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SOCIOECONOMIC ANALYSIS OF A MAJOR REHABILITATION OF IRRIGATION AND WATER MANAGEMENT SYSTEMS IN EASTERN IDAHO

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ABSTRACT

High water tables caused by overuse of irrigation water have created physical and socioeconomic problems in some areas of Southeastern Idaho. In one area, the Snake River Fan of Jefferson County, the irrigation systems and management practices were investigated to determine their contribution to the high water table problem. The investigations showed that the present systems are quite inefficient due to soils with high water intake rates, long irrigation runs and duplication of many irrigation canals.

Engineering and economic analyses were made to determine the least cost method of rehabilitating the present system and to determine the capability of the area to support various rehabilitation schemes. Both analyses utilized linear programming models to determine optimum solutions subject to various social and legal constraints.

The results obtained indicate that present practices are the most economical for the present cost and availability of water. Wells equipped with high head pumps supplying sprinkler systems appear to be the best alternative if a marked increase in overall irrigation efficiency is to be achieved. Farm sizes of 160 acres or more would be necessary to produce enough net income to support any major rehabilitation scheme.

INTRODUCTION

Irrigated agriculture is by far the largest user of water in Idaho. Further expansion of irrigated agriculture will increase the demand for water in the future.

The constitution of Idaho allows for the appropriation and diversion of water for beneficial uses, but it does not require the efficient use of water. It has long been established that irrigation has a high priority among beneficial uses; however, inefficiencies in irrigation systems and practices result in excessive use of water. Overuse of water has created physical and socioeconomic problems in some areas of Idaho. These problems, coupled with the fact that water is a limited resource, have created the need to evaluate the excessive use of water for irrigated agriculture.

The Problem

One area where water is in abundant supply and to which this study is directed lies in Southeastern Idaho. Portions of Southeastern Idaho are faced with a problem of high water tables during the irrigation season. High water tables can cause drainage problems during the irrigation season and also damage adjacent to residential and commercial properties. The problem results from excessive use of water on farms in addition to a dense network of canal systems.

Objectives

In order to improve the efficiency of water use and solve problems associated with high water tables, it is important that water management practices be improved. Various methods can be suggested to improve efficiency at the farm level and also for the water delivery system. Whatever measures taken will affect the economy of the area and also involve some institutional and legal aspects. The effect of any corrective measure on existing economic conditions must be studied in order to determine whether the area can afford to support the change in the existing system.

The specific objectives of this study are:

1) To identify and evaluate irrigation systems and water management practices under the present farm organization in the area.

2) To evaluate long term adjustments in farm organization, cropping patterns, costs, and income if improved water management is introduced.

3) To investigate institutional and legal changes which will be necessary in encouraging greater efficiency of water use.

4) To evaluate the effects that saved upstream water will have on the recharge rates of downstream wells and streamflow in addition to the economic benefits which may be generated from such transfer.

Study Area

The study area shown in Figure 1 is located in Jefferson County in Southeastern Idaho. The area encompasses approximately 100,000 acres and is bounded on the northeast and west by a large bend in the Snake River and on the south by the Jefferson-Bonneville County line.

This entire portion of Jefferson County is an alluvial fan and soils are usually quite shallow, underlain by sands and coarse gravels. Several areas have ten to twenty feet of topsoil whereas other areas have only a few inches. The soils are medium to coarse textured with high water intake rates and low water holding capacities.

The area has moderately warm summers and severe winters. The temperature averages about 68 degrees F in July and 17 degrees F in January, and 0 degrees F temperature or lower occur at least 16 days of each year. The average precipitation in the area is 8.7 inches per annum and growing season is approximately 123 days. Irrigation water is diverted from the South Fork of the Snake River. More than twenty canal companies convey and distribute water to farms through a complex network of unlined channels. Almost no water is measured as it is delivered to farm units where it is applied by means of gravity type application systems.

Procedures

The procedures used in selecting more efficient irrigation systems and adjustments in farm organization and cropping patterns are generalized procedures applicable to other regions.

The first objective was accomplished by obtaining data from experiments conducted in the area supplemented with data from secondary sources. The methodology used to specify least cost irrigation systems involved a two-stage linear-dynamic programming approach (2).

The second objective was accomplished by obtaining data from interviewing 51 farm operators in the area. Information pertaining

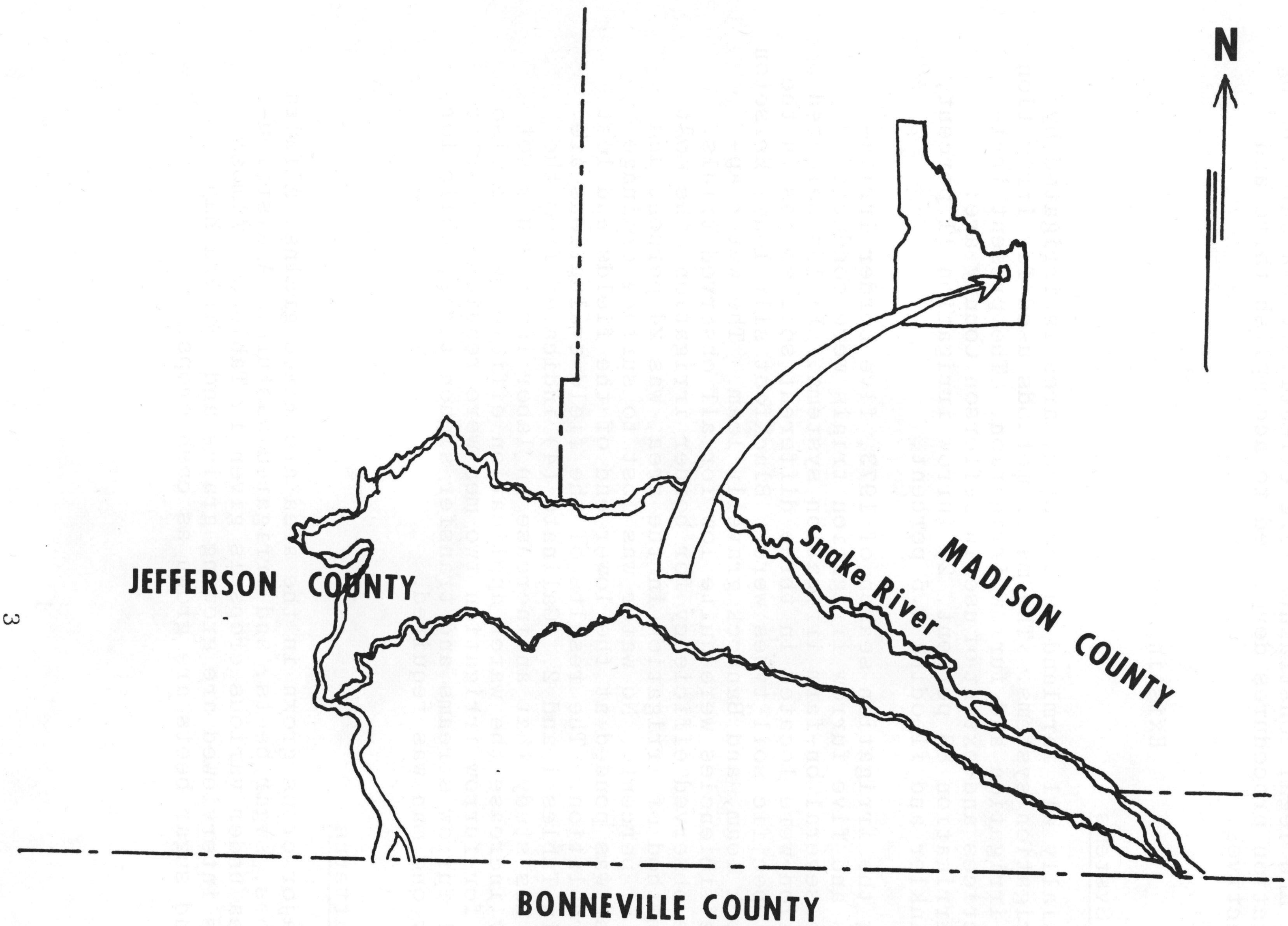

Figure 1. Map of the study area, Jefferson County, Idaho

to various aspects of farm operations such as fertilizer use, water use and other input factors in addition to crop production was obtained. Optimum farm organization and cropping pattern allternatives were selected by means of a linear programming routine involving parametric programming (5).

The results of imposing various hypothetical physical, institutional and legal constraints were effectively evaluated using the optimization procedures developed to accomplish third and fourth objectives.

Existing Practices

Irrigation Systems

Essentially all farmland in the study area is irrigated by surface irrigation systems. The major methods used for irrigation are border irrigation and furrow irrigation. The present irrigation practices and extent of use in Jefferson County are: 1) border irrigation 88 percent, 2) furrow irrigation 11 percent, and 3) sprinkler and flooding 0.5 percent.

During the irrigation season of 1973, five border irrigation trials and five furrow irrigation trials were conducted to evaluate several on-farm irrigation systems. Fields selected for evaluation were located in three different soil series in the area. The specific soil types were: Blackfoot silt loam, Heiseton loam, Bannock loam, and Bannock gravelly loam. The water application efficiencies were quite low for all observed trials. The average observed efficiency for border irrigation, the most prevalent method of irrigation in the area, was 24 percent and for furrow 51 percent. No water was lost to surface drainage as all water was ponded at the lower end of the fields and lost to deep percolation. The results of the field evaluations are presented in Tables 1 and 2. Galinato (4) indicated from the results of his study that an increase in labor input would not necessarily increase the water application efficiency. He also noted that for furrow irrigation two men were required to start and control furrow streams and transfer siphon tubes, while for border only one man was required.

Cropping Patterns

The major crops grown in the area are mixed grains, alfalfa hay, potatoes, sugar beets, and irrigated pasture. A distribution of area under various crops is given in Table 3. Almost all farmers interviewed are growing grains and alfalfa hay. Potatoes and sugar beets are grown as cash crops.

Table 1. Water application efficiencies and water losses in the Snake River Fan, Jefferson County, Idaho (border irrigation)

Trial	Water Applied (inches)	Water Stored (inches)	Water Application Efficiencies* (%)	Runoff (inches)	Deep percolation (inches)	Total Lost (%)**
1	12.2	3.48	28	0.00	8.72	72
2	8.5	2.75	32	0.00	5.75	68
3	13.2	2.54	19	0.00	10.66	81
4	14.4	2.99	21	0.00	11.41	79
5	16.2	3.14	19	0.00	13.06	81
Average	12.5	2.98	24	0.00	9.92	76

$*E_w = \frac{\text{Water Stored}}{\text{Water Applied}} \times 100$

**Percentage of water delivered

(After Galinato, 1974 (4))

Table 2. Water application efficiencies and water losses in the Snake River Fan, Jefferson County, Idaho (furrow irrigation)

Trial	Water Applied (inches)	Water Stored (inches)	Water Application Efficiencies* (%)	Runoff (inches)	Deep percolation (inches)	Total Lost (%)**
1	4.3	2.04	47	0.00	2.26	53
2	3.6	1.84	51	0.00	1.76	49
3	3.5	2.04	58	0.00	1.46	42
4	4.1	1.84	45	0.00	2.26	55
5	2.8	1.51	54	0.00	1.29	46
Average	3.8	1.85	51	0.00	1.81	49

*$E_w = \frac{\text{Water Stored}}{\text{Water Applied}} \times 100$

**Percentage of water delivered

(After Galinato, 1974 (4))

Table 3. Area distribution of crops grown in the Snake River Fan, Jefferson County, Idaho, 1971*

Crops	Area Distribution %
Alfalfa Hay	38.8
Mixed Grain	31.1
Irrigated Pasture	20.6
Potatoes	8.1
Sugar Beets	1.0
Corn	0.4
Total	100.00

*After Brockway (1)

Economic Situation

To determine the economic efficiency level of present farm operations, representative farm budgets were formulated. These budgets were formulated for each crop to determine the net return to land and management under existing farm organization for 80, 160, and 320 acre farms in the study area. Net returns per acre to land and management for major crops in the area are presented in Table 4. Higher per acre returns to land and management on larger farms can be attributed to economies of size.

Table 4. Returns to fixed inputs for different sized representative farms, Snake River Fan, Jefferson County, Idaho 1973*

Farm Size (Acres)	Net Return Per Acre			
	Grain	Alfalfa	Potatoes	Sugar Beets
80	$ 73.45	$30.08	$214.22	$51.96
160	95.68	53.51	251.33	62.67
320	103.03	59.95	271.49	66.08

*Gross income minus variable costs = returns to fixed inputs

Optimum attainable income under the present farm organization with the present constraints on inputs was also determined by using linear programming. Four different farm organizations were stipulated for each farm size and returns were determined under each type of organization. The crops included in the program were grain, alfalfa, sugar beets and potatoes. The return to land and management per acre under present irrigation systems and alternative farm organizations are given in Table 5.

Farm operations with livestock included in the farm organization generated more income than farm operations without livestock. Income per acre increased with increasing farm sizes. The net incomes of the representative farms under the present type of system provide a basis for studying the rehabilitation of the area.

Proposed System Changes

Present irrigation systems and practices within the study area are responsible for problems of high water tables in the area. The basic reasons for the low efficiencies of the present irrigation systems are: high water intake rate of the soils, excessive use of water, long irrigation runs and duplication of distribution canals. The first factor is not within the control of farm operators, but systems could be modified to decrease the loss of water to deep percolation. The second factor is related to the management of water and can be controlled by irrigation. The remaining factors are related to system design which can be modified in various ways.

Modification of Existing System

Modification of on-farm irrigation systems and management practices can greatly improve the operational characteristics of the system. System and management modification considered in the study included the size of stream applied to a furrow or border, the application time and the length of irrigation run. Various recommendations are based upon field investigations in the study area conducted by Galinato (4).

Recommended modifications for furrow irrigation systems on two soil types within the area are contained in Table 6. The data show that length of run and application time should be decreased and the stream size increased. The efficiency on the Heiseton Loam soils would be increased while there would be a slight decrease on the Blackfoot Silt Loam. However, there is a large decrease in the amount of water lost to deep percolation from each system. Such a decrease would help alleviate the high water table problem. Provision would have to be made for drainage or reuse of increased surface runoff.

Table 5. Linear programming solution of net income per acre for three representative farm sizes under four alternative organizations, Jefferson County, Idaho

Representative Farm Size in Acres	Net Income Per Acre*			
	Alternative Organization No. 1 Crops Only	Alternative Organization No. 2 Crops, Beef & Hogs	Alternative Organization No. 3 Crops, Beef & Dairy Operation	Alternative Organization No. 4 Crops & Beef
80	$ 76.80	$178.00	$ 77.25	$ 80.25
160	128.90	145.00	130.40	131.85
320	134.70	**	**	136.30

*Payments to management and interest on land investments have not been deducted from net income

**Under the given resource restrictions the two alternative organizations were not profitable at this level

Table 6. Present and recommended characteristics for furrow irrigation systems, Snake River Fan, Jefferson County, Idaho

Soil Type	System	Length of run (ft)	Application Time (min)	Stream Size (gpm)	Deep Percolation (%)	Runoff (%)	Efficiency (%)
Blackfoot Silt Loam	Present	1260	225	30	37	0	63
	Recommended	900	163	38	3	36	61
Heiseton Loam	Present	1150	215	30	35	0	65
	Recommended	600	90	37	2	18	80

Efficiencies of border irrigation systems within the study area could also be substantially improved by system modification. Present and recommended system characteristics are listed in Table 7. Border length and width should be reduced for all systems. The stream size applied should be adjusted for the proposed border dimensions using the unit stream concept set forth by Criddle et al (3). Adjustment of stream size and application time would allow for the water to be applied more uniformly over the entire border with less loss as indicated by the increased efficiencies estimated for the proposed system modifications. Again, the increased efficiencies accompanying the proposed modifications would result in less water lost to deep percolation.

The proposed modifications for the examples given are realistic considering the soils, slopes, and crops involved. Almost all the recommendations include shortening the length of irrigation run. Such a practice would be easily accomplished. However, it would be approached with reluctance by farmer irrigators as it would involve cross ditches in the fields that would require maintenance and increase the time required for field operations.

Farmers must be willing to invest labor and capital for irrigation system modification. An alternative is to invest in new methods of irrigation. Such action depends upon the costs involved with various alternative systems. Rehabilitation of several farm units must also take into account the irrigation distribution system used to convey and distribute water to individual units.

Major System Alterations

A two-stage dynamic, linear programming model was developed to determine minimum cost irrigation systems that would exist for a given set of conditions (2). The model utilizes both physical and economic data to specify the least cost configuration of distribution and application system components. The configuration specified is subject to physical, social and legal constraints of delivering water to supply crop needs in a large multi-farm area.

The model was applied to the North Rigby Irrigation District located in Jefferson County near Rigby, Idaho.

Four types of water supply and distribution systems were considered. They are gravity, high pressure pipeline, wells with low head (pressure) pumps and wells with high head (pressure) pumps. Costs included in the analysis are costs incurred within the district and include both the costs of conveying and applying the water plus public costs such as those for bridges over canals.

Table 7. Present and recommended characteristics for border irrigation systems, Snake River Fan, Jefferson County, Idaho

Soil Type	Crop	System	Border Length (ft)	Border Width (ft)	Stream Size (cfs)	Application Time (min)	Efficiency (%)
Blackfoot Silt Loam	Alfalfa	Present	750	58	2.4	200	35
		Recommended	750	50	3.4	120	78
Bannock Loam	Alfalfa	Present	1270	65	4.2	370	22
		Recommended	380	35	2.1	50	52
Bannock Gravelly Loam	Barley	Present	1200	66	7.8	195	25
		Recommended	600	35	4.2	40	60

The gravity distribution system consists of either unlined channels, lined channels or pipelines supplying water to either border, furrow or sprinkler systems. Wells with low head pumps would also supply water to any of the applications systems. The high pressure pipeline and wells with high pressure pumps are restricted to deliver water only to sprinkler systems.

Alternative application systems considered in the model and their individual characteristics are described in Tables 8 and 9. Optimum solutions from the linear programming model for various efficiency levels are presented in Table 10. The results indicate that at lower levels of efficiency, the existing irrigation system consisting of unimproved gravity systems is the cheapest to operate and maintain. At higher levels of efficiency, however, most of the area would be irrigated by sprinklers. For example, at the 60 percent level of efficiency, only 2 percent of the area in the North Rigby Irrigation District would remain under unimproved gravity with the rest being irrigated by sprinklers. The distribution system at this level does not change significantly. The cost increase is quite sharp as efficiency level approaches 70 percent limit. This sharp increase in cost is due to a radical change in the distribution system required to meet the 70 percent efficiency level.

Another alteration would be to abandon the present gravity distribution system and install wells with low and/or high pressure pumps for supplying water as an abundant supply of groundwater exists beneath the study area. The cost per acre for low head well supply at different levels of efficiencies is given in Table 11. The results show that costs for low head well supply systems remain nearly constant over the entire range of efficiencies, because increased costs for more efficient application systems are offset by savings in pumping costs.

The costs per acre for high head well supply and high pressure pipelines are much lower at 70 percent efficiency than the cost of low head supply and gravity distribution systems. The cost per acre for wells with high head pumps supplying at 70 percent efficiency is $69.40. Comparing this cost figure with data of Table 10 reveals that it is less than the cost of the gravity supply system operating at an efficiency of 20 percent. The cost per acre for the high pressure pipeline system is $75.80 which is lower than the cost of gravity distribution operating at an efficiency of 40 percent. The cost versus efficiency relationships for all supply systems are shown in Figure 2.

It appears from the above analysis that the most economic alternative to increase the irrigation efficiency markedly is to use wells with high head pumps to supply water to sprinkler systems. However, the rehabilitation of the area whether through modifications of the existing systems or through major alteration, depends upon the economic capability of the area. Net

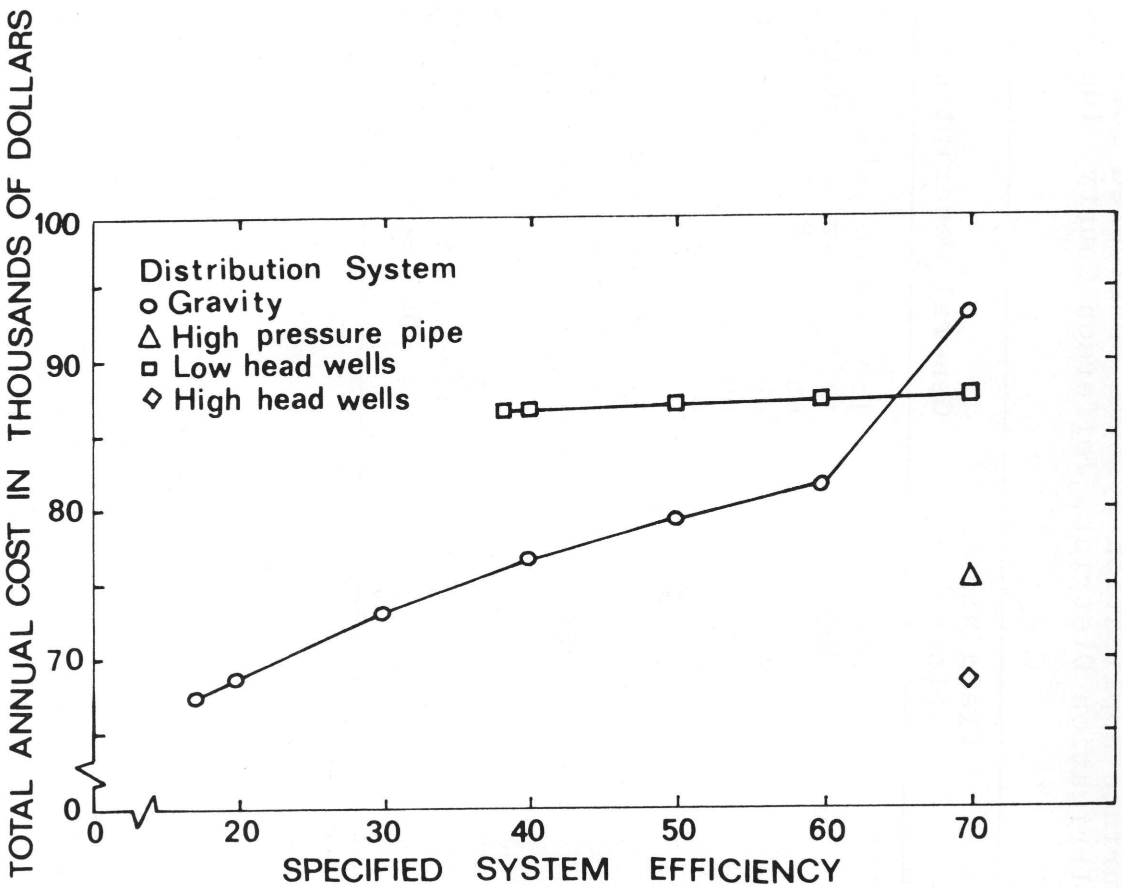

Figure 2. Annual cost per acre for various methods of rehabilitation of various specified system efficiencies

Table 8. Surface application systems considered for North Rigby Irrigation District, Jefferson County, Idaho*

System Type	Field Length (feet)	Field Width (feet)	General Description
Unimproved Gravity	1300 650 400	600 500 250	The system consists of poorly maintained earthen ditches with earthen and wooden structures and portable canvas dams used for water control. Maximum allowable length of irrigation run is 1300 feet.
Improved Gravity	1350 650 400	600 500 250	The system consists of well maintained earthen ditches with concrete and metal structures used for water control. Maximum allowable length of irrigation run is 650 feet. A cross ditch is specified if irrigation run is in excess of 650 feet.

*After Busch (2)

Table 9. Sprinkler application systems considered for North Rigby Irrigation District, Jefferson County, Idaho*

System Type	Mainline Length (feet)	Area Served by Mainline (acres)	Lateral Length (feet)	General Description
Hand-Line Sprinkler	2640	160	1300	The layout of the system consists of hand carried laterals supplied by a permanent or semi-permanent mainline.
	2640	80	1300	
	1960	50	1300	
	1320	40	700	
Side-Roll Sprinkler	2640	160	1300	The layout of the system consists of mechanically moved laterals supplied by a permanent or semi-permanent mainline
	2640	80	1300	
	1960	50	1300	
	1320	40	700	

*After Busch (2)

Table 10. Percentage of the area under various application systems at various efficiency levels for gravity distribution systems, North Rigby Irrigation District, Jefferson County, Idaho

System Efficiency In Percent	Annual Cost Per Acre*	Percent of Area Under Different Application Systems			
		Unimproved Gravity	Improved Gravity	Hand-Line Sprinkler and Pump	Side Roll Sprinkler and Pump
17	$68.13	100	-	-	-
20	69.55	83	7	-	10
30	73.99	54	5	14	27
40	77.51	37	-	19	44
50	80.30	15	-	19	66
60	82.59	2	-	19	79
70	94.02	-	-	19	81

*The cost per acre includes cost of application and distribution system. This cost also includes those costs that are not directly associated with irrigation. However, these costs are included because ultimately they are paid by the farmer through taxes. These costs are: cost of all bridges, cost of right-of-ways and reconstruction of roads. Therefore, the actual direct cost to farmers during irrigation is less than shown.

Table 11. Cost per acre and percentage of the area under application systems at various efficiency levels for low head well supply, Jefferson County, Idaho

System Efficiency In Percent	Annual Cost Per Acre*	Percent of Area Under Different Application Systems			
		Unimproved Gravity	Improved Gravity	Hand-Line Sprinkler and Pump	Side Roll Sprinkler and Pump
38.4	$87.52	54	-	19	27
40.0	87.56	49	-	19	32
50.0	87.79	24	-	19	57
60.0	87.95	8	-	19	73
70.0	88.52	-	-	19	81

*Includes cost of well and application systems incomes of the farmers in the area will determine whether they are able to support any major rehabilitation of the area. Any system change should be economically feasible.

ECONOMIC IMPACT

In analyzing the impact of alternative irrigation systems on the local economy of the area, a linear programming technique was used. Different resource allocation plans were chosen for different farm sizes and the economic implications of alternative methods of rehabilitating the area were analyzed for each representative farm. The representative farms were of the sizes of 80, 160 and 320 acres. The actual distribution of farm sizes for the entire area was about 30 percent of farms of 80 acres, 45 percent about 160 acres and 25 percent about 320 acres and above. Incomes on these representative farms under present farm organization were determined (see Tables 4 and 5) which provided a basis for evaluating the economic feasibility of rehabilitating the area.

One of the methods suggested by Brockway and de Sonneville (1) in rehabilitating the area was to reduce the water supply by 20 percent or more. The optimal combination of alternative irrigation systems obtained in the previous section also suggest that the problem of the area can be solved by using water more efficiently which can be achieved by reducing water application time and by incorporating sprinkler systems along with modified distribution systems.

Decrease in Water Supply

The effect of a decrease in water supply on the income of the farms was analyzed by using a parametric programming routine. Water was decreased at 5 percent intervals to a maximum decrease of 75 percent. Only two percentage levels are given here to represent a decrease in water, the 25 percent and 50 percent levels. The decline in water had significant effect on the income of the farmers as presented in Table 12. The main reason for the loss of income is land kept out of production. It was found that when water was decreased on the representative farms it was more profitable to keep land idle than to change to a rotation or cropping pattern requiring less water. A 25 percent reduction in water supply would leave about 22 percent of the tillable land idle and about half of the tillable land would be left idle at a 50 percent decrease in water supply. Of course, to suggest that farm land should be left idle in order to solve the water table problem is not a realistic solution. The above situation merely indicates that the area cannot adapt to a situation of decreased water supply without introducing some changes in water application techniques. One of the methods of rehabilitating the area was the introduction of sprinkler systems along with improved distribution systems.

Table 12. Reduction in income per acre as a result of reduction in water supply, Jefferson County, Idaho

Farm Size (Acres)	Reduction in income per acre: 25% reduction in water supply	50% reduction in water supply
80*	$19.30	$40.00
160**	20.00	45.00
320*	32.50	68.00

*For all situations referred to in Table 4

**Except for situation 2 in which reduction in income due to water decline was $5.96 at 25% reduction and $21.69 at 50% reduction. This occurred because the hog operation increased in size when water was decreased which compensated for any major decrease in income.

Sprinkler Irrigation Systems

Sprinkler irrigation systems when properly designed give 60 to 70 percent efficiency. Therefore, for the given study area, the water supply can safely be reduced between 25 and 50 percent without decreasing the land under cultivation. Water use at 60 to 70 percent efficiency level will also help solve the drainage problem of the area. The types of sprinkler systems considered for this analysis were hand-moved, wheel-moved and center-pivot. Center-pivot systems were included as alternatives to wheel-moved systems. Hand-moved systems were considered for the 80 and 160 acre representative farms. Hand-moved systems were not considered for the 320 acre representative farms because it was assumed that labor required to move the laterals would not be available at this level. Wheel-moved systems were considered for 80, 160 and 320 acre farms while center-pivot systems were considered only for 160 and 320 acre farms. Annual operating cost per acre for the three systems are given in Table 13.

In order to determine the effect of incorporating sprinklers into the representative farms the linear programming solutions (Tables 4 and 5) were adjusted for fixed costs and for labor cost saved by changing to sprinkler irrigation. Also by changing to sprinkler systems approximately 5 percent of land in canals and ditches can be reclaimed. The additional net income from the reclaimed land was estimated from the linear programming model

Table 13. Annual operating cost per acre for three types of sprinkler systems, Jefferson County, Idaho*

Farm Size In Acres	Annual Cost Per Acre		
	Hand-Moved Sprinkler	Wheel-Moved Sprinkler	Center-Pivot Sprinkler
80	$35.11	$40.76	-
160	33.01	38.16	$43.19
320	-	38.16	46.44

*After Milliner (5)

which indicated how much an additional unit of land would add to net income for each representative farm. These values were estimated to be $87 for the 80 acre farms, $94 for the 160 acre farms, and $145 for the 320 acre farms. The savings in labor costs accrued from introducing sprinkler irrigation systems were added to net income. The cost of sprinkler irrigation was then deducted from the total income. The overall results presented in Table 14 show the net income left over to pay for management and interest on land for each representative farm when a sprinkler system is included in the farm organization.

The present income is reduced by about 28% by incorporating hand-moved sprinklers on 80 acre farms while the reduction in income with wheel-moved sprinklers is about 35 percent. On 160 acre farms, the reduction in income with hand-moved sprinklers is about 17 percent, with wheel-moved sprinklers 21 percent, and with center pivots 25 percent. The reduction in income on the 320 acre representative farm with wheel-moved sprinklers is the same as on the 160 acre representative farm, that is, 21 percent, while with center-pivot, the loss is 27 percent.

Effects of Water Management Options

The effects of various management options on net incomes for the representative farms are presented in Tables 15, 16 and 17. The different irrigation management options are compared with the optimum solutions under the present management situation in the study area. For 80 and 160 acre farms, the least costly way of solving the problem of high water tables is to decrease the water supply by 25 percent instead of the adoption of sprinkler systems. On the 320-acre farms, however, the least costly is to introduce the wheel-moved sprinkler system.

Table 14. Net income by type of irrigation for three representative farm sites*

Type of Irrigation	Net Income Per Acre**
80 Acre Farm	
Gravity (Optimum Solution L.P. Model)	$ 78.09
With Hand-Moved System	56.10
With Wheel-Moved System	50.44
160 Acre Farm	
Gravity (Optimum Solution L.P. Model)	134.38
With Hand-Moved System	111.53
With Wheel-Moved System	106.38
With Center-Pivot	101.32
320 Acre Farm	
Gravity (Optimum Solution L.P. Model)	135.49
With Wheel-Moved System	106.60
With Center-Pivot System	98.32

*After Milliner (5)

**Interest on land and payment to management have not been deducted

Table 15. The effect on optimum net income of introducing five different irrigation management practices on an 80-acre representative farm

Management Options for Representative Farm	Net Income*	Loss in Net Income in Comparison with Optimum Farm
1. Optimum L.P. model farm with gravity irrigation	$6247	$----
2. With 25 percent reduction in water supply under gravity irrigation	4702	1545
3. With 50 percent reduction in water supply under gravity irrigation	3047	3200
4. With a hand-moved sprinkler system	4488	1759
5. With a wheel-moved sprinkler system	4035	2212

*Interest on land and payments to management have not been deducted

Table 16. The effect of optimum net income of introducing six different irrigation management practices on a 160-acre representative farm

Management Options for Representative Farm	Net Income*	Loss in Net Income in Comparison with Optimum Farm
1. Optimum L.P. model farm with gravity irrigation	$21,500	$----
2. With 25 percent reduction in water supply under gravity irrigation	18,300	3200
3. With 50 percent reduction in water supply under gravity irrigation	14,300	7200
4. With hand-moved sprinkler system	17,845	3655
5. With a wheel-moved sprinkler system	17,021	4479
6. With a center-pivot sprinkler system	16,211	5289

*Interest on land and payments to management have not been deducted

Table 17. The effect on optimum net income of introducing five different irrigation management practices on a 320-acre representative farm

Management Options for Representative Farm	Net Income*	Loss in Net Income in Comparison with Optimum Farm
1. Optimum L.P. model farm with gravity irrigation	$43,357	$----
2. With 25 percent reduction in water supply under gravity irrigation	32,957	10,400
3. With 50 percent reduction in water supply under gravity irrigation	21,597	21,760
4. With wheel-moved sprinkler system	34,114	9,243
5. With center-pivot sprinkler system	31,465	11,892

*Interest on land and payments to management have not been deducted

It should be pointed out that it is generally accepted that yield and quality of the crop increase with sprinkler irrigation, however, no estimates have been included in the computation.

The estimates shown in Tables 15, 16 and 17 are based on the present distribution system. The net income on the representative farms will be reduced further if the distribution systems are rehabilitated.

It was estimated that the unlined channel system costs about $7.00 per acre while gravity pipe systems cost about $29.00 per acre. The cost of lining canals which depends upon width and depth of the canal, falls within this range. The cost figures do not include cost of bridges and right-of-ways because these costs are not directly related to farm operation. However, these costs in the long run are being borne by farmers through higher or new taxes, which therefore must be included in the total cost of rehabilitation. When total cost of rehabilitation of the whole irrigation system is considered it becomes apparent that the area can support only a very limited rehabilitation program (compare the data in Tables 5 and 10) under the gravity distribution system. If on the other hand, the present distribution system is replaced by wells with high head pumps, the area would be able to support an extensive rehabilitation of irrigation systems (see Figure 2).

Imposed Water Costs

The effects of imposed water costs for surface water delivered to an irrigation district were investigated. Water charges varying from $0 to $12 per acre foot were imposed upon water entering both the gravity and high pressure pipeline distribution systems. Water from wells was not considered in this part of the analysis as a charge is very seldom levied against pumped groundwater.

The resulting system costs and configurations are shown in Tables 18 and 19. The costs listed in these tables indicate that for a surface water charge of $2.00 or more per acre-foot, it would be more economical to consider a high pressure pipeline system delivering water to sprinkler systems.

The effects of water cost on system efficiency are shown in Figure 3. As can be seen, the efficiency of the high pressure pipeline remains constant at 70 percent. The efficiency of the gravity supply system also approaches the 70 percent level with a 67 percent efficiency attained with an imposed cost of $8.00 or more per acre-foot.

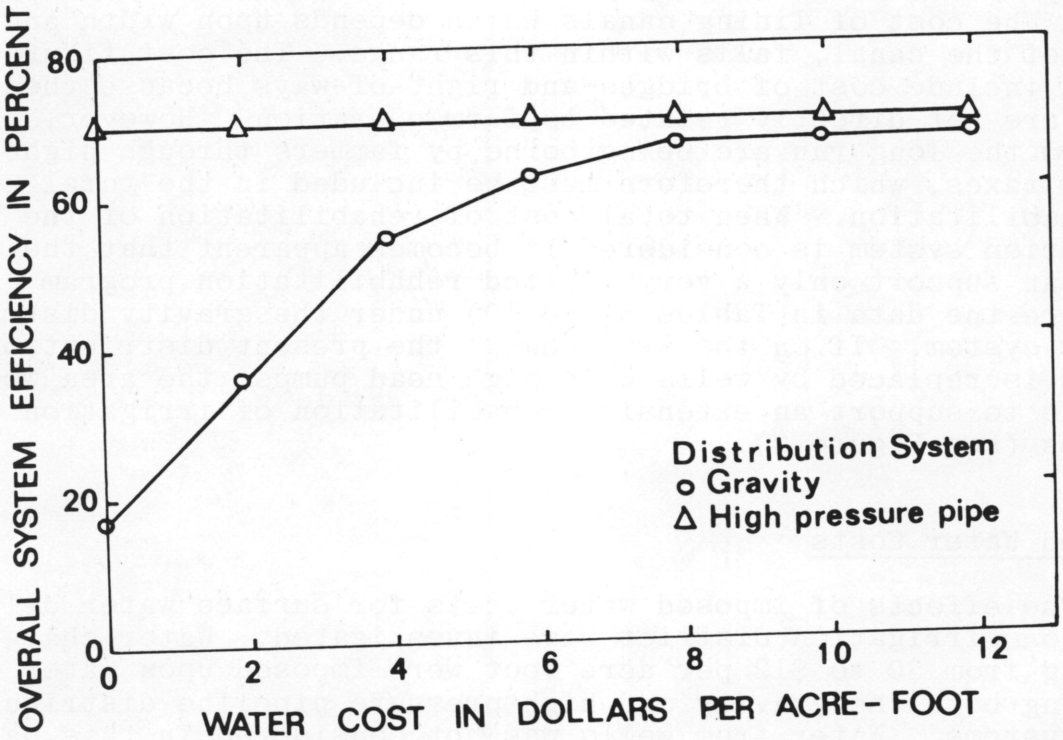

Figure 3. Relationship between system efficiency and water cost

Table 18. Percentage of area under application systems and water use efficiencies for various water costs for gravity distribution systems, North Rigby Irrigation District, Jefferson County, Idaho

Water Cost ($/AF)	System Cost/Acre*	System Efficiency (%)	Percent of Area Under Different Application Systems**			
			UG	IG	HSP	RSP
0	$ 68.13	17.1	100.00	----	---	---
2	85.10	26.0	66.68	6.93	---	26.39
4	93.55	54.8	6.86	----	19.27	73.87
6	99.28	62.5	---	----	19.27	80.73
8	104.47	67.0	---	----	19.27	80.73
10	109.48	67.0	---	----	19.27	80.73
12	114.50	67.0	---	----	19.27	80.73

*Includes cost of application and distribution system

**Application systems:

UG = unimproved gravity

IG = improved gravity

HSP = Hand-moved sprinkler and pump

RSP = Wheel-moved sprinkler and pump

(After Busch (2))

Table 19. Percentage of area under application systems and water use efficiencies for various water costs for high pressure pipeline distribution system, North Rigby Irrigation District, Jefferson County, Idaho

Water Cost ($/AF)	System Cost/Acre	System Efficiency (%)	Percent of Area Under Different Application Systems	
			Hand-Moved Sprinkler	Wheel-Moved Sprinkler
0	$75.80	70	19	81
2	80.61	70	19	81
4	85.41	70	19	81
6	90.21	70	19	81
8	95.02	70	19	81
10	99.82	70	19	81
12	104.62	70	19	81

After Busch (2)

SUMMARY AND CONCLUSIONS

The objectives of the study were to evaluate the present irrigation systems in the study area and to determine the impacts of alternative irrigation systems on the economy of the farms in the area.

Information on various irrigation practices in the area were collected in addition to economic input and output data for the crops grown in the area. Linear programming models along with parametric programming were used both in the engineering analysis as well as in the economic analysis. The present optimum income was used as a comparison to alternative irrigation management changes on the farms.

Experiments were conducted on various types of soils which were considered to be the representative of the area. The soils selected were Bannock loam, Bannock gravelly loam, Blackfoot silt loam and Heiseton loam. The average water use efficiencies were found to be 24 percent for border irrigation and 51 percent for furrow irrigation. As there was no surface drainage, the water lost to deep percolation was 76 percent for border irrigation and 49 percent for furrow. This heavy loss of water under the present irrigation systems contributes significantly towards the drainage problem of the area. The main reasons for these low efficiencies are: high water intake rate of the soils, excessive use of water on farms and a dense network of canals. The high intake rates of the soil cannot be controlled by the farmers. However, existing systems could be modified for less water loss. The second factor can be controlled by the farmers by improved water management. The third factor can be adjusted by redesigning the entire system.

To alleviate the problem of high water tables, major system changes were considered. From imposing increased efficiency levels to the least cost combination of irrigation application and distribution system components was determined by using a two-stage dynamic-linear programming model. It was found that for higher levels of efficiencies the present application systems should be replaced by sprinkler irrigation systems; systems which would save about half the water required by the present system. At a specified 60 percent efficiency of water use, the most economical method of application would be sprinkler systems with little change to the distribution systems. At a specified 70 percent efficiency level, the application and distribution systems would be completely rehabilitated. However, the cost of rehabilitating the entire irrigation system while retaining a gravity distribution system intact would be too great to be economically feasible. Wells with high head pumps supplying sprinkler systems appear to be the best alternative if a marked increase in overall irrigation efficiency is to be achieved.

However, abandoning the present gravity distribution system in favor of wells may involve legal and institutional problems which may make it an undesirable solution.

For a gravity distribution system, the cost of changing the entire irrigation distribution system is prohibitive. Therefore, the effects of various irrigation water management practices on the farms were considered in the analysis. Brockway (1) had concluded that a 20 percent or greater reduction in net diversion of irrigation water would solve the problem of a high water table in the area. Two methods of reducing on farm water use were considered. The first method was to decrease water supply within an optimum organization of representative farms of 80, 160 and 320 acres. The second method was to intorduce sprinkler systems into the representative farms. Both methods had considerable effect on the net farm incomes of the representative farms. The results show that the 80-acre representative farms would have difficulty in deriving enough net income for the farm families from which to sustain a living. Both the 160 and 320-acre farms had net incomes that could support sprinkler systems and have enough net income for the farm families for a reasonable standard of living. Reducing the water supply on the farms by 25 percent and and 50 percent resulted in keeping tillable land out of production. Therefore, this solution is not a practical one as few farmers would agree to keep up to 22 percent of their land idle. Introducing sprinkler systems on the representative farms for the sizes 160 and 320 acres appears to be a realistic solution. The basis for comparison was the net incomes derived from the different farm sizes.

It seems doubtful that the farmers in the area will initiate changes in the application system because at the present time they are substituting water for labor. This is economically rational because the price of water is set by unit of land irrigated rather than unit of water used. When sufficient credit is made available to the farmers they will begin to substitute capital for labor, and they will likely move toward more capital-intensive sprinkler systems resulting in more efficient use of water. The rehabilitation of water distribution and supply systems, possibly including wells, would also likely follow.

With obtaining higher irrigation efficiencies in the study area much of the water now diverted would remain in the river to maintain larger river flows during the irrigation season. However, it is uncertain whether the saved water would be more beneficial for other downstream uses than the benefits from the percolated water lost from the area. The percolated water recharges the aquifers along the Snake River Valley downstream to Thousand Springs and Twin Falls and reenters the river.

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