotment and there is sufficient bottom-land free from flood risk for this allotted acreage, there may be little or no change in land use following flood protection.

Irrigation Effects on Land Use and Organization

The analysis of the effects of irrigation on land use, net returns, and farm organization is the same in principle as the effects of flood protection. The firm is assumed to be initially in a state of equilibrium, and the introduction of water storage for irrigation purposes affects the parameters of the production functions of all crops which can be produced on the irrigable land of the farm. Shifts in the allocation of resource services can be expected to take place until a new equilibrium is achieved.

There are some conceptual differences in the irrigation model as compared with flood control. These differences have to do with the parameters, variables, and number of equations involved, as well as the working out of the process of reaching a new equilibrium. If it is assumed that the farm firm irrigates from the water impounded in the sediment pools only, the assumption that the disturbance factor is a variable exogenous to the firm can be retained. But this does not hold if the farmer enters a cost sharing agreement with the government to add increments to a dam for the purpose of storing more water. This, to the firm, is an internal decision and is in this sense an endogenous factor. However, this decision probably only amounts to a "yes" or "no," as the restrictions of engineering and other physical limitations probably hold the amount of additional storage water within a narrow range.

Assume the farm firm is initially in equilibrium with m production possibilities employing n resources. If X_{n+1} is irrigation water made available by watershed development, there will be a parameter α_{in+1} associated with the resource X_{n+1}, which relates irrigation water to the ith commodity. Thus, the addition of X_{n+1} to the set of X_j's disturbs equilibrium, not merely by changing a parameter as in the case of flood plain land, but also by the introduction of a new variable. In turn, this doubles the number of equations representing the production possibilities open to the firm. This is because it is theoretically possible to irrigate each crop, or not to irrigate. Therefore, for each Y_i there is a set of X_j's and α_{ij}'s associated with dryland production, and another set associated with irrigation.

The farmer will tend to restore equilibrium by using the services of each resource such that the ratio of the marginal value product of each resource to its price is equal to all other such ratios of resources employed. That is, even if enough irrigation water is physically available to irrigate all the farm, there is no need to assume that all (or any) crops will be irrigated. The increased costs associated with irrigation may be greater in some (or all) cases than the increased returns.

For each crop, a decision on whether to irrigate must be made. This is in contrast to flood protection which would result in an increase in net returns without a change from current land uses and production practices. Once a farm firm has decided to irrigate, the adjustments are likely to be of much greater magnitude than in flood protection. In addition to the investment for increasing the economic supply of land by paying for the additional water storage, a large outlay for capital is necessary in order to use the water.

Basically, there are two choices of irrigation systems in the area: flood irrigation, and sprinkler. In the case of flood irrigation, a rather large initial outlay for land leveling is often necessary. This investment in land leveling could be placed in the category with investment in water storage and considered as investment for increasing the economic supply of land. On the other hand, sprinkler systems require heavy outlays for pumps, pipe and sprinklers which must be depreciated out over a relatively few years.

Labor requirements are increased considerably, as well as other non-land inputs such as seed, fertilizer, insecticides, and additional wear and tear on tractors and other machinery (due to more intensive seed-bed preparation and cultivation). Also, a higher level of management is required.

The higher valued crops on irrigable land will tend to receive most of the entrepreneur's efforts and attention, and the non-irrigable lands may shift to even less intensive farming. In a watershed, such as Boggy Creek, where some of the higher value crops, such as cotton and wheat, are restricted by acreage allotments, opportunities to take advantage of the irrigation potential will differ sharply between farms possessing different sizes of allotment as well as amounts of irrigable land.

Marginal Analysis and Linear Programming

Basically, there is no essential difference in principle between the analysis of the more traditional economics of marginal concepts, with continuous production functions and cost curves, and the more recent linear economics. When applied to a single firm, both methods may assume profit maximization as a guiding principle.

The major difficulty in the use of conventional marginal analysis in estimating effects of watershed development is the problem of obtaining the data for this kind of analysis. If certain simplifying assumptions of linear relationships between the input-output variables over relevant ranges can be accepted, linear programming is an operational technique. Linear relationships can be estimated from average input-output coefficients. A maximizing (or minimizing) goal can be assumed for solving a set of linear equations simultaneously.

The transition from the marginal analysis to linear economics only requires a new way of looking at the same set of relationships. It simply involves a change from the infinite to the finite. Emphasis now is upon a production process instead of the production function. A process can be loosely defined simply as a way of doing something to achieve an objective. In production, it is a means of producing by holding all factors of production in constant proportion, allowing the output to vary only with the level of the activity.

In a graph depicting a process with only two inputs, a straight line extending from the origin to infinity would represent a process. Each time the proportions of the inputs are changed, another straight line process is generated. These are called rays or vectors (Figure 3). The optimum is achieved by selecting those processes which yield the greatest profit within the restraints of the available resources.

In applying linear programming to the model of the individual watershed firm, the input-output relationships of the various crop and livestock enterprises constitute the vectors. These can be physically specified and prices applied, thus making the analysis operational.

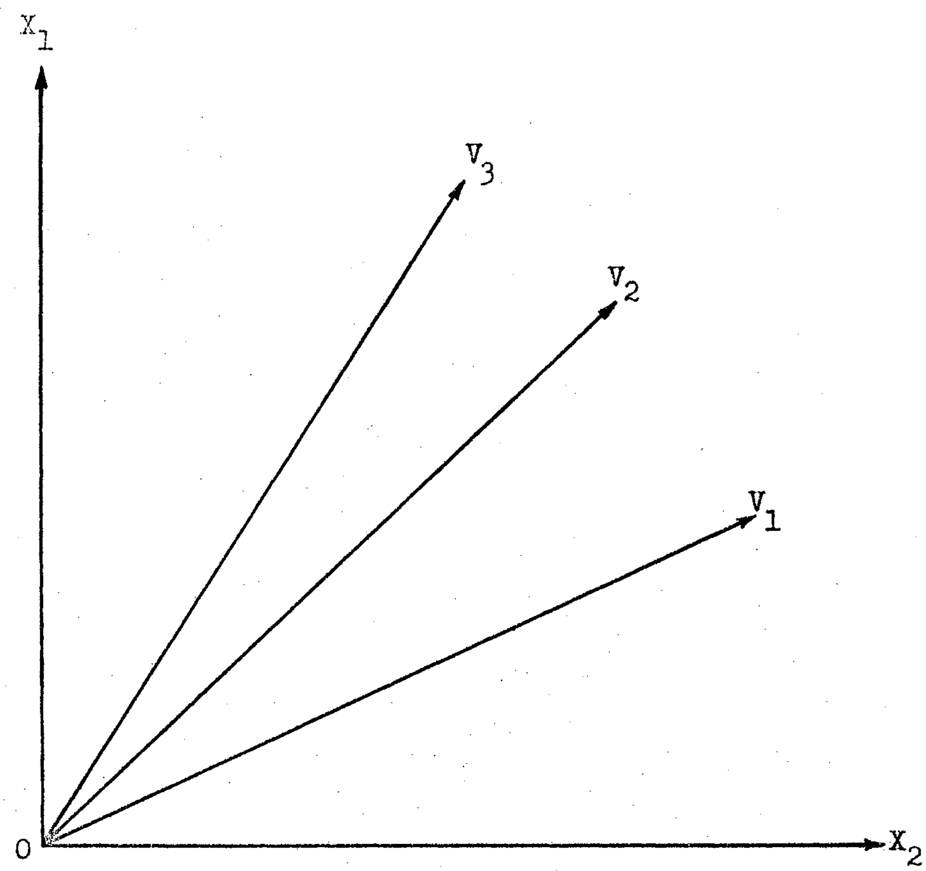

Figure 3. Examples of Vectors

Empirical Procedure

The Construction of the Budgets

The basic budgets require input and output estimates of enterprises at some particular "benchmark" situation. The basic budgets for both the flood control and the irrigation phases of the study are defined as the set of relationships which would exist if there was no danger from flooding.

Data for developing the budgets were obtained primarily from three main sources: (1) A sample of farms in the watershed, (2) agricultural scientists at the following places: Oklahoma State University Experiment Station, State Extension Service personnel, agricultural workers of the Extension Service, Farmers Home Administration, and Soil Conservation Service in eight counties along the Washita River, and (3) the Soil Conservation Planning Party for watershed projects located at Chickasha, Oklahoma.

The data from the sample of watershed farms provided the basic information for constructing the budgets, but many details, such as prices, costs, techniques, and yields, were modified and supplemented from the other sources mentioned above.

Price and cost data were based on approximate current prices and costs for inputs (Appendix Tables I-IV). Costs of machinery included oil, grease, lubrication, repairs, and depreciation due to use. The inclusion of depreciation as a variable cost was on the assumption that machinery would wear out before it became obsolete.

The basic budgets are on a unit basis (Appendix Tables XI-XXVIII). For example, in the case of crop budgets, the unit is an acre of land; in a cow-calf program, the unit is a beef cow and in a feeder operation, the unit is a steer. Budgets specify the physical relationships of inputs to outputs, apply prices to quantities, and show the net returns per unit.

Land Resources

Knowledge of land resources available to the firm was obtained by developing four typical farms to represent the watershed. All cropland was made available for the uses in the linear programming matrix, that is, no provision was made for the land treatment measures presupposed by the Soil Conservation Service such as hay or pasture rotations. However, the uses programmed did not preclude certain treatment measures, such as contour farming, terracing, subsoiling, grassed waterways, etc.

Selection and Description of the Processes

Although it is true that the conceptual number of farming possibilities, or processes, may be infinite in a given watershed, from a practical standpoint, it is only necessary to consider a relatively few alternatives. The criterion used in this study was to select only those enterprises currently active on Boggy Creek.

Cropping Alternatives. The watershed is essentially a cash crop area with wheat the leader, followed by cotton, barley, grain sorghum, alfalfa and a small acreage of other small grains and miscellaneous crops. Some hay and sorghum forage are also grown to support the livestock enterprises.

The basic budgets for the cropping alternatives are in Appendix Tables XI-XXII. These include wheat, cotton, alfalfa, grain sorghum, barley, oats, forage sorghum, small grain hay, sudan grass, Johnson grass, small grain pasture, and re-seeding upland pasture. Alfalfa is considered a cash crop. The programming model gives farmers the alternative of producing or buying hay for their beef cattle enterprises.

Since the objective of the study was to measure the effects of different levels of flood protection under average technology,[15] and not to determine optimum levels of production, it was only necessary to program one method of

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[15]Average technology is here defined as an average of the level of management and input-output relationships experienced by farmers in the Washita River basin. These average practices and input-output relationships were assumed in constructing the budgets. They were primarily based on a 1960 survey of agricultural workers in eight Washita River Basin counties, but were supplemented by data from other studies by the Agricultural Economics Department at Oklahoma State University.

production (or process) for each crop.

Livestock Alternatives. Two cow-calf enterprises and four steer enterprises were used in the analyses. One cow-calf enterprise (Appendix Table XXIII) provided for fall calving and selling good-choice feeder calves in June. The other cow-calf enterprise (Appendix Table XXIV) was spring calving and selling good-choice feeder calves in the fall.

The feeder-cattle enterprises (Appendix Tables XXV-XXVIII) were all fall buy, with selling dates ranging from March to October the following year. The cattle enterprises were selected to provide opportunities to use all the various pasture and forage crops in the programming analysis. In addition to the crop and livestock alternatives, transfer activities for hiring labor, buying hay, and borrowing capital were built into the model.

Procedure for Estimating Equilibrium Positions

The estimates of changes in net returns for computing the different equilibrium positions of the flood protection phase of the study were obtained by applying average damage factors to the basic budgets (Appendix Tables VI-VII). The estimates of changes in net returns for computing the different equilibrium positions of the irrigation phase of the study were obtained by preparing a set of budgets for irrigated crops (Appendix Tables XXXI-XXXIV). These were added to the technology matrix, or system of linear equations, and allowed to compete with dry land budgets for use of bottomland.

The water added a new resource to the matrix. This resource served as a parameter for any equilibrium position at a given level of water. Equilibrium was disturbed by changing the water level, or that is, by changing a parameter as under the flood control phase.

For the flood control phase, the problem was to determine the optimum allocation of the limited resources in the Boggy Creek watershed at varying levels of economic reorganization due to the impact of a flood control project. The Soil Conservation Service personnel actually only planned one level (36 structures), but by additional computations, they provided data for two other levels of flood protection at 10 and 20 structures (as well as acre feet and costs for adding irrigation storage to 10 structures). When present condition (no flood protection), land treatment, and complete protection were added, there was a total of six levels. A program was required for each farm at each level. Since there were four farm types, there were 24 programs for the flood control phase.

In the irrigation phase, four levels of irrigation under "no flooding" was selected as the benchmark situation. There were 12 programs in addition to the flood control phase, for a total of 36 programs.

This chapter has been devoted to the development of conceptual models and a brief account of the nature of the empirical methods devised to accomplish the purposes of the study. The following two chapters will contain the empirical procedure in more detail and the results of the analysis of flood control and irrigation.

CHAPTER III

POTENTIAL FARMING ADJUSTMENTS AND INCOME ASSOCIATED WITH DIFFERENT LEVELS OF FLOOD PROTECTION

The purpose of this chapter is to describe in more detail the methodology, and to present the results of the flood control phase of the study. The results presented emphasize land uses and incomes on selected individual farms for varying degrees of flood protection, and the changes in farm income attributable to (a) reductions of damages to crops and (b) changes in land use.

Defining the Typical Farms

Information relating to land resources, machinery, livestock, and crop enterprises as needed for making the analysis was obtained from a sample of the farms in the watershed with flood plain land. Since it seemed logical that the impact of flood control on an individual farmer's adjustment would be affected by the relative amounts of bottomland and upland on his farm, the 26 farms were divided into four classes on the basis of bottomland and upland as follows:

Upland	Bottomland: 120 acres or less	Bottomland: More than 120 acres
240 acres or less	I (7 farms)	III (6 farms)
More than 240 acres	II (7 farms)	IV (6 farms)

Four "typical farms" were then obtained by using the averages of land resources for each of the four classes (Table I). Aggregation totals for the watershed may be made by using the formula:

$$\sum_{i=1}^{4} \frac{1}{f_1 f_2} X_i$$

where X_i = quantity of a characteristic on the ith typical farm

f_1 = the fraction that the ith farm type is of its class, and

f_2 = the fraction which the sample of 26 farms is of the entire watershed.

Since the degree of confidence in such an aggregation depends on the degree of homogeneity of resource attributes within classes, and since more than four "typical" farms may be necessary for any great confidence in the aggregates for the watershed, the aggregation in this study is mainly for the purpose of demonstrating the method as a possible procedure in watershed evaluation. One way to insure a higher degree of homogeneity within classes would

TABLE I

LAND RESOURCES OF TYPICAL FARMS, BOGGY CREEK, (ACRES)

Item	Farm I	Farm II	Farm III	Farm IV
Cropland, Total	125	353	275	475
Flood Plain	33	40	113	110
Other Bottomland	25	31	85	83
Upland	67	282	77	282
Other Land, Total	47	208	69	267
Rangeland	40	180	52	230
Other[a]	7	28	17	37
Total Acres in Farms Represented	172	561	344	742
Number of Farms in Watershed	17	17	15	15

[a]Farmstead, roads, wasteland, etc.

be to increase the number of "typical" farms.

Developing the Damage Factors

The Soil Conservation Service supplied data for developing damage factors by crops and depth of flooding, and by "flood routings."[1]

The average annual damage was calculated by assuming that the entire flood plain was planted to a particular crop, and by applying the damage factors to an acre in the flood plain assumed to be subject to average flooding hazards (sometimes called a "floating" acre) (Appendix Table VI). This was repeated for each of the crops used in the analysis. This gross damage factor was corrected by a formula developed by the Soil Conservation Service which allows some crop recovery between floods.[2]

More explicitly, the annual damage factor, D_a, for a particular crop A is:

$$D_a = Y\left[\frac{1}{X} \sum_{h=1}^{L} \sum_{i=1}^{N_h} \sum_{j=1}^{hi} P_{hij} X_{hij}\right]$$

[1]A flood routing is an estimate of acres flooded by floods and by depths over a period of time. In this study, the period was the 20 years of 1938-1957. Implicit in the study was the assumption that flooding during this period was representative of what might be expected in any other 20 year period and that the results thus have predictive validity.

[2]Soil Conservation Service, Economics Guide For Watershed Protection and Flood Prevention (Washington, D.C., 1958), Chap. 3, p. 28.

where

$Y = \frac{1}{.7706 + .2387Z}$ is the correction factor used by the Soil Conservation Service to allow for recovery of crops between floods,

Z = X divided by the sum of the areas flooded by the largest flood each year in the period,

L = Number of years in period,

N = Number of floods in period,

X = Total number of acres flooded in period,

P = Percent of acres of crops destroyed

and the subscripts h, i, and j refer to year, flood, and depth of flood, respectively.

The damage factors were used to calculate net returns at the different levels of flooding by applying them to the budgets for crops on bottomland without flooding (Appendix Table VII). The budgets for crops on bottomland (without flooding) and on upland are in Appendix Tables XI-XXII.

Programming Procedure

Linear programming was used to calculate optimum resource allocations and net returns from each of the four typical farms at the following levels of flood protection:

(1) present condition, (2) land treatment only; and land treatment with (3) 10 structures, (4) 20 structures, (5) 36 structures, and (6) no flooding.

The structures for levels 3 and 4 were judged to be the first 10 and the first 20 most effective for flood protection. The 36 structures of level 5 were the total structures planned for the project. The 6th level of "no flooding" programmed from the "basic budgets" is a hypothetical "complete protection" level of flood control.

The "benchmark" situation, or present condition, was defined as the programmed average net incomes of farmers and the allocations of their resources when subjected to the hazards of flooding without any protection. The assumption underlying this definition is that the farmer will act as if each year's outcome with respect to flood risk is equally likely. Adjustments from the present individual farm resource uses that would be profitable without flood protection are excluded as effects of flood protection. Whether any of these adjustments could be attributed to flood protection is discussed in a later section.

The enterprises programmed were the principal land uses in the watershed at present (Table II). Wheat and cotton were restricted to present acreage allotments as based on the averages of the farms surveyed. Alfalfa was restricted to five-eighths of the bottomland on the assumption that a stand normally cannot be maintained more than

TABLE II

PRESENT USE OF CROPLAND BY FARMS AND BY KINDS OF LAND, BOGGY CREEK (ACRES)[a]

Crop or Other Use	Farm I			Farm II			Farm III			Farm IV		
	Bottom-land	Up-land	Total	Bottom-land	Up-land	Total	Bottom-land	Up-land	Total	Bottom-land	Up-land	Total
Wheat	20	35	55	30	142	172	63	47	110	129	149	278
Barley	3	7	10	6	46	52	6	11	17	10	70	80
Cotton	8	5	13	6	34	40	22	3	25	6	8	14
Grain Sorghum	2	5	7	1	13	14	4	0	4	0	5	5
Alfalfa	6	0	6	14	0	14	12	0	12	2	0	2
Small Grain Grazing	0	0	0	0	10	10	0	0	0	0	0	0
Cropland Used as Pasture	4	0	4	7	0	7	40	0	40	18	0	18
Other[b]	15	15	30	7	37	44	51	16	67	28	50	78
Total	58	67	125	71	282	353	198	77	275	193	282	475

[a]Determined by averaging the land uses for the farms in each class.

[b]Includes forage sorghum, sudan hay, oats hay, Johnson grass hay, rye, cover crops, millet hay, conservation reserve, fallow and idle cropland, temporary pasture, etc.

about five out of eight years.

Conservation reserve or soil bank activities were not programmed. Livestock enterprises other than beef were of such minor importance in the watershed that they were excluded.

On the basis of the data from the survey, two-plow equipment was programmed for the smaller farms (farms I and III), and four-plow equipment for the farms with larger acreages (farms II and IV).

Interest on operating capital, and on fixed capital other than land was charged at an annual rate of 6 percent. Operating capital included annual costs for items such as seed, fertilizer, insecticides, and hired labor. Interest was charged on operating capital only for that portion of the year that such capital was needed. Fixed capital included outlays for machinery and equipment, livestock, and other items with more than a year of productive life. Interest on investment in fixed capital was charged against average annual value.

The programming procedure allowed hay to either be produced or bought, and labor to be hired when requirements exceeded the family labor supply. All crops were assumed to be custom harvested with the exception of cotton, which was assumed to be one-half custom harvested and one-half hand picked.

Results of Programming Analysis

Land Use

Cotton, wheat, alfalfa, grain sorghum, small grain grazing and barley were the only crops appearing in the final programmed solutions for any of the farms (Tables III-VI). The variations of cotton and wheat allotments generally account for the differences in land uses among the farms. Farm IV, the largest of the farms, had a small cotton allotment and a large wheat allotment. Farm II had relatively large allotments of both wheat and cotton.

Of crops other than cotton and wheat, alfalfa was predominant on the bottomland for all farms. Before flood protection, grain sorghum, small grain grazing, and barley used some of the flood plain land, but as the flood damage was reduced these were replaced by wheat, cotton, and alfalfa.

With no flood protection, much of the flood plain land was occupied by wheat and alfalfa. Wheat was especially dominant on flood plain land for Farm III (with a small amount of upland), and on Farm IV with the large wheat allotment. This was true for all levels of protection. Cotton was programmed on flood plain land only as the danger of flooding was removed by more intensive flood protection.

The changes in land use with increase in flood protection for each of the farms are summarized in Table VII.

TABLE III

PROGRAMMED USE OF CROPLAND BY KINDS OF LAND AND LEVELS OF FLOOD PROTECTION, FARM I (ACRES)

Level of Protection and Kind of Land	Cotton	Wheat	Alfalfa	Grain Sorghum	Small Grain Grazing	Barley	Total
None							
Flood Plain	0	4	21	0	8	0	33
Other Bottom	10	0	15	0	0	0	25
Upland	3	51	0	13	0	0	67
Total	13	55	36	13	8	0	125
Land Treatment Only							
Flood Plain	0	4	21	0	8	0	33
Other Bottom	10	0	15	0	0	0	25
Upland	3	51	0	13	0	0	67
Total	13	55	36	13	8	0	125
Ten Structures							
Flood Plain	3	9	21	0	0	0	33
Other Bottom	10	0	15	0	0	0	25
Upland	0	46	0	9	12	0	67
Total	13	55	36	9	12	0	125
Twenty Structures							
Flood Plain	3	9	21	0	0	0	33
Other Bottom	10	0	15	0	0	0	25
Upland	0	46	0	9	12	0	67
Total	13	55	36	9	12	0	125
Thirty-Six Structures							
Flood Plain	3	9	21	0	0	0	33
Other Bottom	10	0	15	0	0	0	25
Upland	0	46	0	9	12	0	67
Total	13	55	36	9	12	0	125
Complete Protection							
Flood Plain	3	9	21	0	0	0	33
Other Bottom	10	0	15	0	0	0	25
Upland	0	46	0	9	12	0	67
Total	13	55	36	9	12	0	125

TABLE IV

PROGRAMMED USE OF CROPLAND BY KINDS OF LAND AND LEVELS OF FLOOD PROTECTION, FARM II (ACRES)

Level of Protection and Kind of Land	Cotton	Wheat	Alfalfa	Grain Sorghum	Small Grain Grazing	Barley	Total
None							
Flood Plain	0	0	25	16	0	0	41
Other Bottom	11	0	19	0	0	0	30
Upland	29	172	0	0	42	39	282
Total	40	172	44	16	42	39	353
Land Treatment Only							
Flood Plain	1	15	25	0	0	0	41
Other Bottom	11	0	19	0	0	0	30
Upland	28	157	0	0	46	51	282
Total	40	172	44	0	46	51	353
Ten Structures							
Flood Plain	5	11	25	0	0	0	41
Other Bottom	11	0	19	0	0	0	30
Upland	24	161	0	0	45	52	282
Total	40	172	44	0	45	52	353
Twenty Structures							
Flood Plain	7	9	25	0	0	0	41
Other Bottom	11	0	19	0	0	0	30
Upland	22	163	0	0	45	52	282
Total	40	172	44	0	45	52	353
Thirty-Six Structures							
Flood Plain	8	8	25	0	0	0	41
Other Bottom	11	0	19	0	0	0	30
Upland	21	164	0	0	45	52	282
Total	40	172	44	0	45	52	353
Complete Protection							
Flood Plain	16	0	25	0	0	0	41
Other Bottom	11	0	19	0	0	0	30
Upland	13	172	0	63	34	0	282
Total	40	172	44	63	34	0	353

TABLE V

PROGRAMMED USE OF CROPLAND BY KINDS OF LAND AND LEVELS OF FLOOD PROTECTION, FARM III (ACRES)

Level of Protection and Kind of Land	Cotton	Wheat	Alfalfa	Grain Sorghum	Small Grain Grazing	Barley	Total
None							
Flood Plain	0	25	71	0	17	0	113
Other Bottom	25	7	53	0	0	0	85
Upland	0	77	0	0	0	0	77
Total	25	109	124	0	17	0	275
Land Treatment Only							
Flood Plain	0	25	71	0	17	0	113
Other Bottom	25	7	53	0	0	0	85
Upland	0	77	0	0	0	0	77
Total	25	109	124	0	17	0	275
Ten Structures							
Flood Plain	0	25	71	0	17	0	113
Other Bottom	25	7	53	0	0	0	85
Upland	0	77	0	0	0	0	77
Total	25	109	124	0	17	0	275
Twenty Structures							
Flood Plain	0	25	71	0	17	0	113
Other Bottom	25	7	53	0	0	0	85
Upland	0	77	0	0	0	0	77
Total	25	109	124	0	17	0	275
Thirty-Six Structures							
Flood Plain	0	42	71	0	0	0	113
Other Bottom	25	7	53	0	0	0	85
Upland	0	53	0	0	24	0	77
Total	25	102	124	0	24	0	275
Complete Protection							
Flood Plain	0	42	71	0	0	0	113
Other Bottom	25	7	53	0	0	0	85
Upland	0	53	0	0	24	0	77
Total	25	102	124	0	24	0	275

TABLE VI

PROGRAMMED USE OF CROPLAND BY KINDS OF LAND AND LEVELS OF FLOOD PROTECTION, FARM IV (ACRES)

Level of Protection and Kind of Land	Cotton	Wheat	Alfalfa	Grain Sorghum	Small Grain Grazing	Barley	Total
None							
Flood Plain	0	41	69	0	0	0	110
Other Bottom	14	17	52	0	0	0	83
Upland	0	220	0	0	60	2	282
Total	14	278	121	0	60	2	475
Land Treatment Only							
Flood Plain	0	41	69	0	0	0	110
Other Bottom	14	17	52	0	0	0	83
Upland	0	220	0	0	60	2	282
Total	14	278	121	0	60	2	475
Ten Structures							
Flood Plain	0	41	69	0	0	0	110
Other Bottom	14	17	52	0	0	0	83
Upland	0	220	0	0	60	2	282
Total	14	278	121	0	60	2	475
Twenty Structures							
Flood Plain	0	41	69	0	0	0	110
Other Bottom	14	17	52	0	0	0	83
Upland	0	220	0	0	60	2	282
Total	14	278	121	0	60	2	475
Thirty-Six Structures							
Flood Plain	0	41	69	0	0	0	110
Other Bottom	14	17	52	0	0	0	83
Upland	0	220	0	0	60	2	282
Total	14	278	121	0	60	2	475
Complete Protection							
Flood Plain	0	41	69	0	0	0	110
Other Bottom	14	17	52	0	0	0	83
Upland	0	220	0	3	59	0	282
Total	14	278	121	3	59	0	475

The shifts in land use reflect different pressures from wheat and cotton allotments among farms with different land resource situations. For example, on Farm II, the pressure of the relatively large wheat allotment caused wheat to shift to the flood plain land at the "land treatment only" level of protection and a corresponding shift out of grain sorghum production. At the next level of protection (10 structures), there was a further change in land use on Farm II with cotton replacing some wheat on the flood plain. For Farm I, some small grain grazing on the flood plain was replaced with wheat and cotton with the flood protection of 10 structures, but there were no further changes with succeeding levels of protection. Cotton continued to move to the flood plain with increases in levels of flood protection on Farm II. There were no changes in use of the flood plain on Farm III until 36 structures were installed. At this point, 17 acres of wheat moved in from upland to replace the 17 acres of small grain grazing which, in turn, moved to the upland. An additional seven acres of the wheat allotment on the upland was replaced by small grain grazing. This latter change reflected a higher productivity of this marginal acreage for small grain grazing than for wheat on Farm III. However, as a practical matter, farmers could be expected to plant their wheat acreage allotments in order not to risk future reduction in their allotments. Land use on Farm IV was not changed at any of the levels of flood protection.

In all cases, the increased intensity of flood plain land use with flood protection was associated with a decrease in the intensity of upland use. For example, as cotton replaced wheat on the flood plain, wheat took the acreage vacated by cotton on upland. This is simply a reallocation of land use by the same crops among classes of land. Of course, this might be expected since the two major cash crops are fixed by allotment.

The flood plain land was divided into land subject to flooding and land not subject to flooding in order to permit a determination of changes in uses of these two subclasses of land at increasing levels of flood protection. The cumulative change in use of this land to the protection provided by 36 structures, by subject and not subject to flooding, is presented in Table VIII.

For each of the farms, about one-half of the initial flood plain land shifted into the "not subject to flooding" class at this level of protection. Also, the remaining land subject to flooding had less flood risk than initially. For Farm I, cotton and wheat replaced small grain grazing with flood protection, but the added cotton occupied the "not subject to flooding" flood plain. A similar change in use occurred for Farm II; wheat and cotton replaced grain sorghum, but the cotton was programmed on the land "not subject to flooding". Alfalfa acreage on flood plain land did not change for either of the farms with the change in level of flood protection. However, with the

TABLE VIII

PROGRAMMED CHANGE IN USE OF FLOOD PLAIN LAND FROM NO PROTECTION TO 36 STRUCTURES, BY SUBJECT AND NOT SUBJECT TO FLOODING (ACRES)

Farm and Crop	Use, No Flood Protection	Change in Use to 36 Structures: Total	For Land: Subject to Flooding	For Land: Not Subject to Flooding
Farm I				
Cotton	0	+ 3	0	+ 3
Wheat	4	+ 5	+ 3	+ 2
Alfalfa	21	0	-11	+11
Small Grain Grazing	8	- 8	- 8	0
Total	33	0	-16	+16
Farm II				
Cotton	0	+ 8	0	+ 8
Wheat	0	+ 8	+ 8	0
Alfalfa	25	0	-12	+12
Grain Sorghum	16	-16	-16	0
Total	41	0	-20	+20
Farm III				
Wheat	25	+17	- 4	+21
Alfalfa	71	0	-35	+35
Small Grain Grazing	17	-17	-17	0
Total	113	0	-56	+56
Farm IV				
Wheat	41	0	-20	+20
Alfalfa	69	0	-34	+34
Total	110	0	-54	+54

level of protection afforded by 36 structures, the alfalfa acreage divided about equally between the subject and not subject to flooding portions of the flood plain for each of the farms.

The programmed land uses of individual farms show large acreages of alfalfa on both flood plain and other bottomland (Tables III-VI, pp. 49-52). This is the major change in land use from the way farmers in the watershed presently are using these lands. The price of $23.33 per ton may inadequately account for market uncertainty as viewed by the farmers. However, the results indicated that about the same acreages of alfalfa would be planted even if the price dropped to about $19 per ton (assuming the other product prices remained the same). Such a drop in price would lower net income attributable to flood control, but it would not necessarily affect the uses of land. A price of alfalfa below $19, with other prices remaining unchanged, would permit crops such as grain sorghum, small grain grazing, and barley to occupy the flood plain and other bottomland not used for the wheat and cotton allotments. This would result in much lower estimates of income attributable to flood control than those obtained in this analysis. However, the general relation of income to degrees of flood protection would be the same without alfalfa as a major use of bottomland.

Livestock Enterprises

Except for Farm I, both cow-calf and feeder enterprises were programmed for each of the farms (Table IX). The cow-calf enterprises were so small that it is not likely that farmers would choose exactly the combinations of livestock that were programmed. They probably would specialize in either cow-calf herds or in feeder cattle. In this case, there would be less income than estimated in the programs since these particular combinations represent maximum efficiency in the utilization of range and forage production under the assumed inputs and outputs of the budgets.

Increasing the levels of flood protection had little influence on the numbers of livestock programmed. Farm II would reduce livestock and emphasize cash crops if flood damage could be completely eliminated. Otherwise, the reduction of flooding made little difference in the production of grass and forage which, in turn, would have affected the numbers of livestock.

The programmed initial livestock numbers compared with those actually on farms are as follows:

	Total Number on Four "Typical" Farms -- (1960)	Number Programmed for the Four "Typical" Farms -- (Present Flooding Condition)
Beef Cows	47	17
Steers	71	204
(Animal Units)	(84)	(119)

TABLE IX

LIVESTOCK ENTERPRISES PROGRAMMED BY FARMS AND BY LEVELS OF FLOOD PROTECTION

Farm and Enterprise	Unit	Level of Flood Protection: Present Condition	Land Treatment	Ten Structures	Twenty Structures	Thirty-Six Structures	Complete Protection
Farm I							
Feeders[a]	Number	26	26	27	27	27	27
Farm II							
Cow-Calf[b]	Cow Units[d]	11	11	11	11	11	12
Feeders[c]	Number	60	65	65	65	65	49
Farm III							
Cow-Calf[b]	Cow Units[d]	3	3	3	3	3	3
Feeders[c]	Number	32	32	32	32	34	34
Farm IV							
Cow-Calf[b]	Cow Units[d]	14	14	14	14	14	14
Feeders[c]	Number	86	86	86	86	86	85

[a]About half of feeders to be purchased in September, winter on cotton seed cake and hay, summer graze, sell in July; the other half to be purchased in October, wintered on hay and sold in May.

[b]Calving in February, non-creep feeding, sell good to choice feeder calves in September; cows wintered on cotton seed cake and hay, summer on range.

[c]Buy in October, winter on hay and sell in May.

[d]Cow-units are numbers of cows in the herd that also includes a bull to each 25 cows and the calves during spring and summer.

Fewer beef cows, but a greater number of steers, were programmed than actually were on the farms. When the numbers of cattle were converted to animal units, the actual livestock population in the watershed was 70 percent of that programmed.

Resource Requirements and Income in Relation to Levels of Flood Protection

Resource requirements and income changes with changes in levels of flood protection are summarized in Table X. Generally, gross and net income for all farms increased at all levels of protection with the largest increment occurring when 10 structures were added to land treatment only. The variation in increments to incomes among farms was directly associated with the amounts of bottomland per farm; thus, farms III and IV, with the greater amounts of bottomland, experienced the greater increases in net income due to increases in flood protection.

Labor requirements and non-land capital investments changed insignificantly for each of the farms with increase in flood protection. Neither of the four farms had a labor requirement equivalent to an operator year of employment of about 2300 hours, and the labor requirement was less than half of a man year for Farm I. However, since labor required was distributed unevenly over the year, some labor was hired during peak seasons for each of the farms (Appendix Table VIII).

TABLE X

PROGRAMMED RESOURCE REQUIREMENTS AND FARM INCOME BY LEVELS OF FLOOD PROTECTION AND BY FARMS

Farm and Item	Level of Protection: None (Present Conditions)	Land Treatment Only	Ten Structures	Twenty Structures	Thirty-six Structures	Complete Protection
Farm I						
Labor, hours	820	823	843	842	842	842
Nonland Capital, dollars	6,063	6,087	6,241	6,241	6,243	6,243
Gross Income, dollars	9,344	9,365	9,959	10,056	10,113	10,325
Annual Costs, dollars	5,888	5,862	6,258	6,287	6,307	6,369
Net Income, dollars	3,456	3,504	3,701	3,769	3,806	3,956
Change in Net Income						
From No Protection, dollars	-	48	245	313	350	500
From Preceding Level, dollars	-	48	197	68	37	150
Farm II						
Labor, hours	1,637	1,637	1,673	1,687	1,700	1,730
Nonland Capital, dollars	15,957	15,892	16,581	16,006	16,618	16,624
Gross Income, dollars	22,093	22,804	23,241	23,397	23,476	21,905
Annual Costs, dollars	13,533	14,208	14,393	14,459	14,497	12,591
Net Income, dollars	8,560	8,596	8,848	8,938	8,979	9,314
Change in Net Income						
From No Protection, dollars	-	36	288	378	419	754
From Preceding Level, dollars	-	36	252	90	41	335
Farm III						
Labor, hours	1,682	1,683	1,682	1,681	1,686	1,683
Nonland Capital, dollars	10,865	10,914	10,942	10,940	11,150	11,150
Gross Income, dollars	18,690	18,809	19,756	20,075	20,474	21,240
Annual Costs, dollars	10,389	10,391	10,692	10,791	11,078	11,304
Net Income, dollars	8,321	8,418	9,064	9,284	9,396	9,900
Change in Net Income						
From No Protection, dollars	-	97	743	963	1,075	1,579
From Preceding Level, dollars	-	97	646	220	112	504
Farm IV						
Labor, hours	1,750	1,750	1,748	1,748	1,743	1,743
Nonland Capital, dollars	22,621	22,594	22,416	22,592	22,591	22,462
Gross Income, dollars	31,909	32,037	33,066	33,327	33,491	34,078
Annual Costs, dollars	19,245	19,275	19,645	19,679	19,732	19,827
Net Income, dollars	12,664	12,763	13,421	13,648	13,759	14,251
Change in Net Income						
From No Protection, dollars	-	99	757	984	1,095	1,587
From Preceding Level, dollars	-	99	658	227	111	492

Net Income Changes by Sources[3]

The net farm income increases with changes in degree of flood protection arise from two sources: (1) reduction in flood water damage to crops, and (2) reallocation of land uses among kinds of land, or changes in land use, with flood protection. These two sources of income change were estimated for the individual farms (Table XI).

The major contributor to the net income increase for each of the farms was reduction in flood water damage. This component accounted for all the increment in income to Farm IV, and almost 90 percent of the increase in farm income to Farm III at the level of protection afforded by 36 structures. The income increase attributable to change in land use was of considerable significance for Farms I and II. Farm III experienced no change in land use, or income attributable to this source, until protected from flooding with 36 structures. The changes in income due to land use changes were a net of two effects: (1) the increase in intensity of flood plain land use, and (2) any accompanying decrease in intensity of upland use.

Uncertainty Considerations

In view of the large acreage of alfalfa programmed for flood plain land as compared to that which is actually being planted, a hypothesis that uncertainty due to risk from flooding is causing the flood plain land to be occupied

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[3]Net income is returns to land, family labor and management.

TABLE XI

ESTIMATES OF NET INCOME CHANGE DUE TO REDUCTION IN FLOODWATER DAMAGE TO CROPS AND TO CHANGE IN LAND USE, BY FARMS AND BY LEVELS OF FLOOD PROTECTION (DOLLARS)

Farm and Item	Change in Level of Flood Protection from None to: Land Treatment Only	Ten Structures	Twenty Structures	Thirty-Six Structures	Complete Protection
Farm I					
Cumulative Increase in Net Income	48	245	313	350	500
Increase Due to Flood Damage Reduction	48	179	229	259	373
Increase Due to Change in Land Use	0	66	84	91	127
Farm II					
Cumulative Increase in Net Income	36	288	378	419	692
Increase Due to Flood Damage Reduction	27	212	271	312	498
Increase Due to Change in Land Use	9	76	107	107	194
Farm III					
Cumulative Increase in Net Income	97	743	963	1,075	1,579
Increase Due to Flood Damage Reduction	97	743	963	982	1,408
Increase Due to Change in Land Use	0	0	0	93	171
Farm IV					
Cumulative Increase in Net Income	99	757	984	1,095	1,585
Increase Due to Flood Damage Reduction	99	757	984	1,095	1,585
Increase Due to Change in Land Use	0	0	0	0	0

by less valuable crops than alfalfa warrants consideration.

A first step in the consideration of this hypothesis is to isolate from all sources of uncertainty only the source associated with flood risk. Variability in income due to flooding is only one component of the total variation in income to farmers in the watersheds. It is possible that variability in farm income due to variability in yields independent of flooding (drouth, insects, etc.), and to variability in market prices, may be the major sources of the uncertainty facing farmers in the watershed. However, some assessment of the validity of the hypothesis can be made by considering only the flood risk components of the uncertainty. Specifically, if the variation in net income from alfalfa due to flood risk is greater than other crops competing for the use of flood plain land, then there would be support for the hypothesis that alfalfa is not planted because of risk from flooding. However, if the contrary is true, the hypothesis is open to question.

Estimates of the net returns by crops and by years were made by applying the damage factors to the various crops on an annual basis for the 20-year period 1938-1957 (Appendix Tables IX and X). On the basis of variation in income due to flooding alone, there appears to be no support for the hypothesis that alfalfa would not be planted. Its coefficient of variation of 23 percent is considerably lower than alternative crops: wheat (coefficient of variation of 47 percent), cotton (coefficient of variation of

36 percent), grain sorghum (coefficient of variation of 27 percent), oats (coefficient of variation of 50 percent), barley (coefficient of variation of 54 percent), and small grain hay (coefficient of variation of 32 percent). The estimated coefficients of variation of crops with 36 structures for flood protection show a marked decrease over those for present flooding conditions. For examples, the coefficients of variation were reduced as follows: wheat, from 47 percent to 12 percent; cotton, from 36 percent to 10 percent; alfalfa, from 23 percent to 8 percent; grain sorghum, from 27 percent to 8 percent; oats, from 50 percent to 12 percent; barley from 54 percent to 13 percent and small grain hay, from 32 percent to 9 percent (Appendix Table X). As an additional check on the hypothesis, alternative models of game theory were examined as possible explanations of the reluctance of farmers to produce alfalfa until flood risk was removed. None was successful. Apparently, this reluctance is not due to flood risk, per se, at all, but to other sources of variation in income and/or uncertainty. Some possibilities are uncertainty of markets for alfalfa, or risks associated with establishing the stand.

Implications of Methodology for Watershed Planning

As was pointed out in Chapter I, the present method of estimating the effects of a flood control project that considers only the flood plain land in the aggregate fails to allow for the effects of resource situations of the individual farmers affected and the effects of the project upon use of upland. For example, the present method of estimating benefits accounts for the increase in farm income from more intensive use of flood plain land, but fails to account for the change in income associated with and accompanying changes in use of upland. The programming results indicated less income would accrue to upland as the intensive crops moved to bottomland with flood protection.[4] An example may be seen in Farm II where cotton moved from the upland to the bottomland and was replaced by wheat on the upland. If the net returns from an acre of cotton on the upland is $30.68, and on bottomland $56.98, there is a gain of $26.30 per acre from the shift of this crop to bottomland; however, if net returns from wheat which moved from the bottomland to the upland was reduced from $31.45 to $16.85 per acre, there would be a net loss of $14.60. The algebraical sum of the differences shows a net gain from the substitution of $11.70 attributable to flood protection. If flood plain effects alone are considered, the benefits would be 56.98 - 31.45 = $25.53. The difference between $25.53 and $11.70 of $13.83

[4]This may be a generally expected result, but there may be exceptions such as the introduction of economies of scale for the farm with the increased productivity of flood plain land sufficient to bring about large and more than compensating increases in net income per acre of upland. Linear programming as a technique would have some limitations for identifying such results.

is a measure of the over estimation of flood protection benefits in this case.

Of course, such substitution does not occur in every case. An exception would be where more intensive crops not now being produced on the farm move in as a result of the flood protection. As has been shown in previous sections, the amount of bottomland, and relative proportions of bottomland and upland have important effects on the changes in net returns to a farm and to a watershed. It is not necessarily true that the present method always overestimates the benefits; there may be cases in which the error would be negligible.

An advantage of linear programming used in connection with the whole-farm-approach is that the with and without project resource uses can be determined mathematically with all variables controlled except flooding. Thus, adjustments which profitably could be made prior to the installation of flood protection will already have been taken into account, and the effects of such adjustments would not be confounded with the effects of reduced flooding.

The organizations and net returns to selected "typical" farms can be estimated from data obtained by a sample survey and compared with the programmed results. This comparison could provide the basis for adjusting programmed benefits by the percent actual efficiency of farmers' resource use is of the programmed level of efficiency. The comparison also could provide the basis for making the restrictions or assumptions of the programs more realistic.

This may be illustrated by referring to the data shown in Table XII. The main difference between farms as presently organized and as programmed is in the relatively large acreages of alfalfa and numbers of livestock. This accounts for most of the $147,701 increase in the programmed aggregate net returns over the net returns from farms as presently organized.[5] The project planners might restrict alfalfa acreages or numbers of livestock at some level between actual present organization and the acreages or numbers programmed as a benchmark.

It is possible that the linear programming approach used in this study might be adapted for use by the program planners to yield estimates of benefit cost ratios more rapidly and easily. The actual programming could be done in a central office with the field men performing the service of collecting data for the purposes of adjusting standardized input-output coefficients to the particular watershed. Such a method would not greatly alter the field work presently carried out by the Soil Conservation Service. The nature of the data would need to be changed to get inventory estimates of the resource situations of typical whole farms which operate flood plain land. Input-output coefficients for crops and livestock, and damages to other

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[5]The net returns for the four farms were determined by applying the budgets for enterprises as used in this study to current land uses of the farms.

TABLE XII

ESTIMATED NET FARM INCOME FOR BOGGY CREEK WATERSHED BY ALTERNATIVE FARM ORGANIZATIONS AND LEVELS OF FLOOD PROTECTION (DOLLARS)

Item	Total[a]	Increase in Total: Due to Change in Farm Organization	Increase in Total: Due to Flood Protection
Present Organization, No Flood Protection	367,749[b]	-	-
Programmed Organizations, No Flood Protection	515,450	147,701	-
Land Treatment Only	519,794	-	4,344
Ten Structures	546,711	-	31,261
Twenty Structures	556,009	-	40,559
Thirty-Six Structures	560,633	-	45,183
Complete Protection	582,524	-	67,074

[a]Obtained by expanding net income of individual farms from use of percentage each was of the total farms in the watershed with flood plain land.

[b]Obtained from estimates of present net incomes of the individual farms as follows: Farm I - $2,424; Farm II - $7,388; Farm III - $5,585; and Farm IV - $7,942.

than crops and pasture could be carried out in the usual manner.

The linear programming "typical" farm approach could be pre-tested in one or more watersheds prior to adoption as a general procedure by the Soil Conservation Service. Problems not encountered in this study may arise in application of the method for watershed planning.

Another major implication of the results of the Flood Control Phase of the study is the possibility of more efficient use of public funds through proper choice of intensity of investment for each watershed under development. Although all effects of the development in Boggy Creek were not considered in this study, a sufficient portion were considered to establish the nature of the functional relation depicting diminishing returns to added structures. The Soil Conservation Service does estimate costs and benefits to the marginal structures, but the entire functional relation for a watershed is not determined. Instead of the planned 36 structures for Boggy Creek, there exists the possibility of an optimum number of 10-20 for this watershed when considering either of the following criteria for an optimum: (1) each structure must have a benefit-cost ratio of one or greater, and/or (2) the benefit-cost ratio of the least efficient structure must be equal to or greater than could be obtained for the same (marginal) expenditure in development in any other watershed. It is recognized that determination of the level of flood protection (and the number of structures) in any watershed currently is a joint responsibility of the Soil Conservation Service and local interests; however, even within this policy in arriving at a decision, more efficient use of public expenditures in watershed development could be expected if more than the customary amount of information is available upon which to arrive at the decision.

CHAPTER IV

ECONOMIC POTENTIAL OF IRRIGATION FROM WATERSHED STRUCTURES

The purpose of this phase of the study was to examine the economic potential to farmers of (1) using water for irrigation from the sediment pools of structures as planned for flood protection alone, and (2) developing additional storage for irrigation by entering into cost-sharing agreements with the Federal Government.

The empirical procedure was divided into three steps as follows:

(1) Estimating the value per acre foot of different amounts of irrigation storage for farms of different sizes and land resource characteristics,

(2) Estimating the amounts of water available with and without the increments to dams; and,

(3) Estimating the costs to farmers per acre foot of water for adding to the storage capacities of the structures.

Source of Data and Method of Study

The effects of different amounts of irrigation water on land use, resource requirements, and net incomes were determined by linear programming for the same four typical farms used in the flood control phase of the study. Estimates of water requirements and yields of the crops chosen to be irrigated were developed from published results of irrigation experiments in western Oklahoma and adjacent areas of Texas,[1] from surveys of irrigators in Oklahoma,[2] and from unpublished information provided by staff members of the Agricultural Extension Service and the Oklahoma Agricultural Experiment Station.[3]

Sprinkler systems were assumed to be the means of applying water, and three sizes of sprinkler systems based on the number of acres to be irrigated were designed. Twenty, 40, and 100 acre systems were assumed, and a fourth could be obtained by combining the 100 acre size with one of the smaller systems (Appendix Table XXX).

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[1]James E. Garton and A. D. Barefoot, Irrigation Experiments at Altus and El Reno, Oklahoma, Oklahoma Agricultural Experiment Station Bulletin B-534 (Stillwater, July, 1959).

_______________ and Wayne D. Criddle, Estimates of Consumption-Use and Irrigation Water Requirements of Crops in Oklahoma, Oklahoma Agricultural Experiment Station Technical Bulletin No. T-57 (Stillwater, October, 1955).

William F. Hughes and A. C. Magee, Some Economic Effects of Adjusting to a Changing Water Supply, Texas High Plains, Texas Agricultural Experiment Station Bulletin 966, (College Station, October, 1960).

[2]K. C. Davis, data from surveys of irrigators in southwest Oklahoma counties, unpublished.

[3]Franklin R. Crow and James E. Garton, Department of Agricultural Engineering, William F. Lagrone and K. C. Davis, Department of Agricultural Economics, and James V. Howell and Robert B. Duffin, Agricultural Extension Service.

Irrigation possibilities were confined to bottomland under no flooding conditions.[4] Since the fixed costs per acre for irrigation facilities depended upon the amount of land irrigated, and this amount could not be determined in advance of programming, only variable irrigation costs were programmed. After the programming was completed, the appropriate size of system was assigned to a particular farm and the annual fixed costs subtracted from the net returns. These returns, net of all irrigation costs, were used in determining the value of water (including returns to extra family labor and any increase in risk at the various levels programmed).

The irrigation costs included only costs of pumping and applying the water. Thus, the net returns from the use of water was an estimate of the maximum amount that farmers could afford to pay for water delivered to the field.

The levels of water programmed were not levels in the usual sense of adding increments of water on a per acre and by a crop basis, but they were levels in amounts of water per farm unit. For example, only one level of water was programmed for each of the four crops selected for irrigation. The amounts of water allowed per crop were cotton,

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[4]There was no way to estimate damage factors for irrigated crops, but since the value of irrigation water is calculated by the increased net returns over dryland crops, approximately the same quantitative results could be achieved by programming "no flooding" as some other level of flood protection.

16"; alfalfa, 20"; grain sorghum, 12"; and wheat, 10". It was assumed that water would normally be applied at the rate of about 4" per time over. The amounts programmed were arrived at by providing enough water to supply the average deficiency of rainfall in the area and adding to this an amount to make up for losses in field irrigation efficiency.[5] It is probable that the economic optimum amounts of water per acre by crops are different than the amounts programmed.

Results of Programming Analysis

Effects on Land Use

Generally, the use of the various levels of irrigation water had little effect on the allocation of the land resources to the crops programmed. Of the four crops considered for irrigation (wheat, cotton, alfalfa, and grain sorghum) only grain sorghum failed to enter as an irrigated crop (Table XIII).[6]

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[5]For cotton, alfalfa and grain sorghum, these amounts were derived from Garton and Barefoot, Estimates of Consumption Use and Irrigation Water Requirements of Crops in Oklahoma. The amount for wheat was based on the judgment of staff members of the Extension Service and the Experiment Station.

[6]It is possible that if another level of water had been programmed for grain sorghum, say 6" instead of 12", it may have entered the final program selections as an irrigated crop.

TABLE XIII

PROGRAMMED IRRIGATED AND NON-IRRIGATED USES OF CROPLAND BY FARMS AND BY LEVELS OF IRRIGATION (ACRES)

	Farm I				Farm II				Farm III				Farm IV			
	Levels of Irrigation															
Item	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Bottomland																
Irrigated																
Cotton	0	13	13	13	0	40	40	40	0	25	25	25	0	14	14	14
Wheat	0	0	9	9	0	0	0	0	0	0	63	49	0	0	81	58
Alfalfa	0	0	16	36	0	0	17	31	0	0	45	124	0	0	37	121
Total	0	13	38	58	0	40	57	71	0	25	133	198	0	14	132	193
Non-Irrigated																
Cotton	13	0	0	0	27	0	0	0	25	0	0	0	14	0	0	0
Wheat	9	9	0	0	0	0	0	0	49	49	0	0	58	58	0	0
Alfalfa	36	36	20	0	44	31	14	0	124	124	65	0	121	121	61	0
Total	58	45	20	0	71	31	14	0	198	173	65	0	193	179	61	0
Upland (Non-Irrigated)																
Cotton	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0
Wheat	46	46	46	46	172	172	172	172	53	53	36	42	220	220	197	209
Grain Sorghum	9	9	7	7	63	76	76	76	0	0	0	0	3	3	2	0
Small Grain Grazing	12	12	14	14	34	34	34	34	24	24	41	35	59	59	83	73
Total																
Cotton	13	13	13	13	40	40	40	40	25	25	25	25	14	14	14	14
Wheat	55	55	55	55	172	172	172	172	102	102	99	91	278	278	278	267
Alfalfa	36	36	36	36	44	31	31	31	124	124	110	124	121	121	98	121
Grain Sorghum	9	9	7	7	63	76	76	76	0	0	0	0	3	3	2	0
Small Grain Grazing	12	12	14	14	34	34	34	34	24	24	41	35	59	59	83	73

Only cotton was irrigated at the first farm increment of water, followed by variable amounts of wheat and alfalfa at increments two and three.

The acres in particular crops on Farm I remained almost stationary with successive increments of irrigation water. A slight shift (two acres) from grain sorghum to small grain grazing occurred at the second and third increments.

All the wheat allotment on Farm II remained on the upland leaving alfalfa and cotton as uses of irrigation water on all the bottomland. This was due to the large amount of upland relative to bottomland for this farm. At the first increment of water and thereafter, 13 acres of cotton moved from upland to bottomland to be irrigated. The 13 acres of cotton were replaced on the upland by grain sorghum.

It was profitable to substitute some small grain grazing on upland for the wheat allotment at all levels of irrigation for Farm III. More wheat was irrigated at the intermediate level of water than at level 3. This extra amount of winter grazing made it profitable to grow more livestock and in turn caused a substitution of small grain grazing for wheat allotment on some of the upland. At irrigation level 3, alfalfa was substituted for some of the irrigated wheat, causing a switch back to more wheat on upland and less livestock (Table XIV). This switching back and forth indicates that there is little difference in net

TABLE XIV

LIVESTOCK ENTERPRISES PROGRAMMED BY FARMS AND BY LEVELS OF IRRIGATION

Farm and Enterprise	Activity Number	Unit	Levels of Irrigation 0	1	2	3
Farm I						
Feeders[a]	43	Number	10	11	10	10
Feeders[b]	45	Number	17	17	20	20
Farm II						
Cow-Calf[c]	42	Cow Units[d]	12	12	12	12
Feeders[b]	45	Number	49	49	49	49
Farm III						
Cow-Calf[c]	42	Cow Units[d]	3	3	2	2
Feeders[b]	45	Number	34	34	56	49
Farm IV						
Cow-Calf[c]	42	Cow Units[d]	14	14	13	13
Feeders[b]	45	Number	85	85	118	104

[a]Feeders purchased in September, wintered on cotton seed cake and hay, summer graze, sell in July.

[b]Buy in October, graze on harvested winter wheat and small grain grazed out, sell in May.

[c]Calving in February, non-creep feeding, sell good to choice feeder calves in September; cows wintered on cotton seed cake and hay, summer on range.

[d]Cow units are numbers of cows in herd that includes a bull, replacement heifers, and calves during spring and summer.

returns between the two alternatives, and practically, the allocation of resources would probably be made on the basis of preference for one or the other.

For Farm IV, about the same total acreages of crops were programmed at all levels of irrigation. Some of the wheat allotment was replaced by small grain grazing on upland at irrigation level 3. However, the farmers would not likely make this kind of substitution due to risk of a reduction in future wheat acreage allotments through under planting.

Effects on Resource Requirements and Levels of Income

The resource requirements and income by levels of irrigation for the four "typical farms" are summarized in Tables XV-XVIII. Generally, labor requirements, capital investment, and gross and net farm incomes increased for all the farms with increase in farm increments of water for irrigation. An exception was the negative net income to Farm II for the third increment of irrigation water. This negative result was permitted because the programs were run with only variable costs in the budgets, and the annual fixed costs were deducted from the programmed net incomes. The change in irrigation equipment between irrigation levels 2 and 3 was responsible for the negative returns to the third increment of water. This was due to the necessity for using the 100 acre size irrigation system on 71 acres

TABLE XV

PROGRAMMED RESOURCE REQUIREMENTS AND INCOME BY LEVELS OF IRRIGATION, FARM I

Item	Levels of Irrigation 0	1	2	3
Total Water Used, acre feet	0	17.3	51.8	84.8
Change from Preceding Level of Use, acre feet	-	17.3	34.5	33.0
Labor Required				
Hired, hours	0	0	0	0
Family, hours	842	1,072	1,201	1,321
Total, hours	842	1,072	1,201	1,321
Change in Family Labor Requirements				
From No Irrigation, hours	-	230	359	439
From Preceding Level of Irrigation, hours	-	230	129	80
Non-land Capital Investment, dollars	6,243	7,245	8,900	9,467
Gross Farm Income, dollars	10,325	12,080	13,833	15,326
Annual Costs, dollars	6,369	7,426	8,880	10,023
Net Farm Income, dollars	3,956	4,654	4,953	5,303
Change in Net Farm Income				
From No Irrigation, dollars	-	698	997	1,347
From Preceding Level of Irrigation, dollars	-	698	299	350
Returns per Acre Foot of Water[a]				
From No Irrigation, dollars	-	40.35	19.25	15.88
From Preceding Level of Irrigation, dollars	-	40.35	8.67	10.61

[a]Returns to water, to increments of family labor, and to any increments to risk and management associated with levels of irrigation.

TABLE XVI

PROGRAMMED RESOURCE REQUIREMENTS AND INCOME
BY LEVELS OF IRRIGATION, FARM II

Item	Levels of Irrigation 0	1	2	3
Total Water Used, acre feet	0	53.3	81.3	113.3
Change from Preceding Level of Use, acre feet	-	53.3	28.0	32.0
Labor Required				
Hired, hours	191	900	934	963
Family, hours	1,339	1,593	1,669	1,734
Total, hours	1,730	2,493	2,603	2,697
Change in Family Labor Requirements				
From No Irrigation, hours	-	254	330	395
From Preceding Level of Irrigation, hours	-	254	76	65
Non-land Capital Investment, dollars	16,624	17,677	18,207	20,228
Gross Farm Income, dollars	21,905	27,677	28,269	29,315
Annual Costs, dollars	12,591	15,953	16,971	18,173
Net Farm Income, dollars	9,314	11,048	11,298	11,142
Change in Net Farm Income				
From No Irrigation, dollars	-	1,734	1,984	1,828
From Preceding Level of Irrigation, dollars	-	1,734	250	- 156
Returns per Acre Foot of Water[a]				
From No Irrigation, dollars	-	32.53	24.40	16.13
From Preceding Level of Irrigation, dollars	-	32.53	8.93	-4.88

[a]Returns to water, to increments of family labor, and to any increments to risk and management associated with levels of irrigation.

TABLE XVII

PROGRAMMED RESOURCE REQUIREMENTS AND INCOME BY LEVELS OF IRRIGATION, FARM III

Item	Levels of Irrigation 0	1	2	3
Total Water Used, acre feet	0	33.3	161.1	272.5
Change from Preceding Level of Use, acre feet	-	33.3	127.8	111.4
Labor Required				
Hired, hours	173	482	675	1,111
Family, hours	1,510	1,645	1,910	1,933
Total, hours	1,683	2,127	2,585	3,044
Change in Family Labor Requirements				
From No Irrigation, hours	-	135	400	423
From Preceding Level of Irrigation, hours	-	135	265	23
Non-land Capital Investment, dollars	11,149	12,799	20,127	23,535
Gross Farm Income, dollars	21,240	24,579	32,867	37,375
AnnualCosts, dollars	11,340	13,410	20,597	24,690
Net Farm Income, dollars	9,900	11,169	12,270	12,685
Change in Net Farm Income				
From No Irrigation, dollars	-	1,269	2,370	2,785
From Preceding Level of Irrigation, dollars	-	1,269	1,101	415
Returns per Acre Foot of Water[a]				
From No Irrigation, dollars	-	38.07	14.71	10.22
From Preceding Level of Irrigation, dollars	-	38.07	8.62	3.73

[a]Returns to water, to increments of family labor, and to any increments to risk and management associated with levels of irrigation.

TABLE XVIII

PROGRAMMED RESOURCE REQUIREMENTS AND INCOME BY LEVELS OF IRRIGATION, FARM IV

Item	Levels of Irrigation 0	1	2	3
Total Water Used, acre feet	0	18.7	148.5	269.0
Change from Preceding Level of Use, acre feet	-	18.7	129.8	120.5
Labor Required				
Hired, hours	199	311	539	1,040
Family, hours	1,544	1,681	1,924	1,938
Total, hours	1,743	1,992	2,463	2,978
Change in Family Labor Requirements				
From No Irrigation, hours	-	137	380	394
From Preceding Level of Irrigation, hours	-	137	243	14
Non-land Capital Investment, dollars	22,462	23,759	32,327	35,355
Gross Farm Income, dollars	34,078	35,968	45,004	49,393
Annual Costs, dollars	19,827	21,058	28,938	33,056
Net Farm Income, dollars	14,251	14,910	16,066	16,337
Change in Net Farm Income				
From No Irrigation, dollars	-	659	1,815	2,086
From Preceding Level of Irrigation, dollars	-	659	1,156	271
Returns per Acre Foot of Water[a]				
From No Irrigation, dollars	-	35.24	12.22	7.75
From Preceding Level of Irrigation, dollars	-	35.24	8.91	2.25

[a]Returns to water, to increments of family labor, and to any increments to risk and management associated with levels of irrigation.

irrigated at level 3 which was less efficient than using the 40 acre size on 57 acres at irrigation level 2.

Labor and Non-Land Capital Inputs. For Farm I, family labor increased about 50 percent from no irrigation to full irrigation of bottomland, but it was never necessary to hire any labor. Total labor required almost doubled, and hired labor increased about five-fold, with irrigation of all bottomland on Farms II, III, and IV.

Non-land capital requirements increased by 50 and 25 percent respectively for Farms I and II in going from none to complete irrigation of bottomland. The increases in capital requirements were much greater in the cases of Farms III and IV. These greater increments to the capital required were due to the latter two farms having much larger acreages of bottomland to irrigate as well as to the resulting shift toward more livestock at higher irrigation levels.

Levels of Income. Net returns increased with all increments of water for Farm I (Table XV, page 80). However, the second and third increments to net income were considderably less than the first. The first increment of water irrigated the 13 acre cotton allotment and increased net income by $40.35 per acre foot. This return is to water, additional family labor required for irrigation, and for any increase in risk and management associated with a larger scale of operation. The possibility of a decrease in risk due to a reduction of income variability attributable to drouth was not examined in this study.

The other farms experienced increases in net income similar to Farm I at the different increments of water with the exception of Farm II (Table XVI, page 81). None of the four farms had increases in net income below $8 per acre foot at the second increment. At the third increment, Farm I had an increase in net income over the preceding level of irrigation of more than $10 while the other three farms were all less than $4.

Over-all, the estimated increases in net returns for irrigating cotton ranged from $32.53 to $40.35 per acre foot of water. The income per acre foot dropped to between $8 and $9 on all farms for the second increment of water. The returns to water for irrigation level 3 were below $4 per acre foot for Farms II, III and IV. When the costs of water are considered, this level of irrigation may be unprofitable for these farms. However, the third increment of water for Farm I was worth more than the second increment for this farm. This resulted from the ability to make more efficient use of equipment at the third level than at the second.

Allocation of Alternative Supplies of Water

The principle of achieving maximum economic returns from any scarce resource is that of allocating the resource among its alternative uses in such a manner that those uses yielding higher returns are given priority. To graphically illustrate this principle, increments of water are arranged in magnitude of returns per acre foot as programmed for the farms (Figure 4).

A method of going from the four farms to the approximate amounts used by the watershed is to multiply by the factor 15.5. The result of this expansion to the watershed as indicated by the lower scale of the horizontal axis of Figure 4 (page 87) indicates that about 7,400 acre feet of water could be profitably used in the watershed if the cost of getting it from the reservoirs to the fields (plus extra family labor used in irrigation) did not exceed about $8.50 per acre foot.

However, it may be observed from the graph that if such costs exceed $9.50 per acre foot, only cotton would be profitable to irrigate, and about 1,900 acre feet of water would be sufficient to irrigate the cotton acreage allotments in the watershed.

An alternative (and perhaps more practical) way to allocate water to users and uses would be to rank the farms by average returns per acre foot of water when each farm uses water to its maximum level of profitability.

Assuming all net returns to water below $6 per acre foot would be unprofitable, such an array would be as follows, page 88:

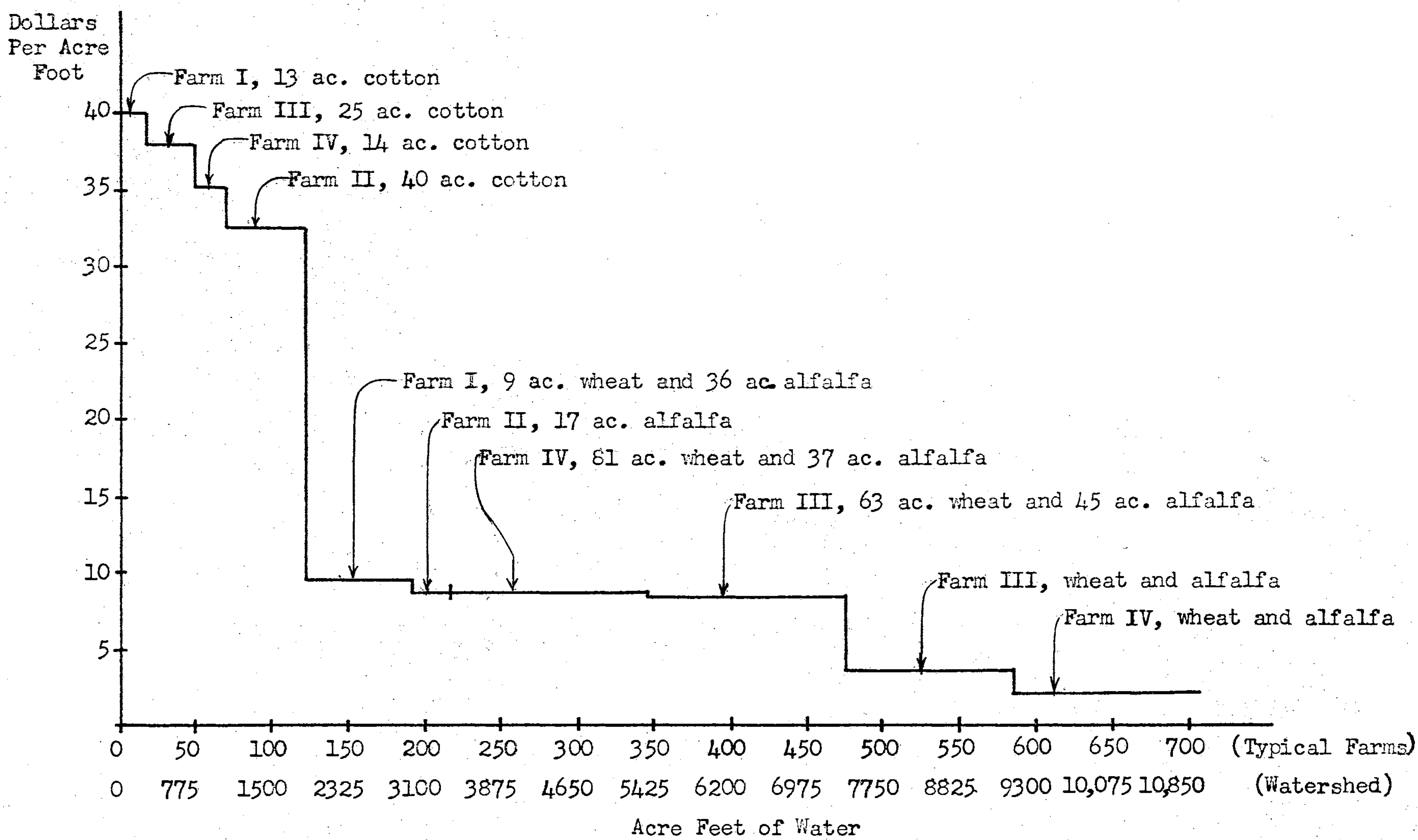

Figure 4. Net Returns Per Acre Foot of Water, Acre Feet of Water Used, and Acreages of Crops Irrigated by Typical Farms

Farm	Crops and Acres Irrigated	Average Value Per Acre Foot
II	40 acres cotton and 17 acres alfalfa	$24.40
I	13 acres cotton, 9 acres wheat and 36 acres alfalfa	15.88
III	25 acres cotton, 63 acres wheat and 45 acres alfalfa	14.71
IV	14 acres cotton, 81 acres wheat and 37 acres alfalfa	12.22

From these data, it is evident that the size of the cotton allotment is a major factor in determining the average returns per acre foot of irrigation water. The size of farm is also an important determinant if cotton allotment is small relative to the amount of irrigable land.

The estimates of returns per acre foot of water presented in this study apply only to assumed price-cost and technical relationships for Boggy Creek and similar watersheds. It is possible that enterprises not programmed may yield greater net returns. For example, alfalfa for on farm dairy cattle feed, peanuts, or truck crops might be more profitable irrigation enterprises. Only enterprises now important in the area were considered. In addition, the estimates of increased yields from irrigation are based on limited information and rather rigid assumptions as to fertilizer and cultural practices (Appendix Tables XXXI-XXXIV).

Potential Supply of Water for Irrigation

Each watershed project developed for flood prevention alone provides some water which may be used for irrigation. This is stored in the sediment pools of the structures. There may be a considerable potential for irrigation from sediment pools of the larger structures. It is crucial from an engineering standpoint that the farmer decide whether to add to the storage of water for irrigation prior to the building of the structure. This may be a difficult decision for most farmers, especially in areas where there is little experience with irrigation from impounded surface water. As a result, about 95 percent of all small watershed structures have been planned for flood prevention alone. If there is an economic potential for irrigation water greater than that stored by a single purpose (flood control) structures, then it clearly is not being used.

The plan for Boggy Creek (without additional storage for irrigation) includes 36 floodwater retarding structures with a storage capacity of 2,850 acre feet of water in the sediment pools. Based on the sample of 10 structures, it is estimated that 46 percent of this water will be lost through evaporation (Table XIX). If it is arbitrarily assumed that an additional 15 percent will be lost from other diversion, there would be only 1,112 acre feet available for irrigation from sediment pools of the 36 structures. This would irrigate about 50 percent of the present cotton

TABLE XIX

ESTIMATED TOTAL ACRE FEET STORED, ACRE FEET LOST BY EVAPORATION, AND ACRE FEET STORED NET OF EVAPORATION LOSS FOR TEN STRUCTURES WITH AND WITHOUT INCREMENTS ADDED FOR IRRIGATION

	With Irrigation Increment[a]			Without Irrigation Increment[b]		
Structure Number	Total Stored	Lost by Evaporation	Net of Evaporation	Total Stored	Lost by Evaporation	Net of Evaporation
1	240	127	113	104	37	67
4	370	150	220	120	44	76
5	270	121	149	104	37	67
10	325	114	211	56	33	23
13	1,800	523	1,277	287	165	122
17	1,050	305	745	209	103	106
21	640	222	418	65	26	39
26	300	134	166	129	44	85
28	475	228	247	98	68	30
29	500	239	261	200	73	127
Totals	5,970	2,163	3,807	1,372	630	742

[a]These amounts are in addition to the acre feet in the sediment pool.

[b]The amounts are estimates as planned for flood control only.

acreage in the watershed. However, this amount is not likely to be available for irrigation because 21 of the planned structures have less than 80 acre feet of water in the sediment pools, leaving only 15 structures with sufficient storage to furnish a farm with enough water to realize its economic potential from irrigation. Thus, irrigation from sediment pools, as planned, has a limited economic potential in Boggy Creek.

The Soil Conservation Service provided data for estimating the costs to farmers for adding to the water storage capacities for 10 of the planned structures which were believed to have the best potential for this development. These 10 structures can be developed to a capacity of 5,970 acre feet at a cost to the farmers of $27.13 per acre foot for construction (Table XIX, page 90). When this cost is amortized over 13 years (the assumed life of the irrigation equipment), the annual cost to farmers would be about $3.06 per acre foot gross storage capacity for irrigation purposes. However, this is not an estimate of cost to farmers delivered to the field. There remains the difficult task of estimating the loss between storage in the structures and the field sites. When this estimate is made, the cost per acre foot of effective storage can be estimated, where effective storage is the total acre feet stored minus such losses.

The capacity in acre feet of storage must be large enough to provide the water required for irrigation plus the water loss. The main sources of loss are (1) evaporation from free water surfaces, and (2) seepage and other losses from the lake and from transmission channels.

Evaporation Loss

The average annual lake evaporation at Cordell, Oklahoma was estimated to be 64" by members of the Department of Agricultural Engineering.[7] The evaporation period relevant for losses to be considered for this study would be from May through October, and evaporation for this period was estimated to be 44". This estimate presupposes that the lake would be filled to storage capacity by May 1. The 44" loss provides a basis for deriving an estimate of the component of loss due to evaporation. The procedure for deriving this estimate was to plot profiles of the surface acres of water against elevations for the 10 structures and to assume an average loss of 44" between the sediment pool and the permanent pool elevations. The results are presented in Table XIX (page 90).

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[7]Franklin R. Crow, and James E. Garton, References cited in support of estimate: United States Weather Bureau, Department of Commerce, Evaporation Maps for the United States, Tech. Paper No. 37, (Washington, D. C., 1959) and United States Geological Survey, "Water Loss Investigations: Lake Heffner Studies" Technical Report, Geological Survey Professional Paper No. 269 (Washington, D. C., 1954), (a reprint of United States Geological Survey, Circular No. 229, 1952).

Losses Other Than Evaporation

The principal losses other than evaporation are from evapo-transpiration from vegetation along the banks of the conveyance streams or channels, and seepage from the bed and banks of the channels. However, evapo-transpiration is small in comparison with seepage.[8]

Some of the factors affecting seepage listed by Robinson and Rohwer are as follows: (1) characteristics of soil, (2) length of time canal has been in operation, (3) depth to ground water, (4) temperature of the soil and of the water, (5) depth of the water in the canal, (6) percentage of entrapped air in the soil, (7) capillary tension, and (8) barometric pressure.[9]

Although no satisfactory formula has ever been developed for estimating seepage, Darcy's Law,[10] $Q = KIA$, is helpful in understanding the fundamental relationships involved. In this formula

Q = quantity of water lost per unit of time

K = coefficient of permeability

I = the hydraulic gradient, and

A = the wetted area of the canal bed and banks.

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[8] Ivan E. Houk, Irrigation Engineering, Vol. I, John Wiley and Sons (New York, 1951), p. 373.

[9] A. R. Robinson and Carl Rohwer, Measuring Seepage From Irrigation Channels, United States Department of Agriculture, Agricultural Research Service Technical Bulletin No. 1203 (Washington, D. C., September, 1959), p. 2.

[10] H. Darcy, Les Fontaines Publiques De La Ville De Dijon, (647 pp. and Atlas) Paris, 1856. (Footnote from A. R. Robinson and Carl Rohwer.)

Houk summarizes the findings of a number of studies over the United States by saying that losses in farm ditches averaged 5-50 percent per mile, and canal seepage losses from unlined canals varied from 15-45 percent of the total diversions.[11] In the absence of actual measurements one can only speculate and guess at the percentage of water stored in the Boggy Creek reservoirs which would be lost before it is delivered to the field site. From a map, it was estimated that the average distance from the selected 10 structures to the irrigated fields was approximately one mile. This corresponds to the measurement above which reports percentage loss per mile to be from 5-50 percent. Since the most important variable is permeability, the median value of 27.5 percent could be selected if median permeability is assumed. This would presuppose that the conditions in the channels on Boggy Creek were similar to the farm ditches in which the studies were made. However, it is very likely that since natural stream beds are used, the permeability is much lower in Boggy Creek than the farm ditches of the studies cited, so that the median figure probably would overestimate the losses. It was arbitrarily assumed that 15 percent of the water stored in the structures would be the net loss from all causes other than evaporation.[12] This component, when added to

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[11] Houk, p. 392

[12] The rainfall and runoff into the lake are plus factors and the seepage from the lake and channels are minus factors for which good estimates are lacking.

the water lost from evaporation, results in a water supply for irrigation (delivered to the fields) as follows:

Total water stored (acre feet)	5,970
Lost by evaporation (acre feet)	2,163
Other losses at 15 percent (acre feet)	895
Water available for irrigation	2,912

Economic Potential

The farmer's share of the cost for developing the increments to the 10 structures would be $55.62 per acre foot of water available for irrigation. When this cost is amortized for 13 years at 6 percent, the annual cost is $6.28 per acre foot. This cost is considerably less than the $12 to $24 average returns per acre foot of water applied to crops.

From these estimates, it is concluded that adding to the flood control structures for irrigation purposes on a cost sharing basis does offer economic possibilities to farmers in Boggy Creek, and possibly to farmers in many other watersheds of similar climatological and agricultural characteristics.

CHAPTER V

SUMMARY AND CONCLUSIONS

The Watershed Protection and Flood Prevention Act of 1954 (Public Law 566 and subsequent amendments thereto) authorizes the construction of upstream watershed improvements for flood control, irrigation, and other purposes. This has created a potential for Oklahoma farmers to increase agricultural production; however, a limited amount of information is available upon which to base economic decisions in adjusting to these opportunities.

This study was limited to one watershed, Boggy Creek, in Washita County of Oklahoma. The major objectives were as follows: (1) to estimate the effects of varying degrees of intensity of flood protection upon resource use and net returns for typical farms of the watershed; (2) to estimate the resource requirements, land use, and net returns for varying levels of irrigation for typical farms of the watershed; (3) to estimate the quantity of water available for irrigation in the sediment pools of the structures as planned for flood control; and, (4) to estimate the economic potential of developing additional storage capacity for irrigation from ten structures judged to be the most suitable for this purpose.

The study represented an aspect of evaluation of watershed development, and, as such, it provided a means for developing and partially testing new procedures for this purpose. The method used by the Soil Conservation Service considered the flood plain to be the appropriate unit for analysis. An alternative method proposed by Timmons and others suggested consideration of the entire watershed as the appropriate unit. The methodology of this study differed from both of these methods in that the farms of the watershed were used as the relevant units for analysis. The major hypothesis in support of this approach was that the effects of watershed development differed among individual farms, and, therefore, the total effects of watershed development would be determined by individual farms as the decision making units.

The theory of the firm provided the guiding concepts of the study. A firm was assumed to be initially in a state of equilibrium, a disturbance was introduced in the form of a change in level of flood protection (or irrigation), and after adjustment, a new equilibrium was achieved. The difference in the magnitudes of the relevant variables at any two equilibrium positions was used as a measure of the effects of the changed level of flood protection or irrigation.

Linear programming was used as the technique for estimating the net returns and allocation of resources for individual farms at the various levels of flood protection and irrigation. Input-output data for the programming analysis were obtained from a sample of farms in the watershed, from personnel of the Oklahoma Agricultural Experiment Station, and from agricultural workers in counties of the Washita River Basin.

Four typical farms were selected for programming on the hypothesis that a major factor affecting an individual farmer's response to watershed development was the proportion of total land operated which was flood plain land. The relative amounts of bottomland and upland on the farms were as follows: Farm I, less than 120 acres of bottomland and less than 240 acres of upland; Farm II, less than 120 acres of bottomland and more than 240 acres of upland; Farm III, more than 120 acres of bottomland and less than 240 acres of upland; and Farm IV, more than 120 acres of bottomland and more than 240 acres of upland. The acreages of cropland were as follows: Farm I, 58 acres of bottomland and 67 acres of upland; Farm II, 71 acres of bottomland and 282 acres of upland; Farm III, 198 acres of bottomland and 77 acres of upland; and Farm IV, 193 acres of bottomland and 282 acres of upland.

The Soil Conservation Service provided data on flooding depths and frequencies for the following levels of flood protection: (1) none, (2) land treatment only, and land treatment with (3) 10 structures, (4) 20 structures, and (5) 36 structures. A sixth level of flood protection, a hypothetical "no flood damage", was assumed for purposes of developing the basic budgets. Damage factors were developed from data supplied by the Soil Conservation Service, and budgets were prepared for each level of protection by applying the damage factors to the basic budgets. For the programming analysis, crop and livestock alternatives were limited to those currently active in the watershed.

The flood control phase of the study was a programming analysis of the four typical farms at the six levels of flood protection. The irrigation phase of the study was a programming analysis of the same four farms at four levels of water per farm as follows: (1) none, (2) an amount sufficient to irrigate the cotton allotment, (3) an intermediate amount between levels (2) and (4), and (4) an amount sufficient to irrigate all the bottomland.

Items included in the programming analysis for the different levels of flood protection and irrigation were estimates of land use for the different kinds of cropland, labor and non-land capital requirements, operating costs, and gross and net incomes for typical farms.

The only crops entering the final programmed solutions for any of the farms were cotton, wheat, alfalfa, grain sorghum, small grain grazing, and barley. The major change from the current use of bottomland was a much greater acreage of alfalfa, which entered all programs at all levels of flood protection by the maximum amounts assumed permissible (five-eighths of the bottomland).

The use of land, and shifts in land use, within farms at increased levels of flood protection varied with the size of cotton and wheat allotments. Farm II, with a 40 acre cotton allotment and only 30 acres of bottomland free from flooding at no flood protection, had a programmed use of 11 acres of cotton on the bottomland and 29 acres on the upland. With increased levels of intensity of flood protection, cotton moved from upland to bottomland until 19 acres were programmed on the bottomland at the level of flood protection afforded by 36 structures. The same farm, with 282 acres of upland and a 172 acre wheat allotment, had all the wheat programmed on upland at all levels of flood protection. Farm IV, with relatively large amounts of both bottomland and upland, had the same land uses programmed at all levels of flood protection. For this farm, the 14 acre cotton allotment was planted on bottomland not subject to flooding, and the 278 acre wheat allotment was mainly on upland. Farm I, with relatively small amounts of both upland and bottomland, had three acres of the cotton allotment on upland and 10 acres on bottomland at the no flood protection level, but, with flood protection, the cotton acreage shifted from upland to bottomland. Farm III had all of the 77 acres of upland used by wheat at the first four levels of flood protection, at the fifth level (36 structures), 17 acres of wheat moved to the bottomland. The 25 acre cotton allotment for this farm was planted on bottomland at all levels of protection.

The increased intensity in use of flood plain land was accompanied by decreased intensity of upland use. On Farm I, the three acres of cotton and five acres of wheat shifting from the upland to bottomland were replaced by small grain grazing on the upland. Farm II had 16 acres of wheat and cotton to move to the bottomland with flood protection, and the vacated upland was used by 13 acres of barley and three acres of small grain grazing. The 17 acres of wheat moving from upland to the bottomland on Farm III with flood protection afforded by 36 structures was replaced by small grain grazing on the upland.

The programmed livestock numbers for present flooding conditions were 26 feeder cattle and no beef cows for Farm I, 60 feeders and 11 beef cows for Farm II, 32 feeders and three beef cows for Farm III, and 86 feeders and 14 beef cows for Farm IV. There was little change in programmed livestock numbers at increased intensity of flood protection. When converted to animal units, the present livestock on farms were about 70 percent of the programmed numbers, and the farmers had more beef cows and fewer feeder cattle than the programmed numbers.

Labor requirements changed insignificantly with increases in level of flood protection. Also, there was little change in capital requirements between no flood protection and protection by 36 structures.

Gross and net incomes increased at all levels of flooding protection for all farms. The changes in net incomes from no flood protection to protection by 36 structures were as follows: Farm I, from $3,456 to $3,806; Farm II, from $8,560 to $8,979; Farm III, from $8,321 to $9,396; and, Farm IV, from $12,664 to $13,759. The greater changes in income for Farms III and IV reflect the greater amounts of bottomland of these farms. Diminishing returns to adding structures for flood protection was evident; the greatest increments in net returns to all farms occurred at 10 structures.

The estimated net returns of farms as presently organized when aggregated to the watershed were about 70 percent of the aggregated programming results for no flood protection. By farms, these comparisons of net returns were as follows: Farm I, $2,424 and $3,456; Farm II, $7,388 and $8,560; Farm III, $5,585 and $8,321; and Farm IV, $7,942 and $12,664. These differences depicted possible opportunities for farmers of the watershed to increase their net returns without flood protection.

Net income increases for the farms attributable to flood protection were due to reduction of flood damage to crops (about 90 percent) and more intensive use of flood plain land (about 10 percent). The change in intensity of flood plain land varied among the farms. Farms I and II, with relatively small amounts of bottomland, had the greater increases in net income attributable to more intensive use of the flood plain. There was a small increase in net income attributable to change in land use of flood plain on Farm III, but none for Farm IV.

The results indicating net returns to farmers, land use changes, and other effects of the watershed project, did vary among the individual farm resource situations, and that increased intensity of use of the flood plain land was associated with decreased intensity in the use of upland, supports the methodology of watershed evaluation which considers the individual farms as the appropriate units for analysis.

Irrigation budgets were prepared for cotton, wheat, alfalfa, and grain sorghum on bottomland for the analysis of economic potential of irrigation for the four "typical" farms. Sprinkler irrigation was assumed, and costs for three sizes of systems, 20 acre, 40 acre, and 100 acre, were estimated for the analysis. A fourth size used was a combination of the 100 acre and the 40 acre sizes.

Generally, there was little change in the use of land at the various levels of water programmed per farm. Irrigated cotton, wheat, and alfalfa replaced approximately the same acreages of these crops programmed without irrigation water. Grain sorghum never entered the programs at any level of water.

Labor and non-land capital requirements, and gross and net returns increased significantly on all farms with increase in levels of irrigation. From no irrigation to the third increment of water, increases in labor by farms were as follows: Farm I, family labor from 842 to 1,321 hours (no labor was hired at any level); Farm II, family labor from 1,339 to 1,734 hours and hired labor from 191 to 963 hours; Farm III, family labor from 1,510 to 1,933 hours and hired labor from 173 to 1,111 hours; and for Farm IV, family labor from 1,544 to 1,938 hours and hired labor from 199 to 1,040 hours. Non-land capital requirements increases by farms were as follows: Farm I, from \$6,243 to \$9,467; Farm II, from \$16,624 to \$20,228; Farm III, from \$11,149 to \$23,535; and for Farm IV, from \$22,462 to \$35,355. Part of these increases in capital were increases in payments for hired labor. Net returns increases by farms from none to the third increment of water were as follows: Farm I, from \$3,956 to \$5,303; Farm II, from \$9,314 to \$11,142; Farm III, from \$9,900 to \$12,685; and Farm IV, from \$14,251 to \$16,337.

Net returns per acre foot for the first increment of water (for irrigating cotton only) ranged from \$32.53 (Farm II) to \$40.35 (Farm I). Net returns per acre foot dropped sharply for the second increment of water to the range of \$8.62 (Farm III) to \$8.93 (Farm II). Net returns per acre foot to the third increment of water ranged from -\$4.88 (Farm II) to \$10.61 (Farm I). The relatively high returns to water for irrigating cotton emphasized the importance of the cotton allotment as a determinant of the value of water for irrigation on an individual farm.

Results of the study indicated that the sediment pools of the 36 structures as planned for flood protection in

Boggy Creek afforded a supply of water with a limited economic potential. The storage capacity of the sediment pools was 2,850 acre feet. Of this amount, it was estimated that 1,112 acre feet would be available for irrigation after deduction for evaporation and other losses. This 1,112 acre feet would irrigate about 50 percent of the cotton acreage in the watershed if all of it could be used. However, 21 of the structures contained less than 80 acre feet of gross storage capacity, and only 15 had enough water each to supply a farm with an amount sufficient to irrigate most of its bottomland.

Development of additional water storage capacity for irrigation to the ten structures judged to be the most suitable for this purpose has economic possibilities to farmers in Boggy Creek. An additional storage capacity of 5,970 acre feet could be developed for the 10 structures from which 2,912 acre feet would be net of evaporation and other losses. The farmers' share of developing the additional storage capacity was estimated to be $55.62 per acre foot for the 2,912 acre feet. When this cost was amortized over 13 years (the estimated life of the irrigation equipment) at 6 percent, the annual cost to farmers was $6.28 per acre foot. This cost was considerably less than the estimated $12 to $24 average returns per acre foot of water to the farmers.

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APPENDIX

APPENDIX TABLE I

ASSUMED PRICES OF INPUTS AS USED IN FARM PROGRAMMING ANALYSIS

Item	Unit	Price (dollars)
Seed and Feed		
Cotton Seed, Delinted	lb.	.15
Wheat Seed	bu.	2.25
Barley Seed	bu.	2.00
Oats Seed	bu.	1.10
Grain Sorghum Seed	cwt.	15.00
Forage Sorghum Seed	cwt.	15.00
Sweet Sudan Seed	cwt.	6.00
Alfalfa Seed	lb.	.34
Cottonseed Cake	ton	76.00
Fertilizer		
32-0-0	cwt.	4.00
16-20-0	cwt.	4.45
10-20-10	cwt.	3.65
13-39-0	cwt.	5.25
0-45-0	cwt.	3.95
Custom Rates		
Combining	acre	3.00
Cotton Stripping	cwt. seed cotton	1.00
Cotton Snapping (hand)	cwt. seed cotton	2.00
Cotton, Ginning and Wrapping	cwt. seed cotton	.85
Cotton Defoliation	acre	3.50
Cotton Insect Control	acre (1 time over)	2.50
Hay Baling	ton	4.80
Hauling		
Hay	ton	2.50
Wheat	bu.	.07
Grain Sorghum	bu.	.06
Barley	bu.	.05
Oats	bu.	.05
Seed Cotton	cwt.	.25
Fuel and Lubricant		
Gasoline	gal.	.20
L. P. Gas	gal.	.09
Diesel Oil	gal.	.16
Kerosene	gal.	.15
Motor Oil	gal.	1.00
Lubricant	lb.	.20

Source: Survey of agricultural workers in the Washita River Basin during 1960, Larry J. Connor, James S. Plaxico, and William F. Lagrone, Resource Requirements, Costs, and Expected Returns: Alternative Crop and Livestock Enterprises; Loam Soils of Southwestern Oklahoma, Processed Series P-368, February, 1961, Appendix Table 2, p. 45.

APPENDIX TABLE II

ASSUMED PRICES OF PRODUCTS AS USED IN FARM PROGRAMMING ANALYSIS

Item	Unit	Price (dollars)
Crops		
Cotton, Lint	lb.	.28
Cotton, Seed	ton	45.00
Wheat	bu.	1.85
Grain Sorghum	bu.	.90
Alfalfa Hay	ton	23.33
Barley	bu.	.80
Oats	bu.	.65
Beef Cattle		
Cull Cows (Sept.)	cwt.	13.50
Cull Cows (June)	cwt.	14.25
Heifer Calves (June 15)	cwt.	21.50
Heifer Calves (Sept. 10)	cwt.	21.00
Steer Calves (June 15)	cwt.	23.50
Steer Calves (Sept. 10)	cwt.	23.00
Good Feeders (March 10)	cwt.	22.50
Good Feeders (May 10)	cwt.	22.50
Good Feeders (July 10)	cwt.	23.00

Source (Crops): G. P. Collins, and W. G. Hill, Oklahoma Agri. Sta., and AMS, USDA, Prices Received by Oklahoma Farmers, 1910-1957 (and supplements), Processed Series P-297, June 1958. Prices were adjusted by taking a "weighted" average of the years 1955-1959. The "weight" was designed to give more emphasis to the more recent years; that is, prices in 1959 were weighted by 5, prices in 1958 were weighted by 4, etc.

Source (Beef Cattle): Larry J. Connor, James S. Plaxico, and William F. Lagrone, Processed Series P-368, February, 1961, Appendix Table 3, p. 47.

APPENDIX TABLE III

ESTIMATED TOTAL COST AND COST PER HOUR OF USE FOR SELECTED ITEMS OF TWO-PLOW EQUIPMENT AS USED IN FARM PROGRAMMING ANALYSIS

Item	Specifications	Total Cost (dollars)	Cost Per Hour of Use (dollars)
Tractor	3 or 2-16 tricycle L.P., P.S., PTO, hydraulic system, 3-point, 43 h.p.	3,100.00	1.00
Moldboard Plow	2-16" integral	290.00	.25
Tandom Disk	6-7' 3-point hitch	195.00	.13
One-Way	8'	515.00	.33
Spike-Tooth Harrow	12'	100.00	.05
Planter	2-row	310.00	.33
Rotary Hoe	7' integral	225.00	.17
Cultivator	2-row	610.00	.32
Spring-Tooth Harrow	8'	115.00	.08
Grain Drill	16-8 press wheel	730.00	.78
Mower	7' integral	310.00	.27
Side Delivery Rake	10' P.T.O.	315.00	.34
Gyromor (Stalk Cutter)	5'	360.00	.22
Total		7,175.00	

Source: William F. Lagrone, unpublished data. Cost per hour of use includes repair, lubrication, depreciation due to wear, fuel and oil. All figures are based on assumption that equipment will wear out before it becomes obsolete.

APPENDIX TABLE IV

ESTIMATED TOTAL COST AND COSTS PER HOUR OF USE FOR SELECTED ITEMS OF FOUR-PLOW EQUIPMENT AS USED IN FARM PROGRAMMING ANALYSIS

Item	Specifications	Total Cost (dollars)	Cost Per Hour of Use (dollars)
Tractor	4' or 3-16 tricycle, L.P., P.S., hydraulic system, PTO	4,400.00	1.27
Moldboard Plow	4-16" integral	520.00	.46
One-Way	12'	900.00	.57
Tandem Disk	10' wheel type	450.00	.29
Tool Bar	12'	495.00	.34
Cultivator	4-row	610.00	.32
Rotary Hoe	14'	380.00	.29
Planter	4-row	720.00	.33
Gyromor (Stalk Cutter)	5'	360.00	.22
Mower	7' integral	310.00	.27
Side Delivery Rake	10' P.T.O.	315.00	.34
Drill	16-8"	730.00	.78
Spike-Tooth Harrow	24'	135.00	.59
Total		10,325.00	

Source: William F. Lagrone, unpublished data. Cost per hour of use includes repair, lubrication, depreciation due to wear, fuel and oil. All figures are based on assumption that equipment will wear out before it becomes obsolete.

APPENDIX TABLE V

PERFORMANCE OF POWER AND EQUIPMENT AS USED IN FARM PROGRAMMING ANALYSIS

Operation or Tool Used	Performance One Time Over			
	Two-Plow		Four-Plow	
	Acres Per Hour	Hours Per Acre	Acres Per Hour	Hours Per Acre
Breaking Land	1.30	.77	2.0	.50
Disking	2.50	.40	-	-
One-Way	2.00	.50	4.5	.22
Spike-Tooth Harrow	3.00	.33	8.0	.13
Planter	2.00	.50	4.0	.25
Rotary Hoe	2.00	.50	-	-
Cultivator	2.00	.50	4.0	.25
Spring-Tooth	2.00	.50	-	-
Grain Drill	3.50	.29	4.0	.25
Mower	2.00	.50	2.0	.50
Side Delivery Rake	2.00	.50	2.0	.50
Pickup Baler	2.00	.50	2.0	.50
Gyromor (Stalk Cutter)	2.00	.50	3.0	.33

Source: Survey of agricultural workers in Washita River Basin during 1960, and William F. Lagrone, unpublished data.

APPENDIX TABLE VI

DAMAGE FACTORS BY LEVELS OF FLOOD PROTECTION AND BY CROPS AS USED IN PROGRAMMING ANALYSIS (PERCENT)

Item and Crop	Levels of Flood Protection				
	Present Condition	Land Treatment	Ten Structures	Twenty Structures	Thirty-Six Structures
Cotton	26.57	25.40	20.69	18.08	16.37
Wheat	30.00	28.45	22.49	19.58	17.58
Alfalfa	19.92	19.07	15.41	13.60	12.33
Grain Sorghum	22.77	21.78	17.27	14.98	13.33
Oats and Barley	28.14	26.81	21.31	18.62	16.74
Hay (other than alfalfa)	15.56	14.92	12.08	10.54	9.55
Forage Sorghum	22.96	21.98	17.55	15.16	13.54
Sudan Grass Pasture	10.84	10.32	7.79	6.48	5.67
Pasture	10.56	10.11	8.20	7.19	6.53

Source: Calculated from data on damages and flood routings in Boggy Creek provided by the Soil Conservation Service.

Acres subject to flooding were as follows: Present Condition, 4792; Land Treatment, 4692; Ten Structures, 3271; Twenty Structures, 2712; and Thirty-Six Structures, 2439.

APPENDIX TABLE VII

ESTIMATED NET INCOME PER ACRE FOR INDIVIDUAL CROPS ON BOTTOMLAND SUBJECT TO FLOODING BY LEVELS OF FLOOD PROTECTION AND BY FARM MACHINERY SITUATIONS (DOLLARS)

	Level of Flood Protection					
Crop	None (Present Condition)	Land Treatment Only	Ten Structures	Twenty Structures	Thirty-Six Structures	No Flooding
			Two-Plow Equipment			
Cotton	28.94	30.07	34.63	37.17	38.82	54.67
Wheat	17.83	18.48	21.02	22.26	23.11	30.59
Alfalfa	27.99	28.65	31.46	32.86	33.84	43.33
Grain Sorghum	13.95	14.27	15.69	16.41	16.93	21.13
Barley	6.40	6.71	8.03	8.68	9.13	13.16
Oats	6.44	6.76	8.05	8.68	9.11	13.04
			Four-Plow Equipment			
Cotton	31.25	32.38	36.94	39.48	41.13	56.98
Wheat	18.68	19.34	21.88	23.12	23.98	31.45
Alfalfa	27.19	27.85	30.66	32.06	33.04	42.53
Grain Sorghum	15.12	15.42	16.84	17.56	18.09	22.30
Barley	7.32	7.65	8.97	9.61	10.06	14.08
Oats	7.41	7.71	9.01	9.64	10.09	14.04

APPENDIX TABLE VIII

ESTIMATED LABOR REQUIREMENTS PER ACRE BY TYPE OF EQUIPMENT, SEASONS, CROPS AND LEVELS OF FLOOD PROTECTION AS USED IN PROGRAMMING ANALYSIS (HOURS)

Crop and Level of Flood Protection	Two-Plow Equipment					Four-Plow Equipment				
	Jan.-April	May-July	Aug.-Sept.	Oct.-Dec.	Total	Jan.-April	May-July	Aug.-Sept.	Oct.-Dec.	Total
Wheat, Barley, Oats, and Small Grain Grazing - All Levels of Protection[a]	0	1.43	.71	.35	2.49	0	.67	.33	.16	1.16
Alfalfa[a]										
None to 36 Structures	0	3.39	1.16	0	4.55	0	3.02	1.06	0	4.08
Complete Protection	0	3.30	1.16	0	4.46	0	2.96	1.04	0	4.00
Grain Sorghum[a]										
None to 36 Structures	1.69	1.67	0	0	3.34	.89	.88	0	0	1.77
Complete Protection	1.67	1.65	0	0	3.32	.89	.88	0	0	1.77
Cotton[a]										
No Protection	2.50	7.40	0	9.82	19.72	1.27	5.40	0	9.82	16.49
Land Treatment Only	2.50	7.40	0	10.08	19.98	1.27	5.40	0	10.08	16.75
10 Structures	2.50	7.40	0	11.24	21.14	1.27	5.40	0	11.24	17.91
20 Structures	2.50	7.40	0	11.88	21.78	1.27	5.40	0	11.88	18.55
36 Structures	2.50	7.40	0	12.19	22.09	1.27	5.40	0	12.19	18.86
Complete Protection	2.40	7.30	0	16.20	25.90	1.22	5.35	0	16.20	22.77
Forage Sorghum[a]										
None to 36 Structures	1.91	2.07	1.20	0	5.18	.99	1.07	.63	0	2.69
Complete Protection	1.88	2.03	1.20	0	5.11	.98	1.06	.62	0	2.66
Sudan Grass										
None to 36 Structures	1.88	1.43	0	0	3.31	.83	.63	0	0	1.46
Complete Protection	1.88	1.43	0	0	3.31	.83	.63	0	0	1.46

APPENDIX TABLE VIII (Continued)

Crop and Level of Flood Protection	Two-Plow Equipment Jan. April	May-July	Aug.-Sept.	Oct.-Dec.	Total	Four-Plow Equipment Jan.-April	May-July	Aug.-Sept.	Oct.-Dec.	Total
Small Grain Hay[a]										
None to 36 Structures	0	2.41	.71	.35	3.47	0	1.58	.46	.23	2.27
Complete Protection	0	2.41	.71	.35	3.47	0	1.58	.46	.23	2.27
Johnson Grass										
None to 36 Structures	0	.60	0	0	.60	0	.42	0	0	.42
Complete Protection	0	.60	0	0	.60	0	.42	0	0	.42

[a]Excludes all of the harvesting operations which were custom hired.

APPENDIX TABLE IX

ESTIMATED VARIATION IN NET RETURNS PER ACRE ATTRIBUTABLE TO FLOOD DAMAGE BY CROPS AND BY YEARS, NO FLOOD PROTECTION (DOLLARS)

Year	X_1 Wheat	X_2 Cotton	X_3 Alfalfa	X_4 Grain Sorghum	X_5 Oats	X_6 Barley	X_7 Small Grain Pasture Grazed Out	X_8 Small Grain Hay	X_9 Forage Sorghum	X_{10} Sudan Pasture	X_{11} Johnson Grass Pasture
1938	20.85	33.57	33.32	18.17	8.84	8.31	19.04	7.75	5.62	15.51	19.43
1939	30.07	30.07	29.11	13.73	11.66	11.70	18.46	5.20	.66	13.53	18.93
1940	28.22	38.22	37.49	16.83	11.39	11.42	19.14	7.31	4.19	14.13	19.52
1941	19.21	16.33	23.46	8.70	7.30	7.11	17.17	3.28	-4.61	13.83	17.83
1942	18.28	21.47	22.06	11.75	4.83	4.50	16.63	2.98	-2.16	12.44	17.36
1943	20.56	44.41	32.80	18.42	7.26	7.06	18.86	7.48	5.69	15.72	19.27
1944	1.75	14.29	17.64	10.23	4.38	4.03	16.02	1.86	-3.46	11.55	16.84
1945	22.18	41.14	32.12	17.64	7.62	7.44	18.32	6.63	4.91	14.91	18.81
1946	18.97	33.30	31.20	16.53	6.61	6.38	18.60	6.95	3.54	15.49	19.04
1947	9.03	25.74	22.80	16.05	1.75	1.25	17.11	5.12	2.23	14.18	17.78
1948	28.87	26.85	27.44	13.12	10.72	10.71	18.29	4.69	.26	12.89	18.78
1949	21.99	31.31	31.86	14.63	8.55	8.42	18.61	6.41	1.06	15.21	19.06
1950	21.15	42.24	32.79	17.87	7.27	7.08	18.65	7.14	5.21	15.28	19.10
1951	4.35	11.40	17.07	10.45	3.16	2.73	16.42	2.98	-3.15	12.46	17.18
1952	9.49	26.14	22.38	14.91	.78	.22	16.68	4.62	2.35	13.83	17.40
1953	21.77	25.41	32.95	11.52	9.23	9.14	18.00	5.36	-1.68	14.51	18.54
1954	11.19	29.18	23.58	10.82	1.75	1.25	17.29	5.25	2.96	14.55	17.93
1955	5.00	12.16	21.92	4.70	3.66	3.27	16.40	7.15	-8.44	15.26	17.17
1956	28.11	43.44	39.00	18.47	11.40	11.43	19.62	8.34	5.61	15.54	19.92
1957	19.55	40.17	32.13	17.71	6.52	6.28	18.64	6.92	4.94	15.33	19.08
$\bar{X}_i$	18.03	29.34	28.16	14.06	6.73	6.49	17.90	5.67	1.29	14.31	18.45
s_{Xi}	8.48	10.47	6.36	3.83	3.37	3.54	1.08	1.84	4.04	1.22	.92
$\frac{s_{Xi}}{\bar{X}_i} \cdot 100$	47.03	35.70	22.58	27.26	50.05	54.62	6.02	32.37	313.54	8.51	5.00

APPENDIX TABLE X

ESTIMATED VARIATION IN NET RETURNS PER ACRE ATTRIBUTABLE TO FLOODING BY CROP AND BY YEARS, 36 STRUCTURES (DOLLARS)

Year	X_1 Wheat	X_2 Cotton	X_3 Alfalfa	X_4 Grain Sorghum	X_5 Oats	X_6 Barley	X_7 Small Grain Pasture Grazed Out	X_8 Small Grain Hay	X_9 Forage Sorghum	X_{10} Sudan Pasture	X_{11} Johnson Grass Pasture
1938	28.72	50.15	41.13	20.51	12.09	12.15	20.23	9.52	7.94	16.45	21.58
1939	30.50	47.43	38.66	18.95	12.69	12.79	19.89	8.56	6.25	15.83	21.29
1940	30.22	50.98	42.17	20.18	12.75	12.86	20.24	9.45	7.56	16.12	21.60
1941	27.89	43.50	37.72	17.64	11.63	11.67	19.62	8.12	4.61	15.96	21.06
1942	26.92	45.07	36.92	18.58	10.50	10.48	19.35	7.88	5.57	15.57	19.83
1943	28.30	52.36	40.82	20.59	11.66	11.70	20.15	9.40	7.94	16.48	21.42
1944	19.25	39.97	32.38	16.55	10.46	10.44	18.76	6.60	3.66	14.70	20.33
1945	28.42	51.27	40.35	20.37	11.54	11.58	19.94	9.10	7.73	16.29	21.34
1946	27.59	48.96	40.01	20.07	11.31	11.34	20.02	9.17	7.30	16.40	21.40
1947	22.79	43.13	35.37	19.11	8.61	8.48	19.22	8.05	6.42	15.89	20.72
1948	30.18	46.60	38.30	18.80	12.47	12.56	19.85	8.44	6.17	15.67	21.26
1949	28.89	49.21	40.68	19.69	12.08	12.15	20.11	9.19	6.78	16.35	21.49
1950	28.45	51.75	40.83	20.44	11.70	11.75	20.09	9.31	7.80	16.38	21.47
1951	21.16	38.91	33.37	17.81	8.87	8.76	18.98	7.47	4.90	15.40	20.52
1952	23.37	44.23	35.74	19.30	8.64	8.52	19.13	7.97	6.64	15.85	20.65
1953	28.61	46.44	40.74	18.53	12.09	12.15	19.90	8.80	5.54	16.15	21.30
1954	24.63	46.23	36.98	17.70	9.47	9.39	19.49	8.44	7.00	16.12	20.95
1955	22.11	36.65	35.42	14.57	9.61	9.55	19.01	8.91	1.19	16.24	20.54
1956	30.01	51.96	42.28	20.54	12.64	12.74	20.32	9.62	7.86	16.40	21.67
1957	28.15	50.42	40.70	20.41	11.55	11.59	20.11	9.29	7.75	16.39	21.49
$\bar{X}_i$	26.81	46.76	38.53	19.02	11.12	11.13	19.72	8.66	6.33	16.03	21.10
s_{X_i}	3.35	4.59	2.92	1.58	1.39	1.47	.49	.79	1.73	.44	.50
$\frac{s_{X_i}}{\bar{X}_i} \cdot 100$	12.49	9.83	7.58	8.29	12.49	13.17	2.47	9.17	27.28	2.77	2.39

APPENDIX TABLE XI

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF WHEAT AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding)		Upland	
			Amount	Value or Cost (Dollars)	Amount	Value or Cost (Dollars)
Production and Sales						
Wheat	bu.	1.85	23.00	42.55	14.80	27.38
Grazing	AUM	---	.40	---	.30	---
Costs						
Seed	bu.	2.25	1.00	2.25	1.00	2.25
Fertilizer	cwt.	3.65	.50	1.82	.50	1.82
Combining	acre	3.00	1.00	3.00	1.00	3.00
Hauling	bu.	.07	23.00	1.61	14.80	1.04
Machinery, Two-Plow						
Power	hrs.	1.00	2.08	2.08	2.08	2.08
Other	hrs.	.24	1.89	.46	1.89	.46
Machinery, Four-Plow						
Power	hrs.	1.27	.98	1.24	.98	1.24
Other	hrs.	.58	.89	.52	.89	.52
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	12.33	.74	12.33	.74
Four-Plow Equipment	dollars	.06	11.02	.66	11.02	.66
Total						
Two-Plow Equipment	acre	---	---	11.96	---	11.39
Four-Plow Equipment	acre	---	---	11.10	---	10.53
Net Income						
Two-Plow Equipment	acre	---	---	30.59	---	15.99
Four-Plow Equipment	acre	---	---	31.45	---	16.85

APPENDIX TABLE XII

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF COTTON AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production and Sales						
Lint	cwt.	28.00	3.05	85.40	2.07	57.96
Seed	cwt.	2.25	5.09	11.45	3.46	7.78
Total				96.85		65.74
Costs						
Seed	lb.	.15	22.00	3.30	22.00	3.30
Fertilizer	cwt.	3.65	.80	2.92	.80	2.92
Insecticide	times over	2.50	2.00	5.00	2.00	5.00
Dessicant	times over	2.00	1.00	2.00	1.00	2.00
Stripping	hrs.	1.00	5.99	5.99	4.07	4.07
Hauling	cwt.	.25	11.98	3.00	8.14	2.04
Ginning and Wrapping	cwt.	.85	11.98	10.18	8.14	6.92
Grade Loss	cwt.	1.00	1.52	1.52	1.04	1.04
Machinery, Two-Plow						
Power	hrs.	1.00	5.56	5.56	5.56	5.56
Other	hrs.	.196	5.05	.99	5.05	.99
Machinery, Four-Plow						
Power	hrs.	1.27	2.82	3.58	2.82	3.58
Other	hrs.	.38	2.56	.96	2.56	.96
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	28.70	1.72	28.70	1.72
Four-Plow Equipment	dollars	.06	23.70	1.42	23.70	1.42
Total						
Two-Plow Equipment	acre	--	--	42.18	--	35.56
Four-Plow Equipment	acre	--	--	39.87	--	33.25
Net Income						
Two-Plow Equipment	acre	--	--	54.67	--	30.18
Four-Plow Equipment	acre	--	--	56.98	--	32.49

APPENDIX TABLE XIII

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF ALFALFA AS USED IN PROGRAMMING ANALYSIS, BOTTOMLAND (NO FLOODING)

Item	Unit	Price or Cost Per Unit (Dollars)	Amount	Value or Cost (Dollars)
Production and Sales	tons	23.33	3.30	77.00
Costs[a]				
Seed	lbs.	.34	5.00	1.70
Fertilizer	cwt.	1.95	.50	.98
Baling	ton	4.80	3.30	15.84
Hauling	ton	2.50	3.30	8.25
Machinery, Two-Plow				
Power	hr.	1.00	3.90	3.90
Other	hr.	.38	3.55	1.34
Machinery, Four-Plow				
Power	hr.	1.27	3.66	4.65
Other	hr.	.40	3.33	1.34
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	27.74	1.66
Four-Plow Equipment	dollars	.06	28.44	1.71
Total				
Two-Plow Equipment	acre	---	---	33.67
Four-Plow Equipment	acre	---	---	34.47
Net Income				
Two-Plow Equipment	acre	---	---	43.33
Four-Plow Equipment	acre	---	---	42.53

[a]Includes establishment cost prorated over four years.

APPENDIX TABLE XIV

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF GRAIN SORGHUM AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production and Sales	bu.	.90	35.00	31.50	25.00	22.50
Costs						
Seed	lb.	.15	5.00	.75	5.00	.75
Combining	acre	3.00	1.00	3.00	1.00	3.00
Hauling	bu.	.06	35.00	2.10	25.00	1.50
Machinery, Two-Plow						
Power	hrs.	1.00	3.05	3.05	3.05	3.05
Other	hrs.	.27	2.18	.59	2.18	.59
Machinery, Four-Plow						
Power	hrs.	1.27	1.62	2.06	1.62	2.06
Other	hrs.	.43	1.47	.63	1.47	.63
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	14.65	.88	14.65	.88
Four-Plow Equipment	dollars	.06	11.16	.66	11.16	.66
Total						
Two-Plow Equipment	acre	--	--	10.37	--	9.77
Four-Plow Equipment	acre	--	--	9.20	--	8.60
Net Income						
Two-Plow Equipment	acre	--	--	21.13	--	12.73
Four-Plow Equipment	acre	--	--	22.30	--	13.90

APPENDIX TABLE XV

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF BARLEY AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production and Sales	bu.	.80	30.00	24.00	22.00	17.60
Grazing	AUM	---	.40	---	.30	---
Costs						
Seed	bu.	2.00	1.50	3.00	1.50	3.00
Combining	acre	3.00	1.00	3.00	1.00	3.00
Hauling	bu.	.05	30.00	1.50	22.00	1.10
Machinery, Two-Plow						
Power	hrs.	1.00	2.08	2.08	2.08	2.08
Other	hrs.	.27	1.79	.49	1.79	.49
Machinery, Four-Plow						
Power	hrs.	1.27	.98	1.24	.98	1.24
Other	hrs.	.58	.89	.52	.89	.52
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	12.91	.77	12.91	.77
Four-Plow Equipment	dollars	.06	11.02	.66	11.02	.66
Total						
Two-Plow Equipment	acre	---	---	10.84	---	10.44
Four-Plow Equipment	acre	---	---	9.92	---	9.52
Net Income						
Two-Plow Equipment	acre	---	---	13.16	---	7.16
Four-Plow Equipment	acre	---	---	14.08	---	8.08

APPENDIX TABLE XVI

ESTIMATED PRODUCTION AND COST PER ACRE OF SMALL GRAIN GRAZING
AS USED IN PROGRAMMING ANALYSIS,
UPLAND AND BOTTOMLAND
(NO FLOODING)

Item	Unit	Cost Per Unit (Dollars)	Amount	Cost (Dollars)
Production				
Bottomland	AUM	--	3.50	--
Upland	AUM	--	2.50	--
Costs				
Seed	bu.	1.10	1.50	1.65
Machinery, Two-Plow				
Power	hrs.	1.00	2.08	2.08
Other	hrs.	.26	1.89	.49
Machinery, Four-Plow				
Power	hrs.	1.27	.98	1.24
Other	hrs.	.58	.89	.52
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	12.25	.74
Four-Plow Equipment	dollars	.06	9.21	.55
Total				
Two-Plow Equipment	acre	--	--	4.96
Four-Plow Equipment	acre	--	--	3.96

APPENDIX TABLE XVII

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF OATS AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production and Sales						
Oats	bu.	.65	35.00	22.75	25.00	16.25
Grazing	AUM	.40	--	--	.40	--
Costs						
Seed	bu.	1.10	1.50	1.65	1.50	1.65
Combining	acre	3.00	1.00	3.00	1.00	3.00
Hauling	bu.	.05	35.00	1.75	25.00	1.25
Machinery, Two-Plow						
Power	hr.	1.00	2.08	2.08	2.08	2.08
Other	hr.	.26	1.89	.49	1.89	.49
Machinery, Four-Plow						
Power	hr.	1.27	.98	1.24	.98	1.24
Other	hr.	.58	.89	.52	.89	.52
Interest on Annual Investment						
Two-Plow Equipment	dollar	.06	12.25	.74	12.25	.74
Four-Plow Equipment	dollar	.06	9.21	.55	9.21	.55
Total Cost						
Two-Plow Equipment	acre	--	--	9.71	--	9.21
Four-Plow Equipment	acre	--	--	8.71	--	8.21
Net Income						
Two-Plow Equipment	acre	--	--	13.04	--	7.04
Four-Plow Equipment	acre	--	--	14.04	--	8.04

APPENDIX TABLE XVIII

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF SMALL GRAIN HAY AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production						
Hay	ton	19.00	1.50	28.50	1.00	19.00
Grazing	AUM	--	.40	--	.40	--
Costs						
Seed	bu.	1.10	1.50	1.65	1.50	1.65
Baling	ton	4.80	1.50	7.20	1.00	4.80
Hauling	ton	2.40	1.50	3.60	1.00	2.40
Machinery, Two-Plow						
Power	hr.	1.00	3.18	3.18	3.18	3.18
Other	hr.	.31	2.89	.90	2.89	.90
Machinery, Four-Plow						
Power	hr.	1.27	2.08	2.64	2.08	2.64
Other	hr.	.49	1.89	.92	1.89	.92
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	32.37	1.94	32.37	1.94
Four-Plow Equipment	dollars	.06	26.64	1.60	26.64	1.60
Total Costs						
Two-Plow Equipment	acre	--	--	18.47	--	14.87
Four-Plow Equipment	acre	--	--	17.61	--	14.01
Net Income						
Two-Plow Equipment	acre	--	--	10.03	--	4.13
Four-Plow Equipment	acre	--	--	10.89	--	4.99

APPENDIX TABLE XIX

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF FORAGE SORGHUM AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production and Sales						
Forage Sorghum	ton	16.00	2.00	32.00	1.20	19.20
Costs						
Seed	lb.	.15	6.00	.90	6.00	.90
Harvesting	ton	4.80	2.00	9.60	1.20	5.76
Hauling	ton	2.50	2.00	5.00	1.20	3.00
Machinery, Two-Plow						
Power	hr.	1.00	4.69	4.69	—	4.69
Other	hr.	.25	4.26	1.07	—	1.07
Machinery, Four-Plow						
Power	hr.	1.27	2.44	3.10	2.44	3.10
Other	hr.	.43	2.22	.96	2.22	.96
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	37.20	2.24	—	2.24
Four-Plow Equipment	dollars	.06	30.74	1.84	—	1.84
Total Costs						
Two-Plow Equipment	acre	—	—	23.50	—	17.66
Four-Plow Equipment	acre	—	—	21.40	—	15.56
Net Income						
Two-Plow Equipment	acre	—	—	8.50	—	1.54
Four-Plow Equipment	acre	—	—	10.60	—	3.64

APPENDIX TABLE XX

ESTIMATED PRODUCTION, AND COSTS PER ACRE OF SUDAN GRASS PASTURE AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)	Upland Amount	Upland Value or Cost (Dollars)
Production						
Sudan Grazing	AUM	--	3.00	--	1.70	--
Costs						
Seed	lbs.	.06	10.00	.60	10.00	.60
Machinery, Two-Plow						
Power	hr.	1.00	3.04	3.04	3.04	3.04
Other	hr.	.25	2.76	.69	2.76	.69
Machinery, Four-Plow						
Power	hr.	1.27	1.34	1.70	1.34	1.70
Other	hr.	.45	1.22	.55	1.22	.55
Interest on Annual Investment						
Two-Plow Equipment	dollars	.06	14.75	.88	14.75	.88
Four-Plow Equipment	dollars	.06	9.86	.59	9.86	.59
Total Costs						
Two-Plow Equipment	acre	--	--	5.21	--	5.21
Four-Plow Equipment	acre	--	--	3.44	--	3.44

APPENDIX TABLE XXI

ESTIMATED PRODUCTION, AND COSTS PER ACRE OF JOHNSON GRASS PASTURE ON BOTTOMLAND AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Bottomland (No Flooding) Amount	Bottomland (No Flooding) Value or Cost (Dollars)
Production				
Grazing	AUM	--	3.00	--
Costs[a]				
Seed	lbs.	.30	.60	.18
Machinery, Two-Plow				
Power	hr.	1.00	.67	.67
Other	hr.	.18	.60	.11
Machinery, Four-Plow				
Power	hr.	1.27	.40	.51
Other	hr.	.39	.36	.14
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	3.06	.18
Four-Plow Equipment	dollars	.06	3.06	.18
Total Costs				
Two-Plow Equipment	acres	--	--	1.14
Four-Plow Equipment	acres	--	--	1.01

[a]Includes establishment costs prorated over ten years.

APPENDIX TABLE XXII

ESTIMATED PER ACRE PRODUCTION AND COSTS PER ACRE FOR SEEDING AND MAINTAINING A NATIVE GRASS PASTURE AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Upland	
			Amount	Value or Cost (Dollars)
Production				
Grazing	AUM	--	.80	--
Costs[a]				
Seed	lbs.	.60	1.00	.60
Spray	acre	1.50	.10	.15
Machinery, Two-Plow				
Power	hr.	1.00	.32	.32
Other	hr.	.31	.29	.09
Machinery, Four-Plow				
Power	hr.	1.09	.22	.24
Other	hr.	.42	.19	.08
Interest on Investment				
Two-Plow Equipment	dollars	.06	11.86	.71
Four-Plow Equipment	dollars	.06	11.56	.68
Total Costs				
Two-Plow Equipment	acres	--	--	1.87
Four-Plow Equipment	acres	--	--	1.75

[a]Includes establishment costs prorated over ten years.

APPENDIX TABLE XXIII

ESTIMATED ANNUAL SALES, COSTS AND NET INCOME FOR COW-CALF ENTERPRISE, FALL CALVING, AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Quantity per Cow Unit	Price Per Unit (Dollars)	Dollars Per Cow Unit
Sales				
Cull cows	cwt.	1.18	14.25	16.88
Heifer calves	cwt.	1.20	21.50	25.88
Steer calves	cwt.	1.84	23.50	43.24
Total	cow-unit	--	--	86.00
Costs				
Veterinary Charges	cow-unit	--	--	3.36
Minerals	lb.	33.66	.03	1.01
Cottonseed cake	cwt.	.82	3.80	3.12
Selling	cow-unit	--	--	2.11
Bull depreciation	cow-unit	--	--	1.40
Miscellaneous[a]	cow-unit	--	--	18.97
Total				29.97
Net Income	cow-units	--	--	56.03

[a]Includes interest on investment in cattle and facilities, repairs and maintenance of facilities such as buildings and fences.

APPENDIX TABLE XXIV

ESTIMATED ANNUAL SALES, COSTS AND NET INCOME FOR COW-CALF ENTERPRISE, SPRING CALVING, AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Quantity Per Cow Unit	Price Per Unit (Dollars)	Dollars Per Cow Unit
Sales				
Cull Cows	cwt.	1.18	13.50	15.93
Heifer Calves	cwt.	1.29	21.00	27.09
Steer Calves	cwt.	2.13	23.00	48.99
Total	cow-unit	--	--	92.01
Costs				
Veterinary Charges	cow-unit	--	--	3.36
Minerals	lb.	33.66	.03	1.01
Cottonseed Cake	cwt.	2.46	3.80	9.33
Selling	cow-unit	--	--	2.30
Bull Depreciation	cow-unit	--	--	1.40
Miscellaneous[a]	cow-unit	--	--	15.72
Total				33.12
Net Income	cow-unit	--	--	58.89

[a]Includes interest on capital investment in cattle and facilities, and repair and maintenance of facilities such as buildings and fences.

APPENDIX TABLE XXV

ESTIMATED ANNUAL SALES, COSTS AND NET INCOME FOR STEER ENTERPRISE (BUY IN SEPTEMBER AND SELL IN JULY) AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Quantity Per Steer	Price Per Unit (Dollars)	Dollars Per Steer
Sales	cwt.	7.60	21.00	159.60
Less 1 percent for death loss				158.00
Costs				
Calf	cwt.	4.50	23.00	103.50
Veterinary Charges	steer	--	--	1.45
Minerals	lb.	16.30	.03	.49
Cottonseed Cake	cwt.	.69	3.80	2.62
Buying and Selling	cwt.	12.10	.50	6.06
Miscellaneous[a]	steer	--	--	11.13
Total	steer	--	--	125.25
Net Income	steer	--	--	32.75

[a]Includes interest on capital invested in steers and facilities, and repair and maintenance of facilities such as buildings and fences.

APPENDIX TABLE XXVI

ESTIMATED ANNUAL SALES, COSTS AND NET INCOME FOR STEER ENTERPRISE (BUY IN OCTOBER AND SELL IN MAY) AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Quantity Per Steer	Price Per Unit (Dollars)	Dollars Per Steer
Sales	cwt.	7.16	22.50	161.10
Less 1 percent for death loss				159.49
Costs				
Calf	cwt.	4.50	22.50	101.25
Veterinary Charges	steer	--	--	1.45
Minerals	lb.	16.30	.03	.49
Cottonseed Cake	cwt.	.69	3.80	2.62
Buying and Selling	cwt.	11.66	.50	5.83
Miscellaneous[a]	steer	--	--	11.88
Total	steer	--	--	123.52
Net Income	steer	--	--	35.97

[a]Includes interest on capital invested in steers and facilities, and repairs and maintenance of facilities such as buildings and fences.

APPENDIX TABLE XXVII

ESTIMATED ANNUAL SALES, COSTS AND NET INCOME FOR STEER ENTERPRISE (BUY IN OCTOBER AND SELL IN MARCH) AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Quantity Per Steer	Price Per Unit (Dollars)	Dollars Per Steer
Sales	cwt.	6.14	22.25	136.62
Less 1 percent for death loss				135.25
Costs				
Calf	cwt.	4.50	22.50	101.25
Veterinary Charges	steer	--	--	1.45
Minerals	lb.	8.00	.03	.24
Buying and Selling	cwt.	10.64	.50	5.32
Miscellaneous[a]	steer	--	--	11.43
Total	steer			119.69
Net Income	steer	--	--	15.56

[a]Includes interest on capital invested in steers and facilities, and repairs and maintenance of facilities such as buildings and fences.

APPENDIX TABLE XXVIII

ESTIMATED ANNUAL SALES, COSTS, AND NET INCOME FROM STEER ENTERPRISE (BUY IN OCTOBER AND SELL IN OCTOBER) AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Quantity Per Steer	Price Per Unit (Dollars)	Dollars Per Steer
Sales	cwt.	8.30	20.50	170.15
Less 1 percent for death loss				168.45
Costs				
Calf	cwt.	4.50	23.00	103.50
Veterinary Charges	steer	---	---	1.70
Minerals	steer	22.00	.03	.66
Cottonseed Cake	cwt.	2.25	3.80	8.55
Buying and Selling	cwt.	12.80	.33	4.22
Miscellaneous	steer	---	---	9.24
Total				127.87
Net Income	steer	--	--	40.58

APPENDIX TABLE XXIX

ESTIMATED LABOR REQUIREMENTS PER ACRE FOR IRRIGATED CROPS, BY IRRIGATION AND NON-IRRIGATION ACTIVITIES, AS USED IN PROGRAMMING ANALYSIS (HOURS)

Crop and Kind of Activity	Two-Plow Equipment					Four-Plow Equipment				
	Jan.-April	May-July	Aug.-Sept.	Oct.-Dec.	Total	Jan.-April	May-July	Aug.-Sept.	Oct.-Dec.	Total
Wheat										
Irrigation	.70	.70	0.00	.70	2.10	.70	.70	0.00	.70	2.10
Non-Irrigation	0.00	1.43	.71	.35	2.49	0.00	.93	.33	.16	1.42
Total	.70	2.13	.71	1.05	4.59	.70	1.63	.33	.86	3.52
Cotton										
Irrigation	0.00	1.40	1.40	0.00	2.80	0.00	1.40	1.40	0.00	2.80
Non-Irrigation	2.40	9.80	0.00	28.68	40.88	1.22	7.85	0.00	28.68	37.75
Total	2.40	11.20	1.40	28.68	43.68	1.22	9.25	1.40	28.68	40.55
Alfalfa										
Irrigation	0.00	1.40	2.10	0.00	3.50	0.00	1.40	2.10	0.00	3.50
Non-Irrigation	.55	3.60	3.00	0.00	7.15	.55	3.60	2.90	0.00	7.05
Total	.55	5.00	5.10	0.00	10.65	0.55	5.00	5.00	0.00	10.55
Grain Sorghum										
Irrigation	0.00	2.10	0.00	0.00	2.10	0.00	2.10	0.00	0.00	2.10
Non-Irrigation	2.09	2.17	0.00	0.00	4.26	.89	1.14	0.00	0.00	2.03
Total	2.09	4.27	0.00	0.00	6.36	.89	3.24	0.00	0.00	4.13

APPENDIX TABLE XXX

ESTIMATED INVESTMENT IN IRRIGATION EQUIPMENT AND ANNUAL FIXED COSTS BY SIZES OF IRRIGATION SYSTEMS[a]
(DOLLARS)

Item	Size of Irrigation System 20 Acres	40 Acres	100 Acres	160[b] Acres
Investment				
Pump and Motor	640	1,470	2,400	3,870
Pipe, mainline	512	512	1,452	1,964
Pipe, laterals	832	1,248	2,112	3,360
Sprinklers	96	252	594	846
Risers	19	29	50	79
Misc. Items[c]	25	50	100	150
Total Investment	2,124	3,561	6,708	10,269
Average Annual Investment	1,062	1,780	3,354	5,134
Annual Fixed Cost				
Depreciation (13 years)	163	274	516	790
Taxes & Insurance (2%)	21	36	67	103
(Interest 6%)	64	107	201	308
Total	248	417	784	1,201

[a]Systems are somewhat over-designed to enable greater acreage by pumping more hours.

[b]40 and 100 acre systems combined.

[c]Elbows, t-joints, small tools, etc.

APPENDIX TABLE XXXI

ESTIMATED PRODUCTION, SALES, COSTS, AND NET INCOME PER ACRE OF IRRIGATED WHEAT USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Amount	Value or Cost (Dollars)
Production and Sales				
Wheat	bu.	1.85	40.00	74.00
Grazing	AUM	--	.80	--
Costs				
Seed	bu.	2.25	1.00	2.25
Fertilizer				
0-45-0	cwt.	3.95	.60	2.37
33-0-0	cwt.	4.00	1.00	4.00
Irrigation (4" application)				
Fuel and Oil	times over	2.77	2.50	6.92
Maintenance	acre	2.15	1.00	2.15
Combining	acre	4.00	1.00	4.00
Hauling	bu.	.07	40.00	2.80
Machinery, Two-Plow				
Power	hrs.	1.00	2.08	2.08
Other	hrs.	.26	1.89	.50
Machinery, Four-Plow				
Power	hrs.	1.27	1.20	1.52
Other	hrs.	.54	1.09	.39
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	22.83	1.43
Four-Plow Equipment	dollars	.06	23.97	1.44
Total				
Two-Plow Equipment	acre	--	--	28.50
Four-Plow Equipment	acre	--	--	28.04
Net Income				
Two-Plow Equipment	acre	--	--	45.50
Four-Plow Equipment	acre	--	--	45.96

APPENDIX TABLE XXXII

ESTIMATED PRODUCTION, SALES, COSTS, AND NET INCOME PER ACRE OF IRRIGATED COTTON AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Amount	Value or Cost (Dollars)
Production and Sales				
Lint	cwt.	28.00	7.30	204.40
Seed	cwt.	2.25	12.20	27.45
Total				231.85
Costs				
Seed	lbs.	.15	22.00	3.30
Fertilizer	cwt.	4.00	1.00	4.00
Fertilizer	cwt.	4.45	1.50	6.68
Fertilizer	cwt.	3.65	--	
Insecticide	times over	3.00	5.00	15.00
Dessicant	times over	3.00	1.00	3.00
Irrigation (4" application)				
Fuel and Oil	times over	2.77	4.00	11.08
Maintenance	acre	2.15	1.00	2.15
Stripping	cwt.	1.00	14.34	14.34
Hauling	cwt.	.25	28.68	7.17
Ginning and Wrapping	cwt.	.85	28.68	24.38
Grade Loss	cwt.	1.00	3.60	3.60
Machinery, Two-Plow				
Power	hrs.	1.00	5.56	5.56
Other	hrs.	.20	5.05	.99
Machinery, Four-Plow				
Power	hrs.	1.27	2.82	3.58
Other	hrs.	.38	2.56	.96
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	51.94	3.12
Four-Plow Equipment	dollars	.06	46.94	2.82
Total				
Two-Plow Equipment	acre	--	--	104.37
Four-Plow Equipment	acre	--	--	102.06
Net Income				
Two-Plow Equipment	acre	--	--	127.48
Four-Plow Equipment	acre	--	--	129.79

APPENDIX TABLE XXXIII

ESTIMATED PRODUCTION SALES, COSTS, AND NET INCOME PER ACRE OF IRRIGATED GRAIN SORGHUM AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Amount	Value or Cost (Dollars)
Production and Sales				
Grain Sorghum	bu.	.90	69.00	62.10
Costs				
Seed	lbs.	.15	10.00	1.50
Fertilizer	cwt.	3.95	.50	1.98
Fertilizer	cwt.	4.00	2.00	8.00
Irrigation (4" application)				
Fuel and Oil	times over	2.77	3.00	8.31
Maintenance		2.15	1.00	2.15
Combining	acre	4.00	1.00	4.00
Hauling	bu.	.06	69.00	4.14
Machinery, Two-Plow				
Power	hrs.	1.00	3.92	3.92
Other	hrs.	.21	3.37	.69
Machinery, Four-Plow				
Power	hrs.	1.27	1.86	2.36
Other	hrs.	.46	1.69	.77
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	24.73	1.48
Four-Plow Equipment	dollars	.06	24.81	1.49
Total				
Two-Plow Equipment	acre	--	--	36.17
Four-Plow Equipment	acre	--	--	34.70
Net Income				
Two-Plow Equipment	acre	--	--	25.93
Four-Plow Equipment	acre	--	--	27.40

APPENDIX TABLE XXXIV

ESTIMATED PRODUCTION, SALES, COSTS AND NET INCOME PER ACRE OF IRRIGATED ALFALFA AS USED IN PROGRAMMING ANALYSIS

Item	Unit	Price or Cost Per Unit (Dollars)	Amount	Value or Cost (Dollars)
Production and Sales				
Alfalfa Hay	tons	23.33	6.50	151.64
Costs[a]				
Seed	lbs.	.34	5.00	1.70
Fertilizer	cwt.	3.95	1.75	6.91
Insecticide	times over	3.00	2.00	6.00
Irrigation (4" application)				
Fuel and Oil	times over	2.77	5.00	13.85
Maintenance	acre	2.15	1.00	2.15
Baling	ton	4.80	6.50	31.20
Hauling	ton	2.50	6.50	16.25
Machinery, Two-Plow				
Power	hr.	1.00	6.80	6.80
Other	hr.	.38	6.23	2.36
Machinery, Four-Plow				
Power	hr.	1.27	6.46	8.20
Other	hr.	.41	5.91	2.43
Interest on Annual Investment				
Two-Plow Equipment	dollars	.06	56.40	3.38
Four-Plow Equipment	dollars	.06	57.92	3.48
Total				
Two-Plow Equipment	acre	--	--	90.60
Four-Plow Equipment	acre	--	--	92.17
Net Income				
Two-Plow Equipment	acre	--	--	61.04
Four-Plow Equipment	acre	--	--	59.47

[a]Includes establishment costs prorated over four years.

VITA

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