B-006

FILE COP

UNIVERSITY OF IDAHO

College of Agriculture

Economic Values of Irrigation Water in Four Areas Along the Snake River in Idaho

Karl Lindeborg

Idaho Agricultural
Experiment Station

Bulletin 513
January 1970

Contents

The Concept of Marginal Values. 3

Definition of Terms. 4

The Study Areas. 5

Primary Data and Analysis. 7

Assumptions. 7

Empirical Analysis. 7

Irrigation Water Requirements. 10

Estimating the Marginal Value Product of Water. 10

Programming Models. 11

The Average Marginal Value Product. 14

Marginal Value Products For Varying Farm Sizes. 17

Effect of Water Transfer On Estimated Price of Water. 22

Summary and Conclusions. 23

Acknowledgments. 24

References. 24

Appendix. 25

The Author

Dr. Karl Lindeborg is professor and agricultural economist, Department of Agricultural Economics. A member of the University of Idaho faculty since 1959, he has degrees from The Royal Veterinary and Agricultural College in Copenhagen, Denmark, and from Utah State and Oregon State Universities. Water resource economics and production economics are his areas of specialization for both research and teaching at the University.

AGRICULTURAL EXPERIMENT STATION
University Of Idaho College of Agriculture
Moscow, Idaho NR 2M 1-70

Economic Values of Irrigation Water in Four Areas Along the Snake River in Idaho

Karl Lindeborg

The demand for water is steadily increasing because of its many uses in industry and agriculture. However, the supply is relatively fixed over time and must therefore be allocated among its uses in such a manner that it contributes the most to the economic and social welfare of the society.

In Idaho, about 97 percent of total water use is for irrigation. Some of the state's major exports are produced on irrigated acreage and the future prosperity of Idaho seems to depend on expanded food processing and food exports which in turn depend on increased agricultural production. Large increases in agricultural production can only be achieved through greater efficiencies in use of present resources or through including new land under irrigation. However, agriculture must compete with other water uses, such as industry, recreation and urban, for the available supply. In order to allocate water among its efficient uses, some estimates of its price or value must be available for the water distribution administrator.

There are growing controversies over alternative uses of water resources in the western region and over the marketing and pricing methods by which water is allocated among the users. Many uses of water are competitive, while others are complementary to each other. Water prices may not reflect the relative productivity of water in the different uses. In allocation of water resources the economic aspect of water cannot stand alone but must be analyzed together with the physical and social entities. However, the purpose of this report is to determine only the marginal value product of water in its alternative uses within agriculture in four areas along the Snake River in Southern Idaho.

The Concept of Marginal Values

The concept of marginal values (prices) is based on the efficiency criterion of production. Efficiency models as applied to water resources allocation assume that society will indicate its preferences through the market place.

If a free market existed for water such as exists for potatoes, that is, if potential users could buy water from potential sellers, the market price of water in its alternative uses would be readily available. The less efficient users would be bid off the market by the more efficient ones, and water would then be employed in its most efficient uses. No such market for water exists in Idaho. For the most part, the allocation of water among the host of users is in the hands of public agencies and organizations. These public agencies and organizations must have some measure of the value of water in the various uses if they are expected to allocate present and future water supplies in an economically efficient manner.

Since water has no free market, its price can be estimated by the value of the increase in output resulting from the final unit of water used in producing the output. If the marginal value of water in all its alternative uses is thus estimated, the water resource allocation authorities will have quantitative figures to guide them in allocating water among various users.

The marginal value of water varies with different crop enterprises and with the relative size of each enterprise. This means that the marginal value of some quantity of water used in producing potatoes will be different from the value of an equal quantity of water used in producing wheat, and the marginal value of water used on the same crop may vary with the size of acreage because of the combination of production factors. The marginal value of water in general varies with soil productivity, climatic conditions, production efficiency, and the relative prices of output.

The size of farm on which water is used, the managerial ability of the operator, and the level of technology employed also influence the marginal value of water. Farm size limits the level of the activity or activities that may be conducted. It also limits the level of technology which may be economically employed. For instance, it will invariably be uneconomical to employ the most modern and most efficient beet or potato harvesting equipment on a 100-acre farm. The ability of the manager to select the correct combination of activities and production techniques will substantially affect the marginal value of water on any farm.

Definition of Terms

Marginal value product of water as a production factor is the value of the increase in output obtained by adding an additional acre-foot of water to a fixed amount of other production factors.

The concept of equating marginal values involves more than one output or enterprise on a given farm or, when comparing areas, among farms. Suppose that two water users are both given rights to certain amounts of water and they are considering trading these water rights between them in monetary terms. Now suppose that the last acre-foot of water is worth $5 to the first user and $30 to the second user. This is a disparity of $25 between the two users. If the two users are big operators, a transfer of water from the first to the second at a price between $5 and $30 will make them both better off in terms of their own preferences.

Irrigation efficiency is the percentage of irrigation water delivered to the farm headgate that is available for consumptive use by the plants.

Irrigation requirement is the consumptive use of plants plus the losses of irrigation water in supplying the consumptive irrigation requirement. It is computed by dividing the consumptive irrigation requirements by the irrigation efficiency (1).

The Study Areas

Four areas were selected for inclusion in this study. All are situated along the Snake River, one in southwest Idaho and three in southcentral Idaho (Fig. 1).

The study area in southwest Idaho is known as the Dry Lake area. This is a relatively new irrigation project. Most of the farmland has been reclaimed from sagebrush since 1962. Part of the irrigation water is pumped directly from the Snake River, a lift of 500 to 600 feet. The remainder is obtained from wells. The topography of the area is gently rolling so sprinkler irrigation is necessary on most of the farms.

The soil is very productive. The length of growing season and average seasonal temperature make the area ideally suited to the production of most agricultural crops. The average length of growing season is 144 days. Precipitation during the growing season is negligible so the water requirements of crops must be supplied by irrigation. Farms are larger than in the other areas, and the farming is highly mechanized.

The three study areas in southcentral Idaho are known as Minidoka, Twin Falls, and Oakley Fan areas. Farms in these areas have been in operation from 10 to 15 years and were reclaimed from sagebrush. These lands are well suited for gravity flow irrigation. The soils are fertile sandy loam but yields are not as high as in the Dry Lake area because of the somewhat shorter growing season.

Sizes of farms in the four study areas are shown in Table 1. The sample farms in the Minidoka area are smaller than in the other areas.

Table 1. Size distribution of farms included in the study.

Location of study areas	Number of farms			Total acres in study
	Less than 320 acres	Between 320-640 acres	Above 640 acres	
Dry Lake (Nampa)	1	4	3	6,963
Minidoka (Rupert)	47	3	2	8,745
Twin Falls	16	6	4	8,672
Oakley Fan (Burley)	8	7	3	10,076
Total	72	20	12	34,456

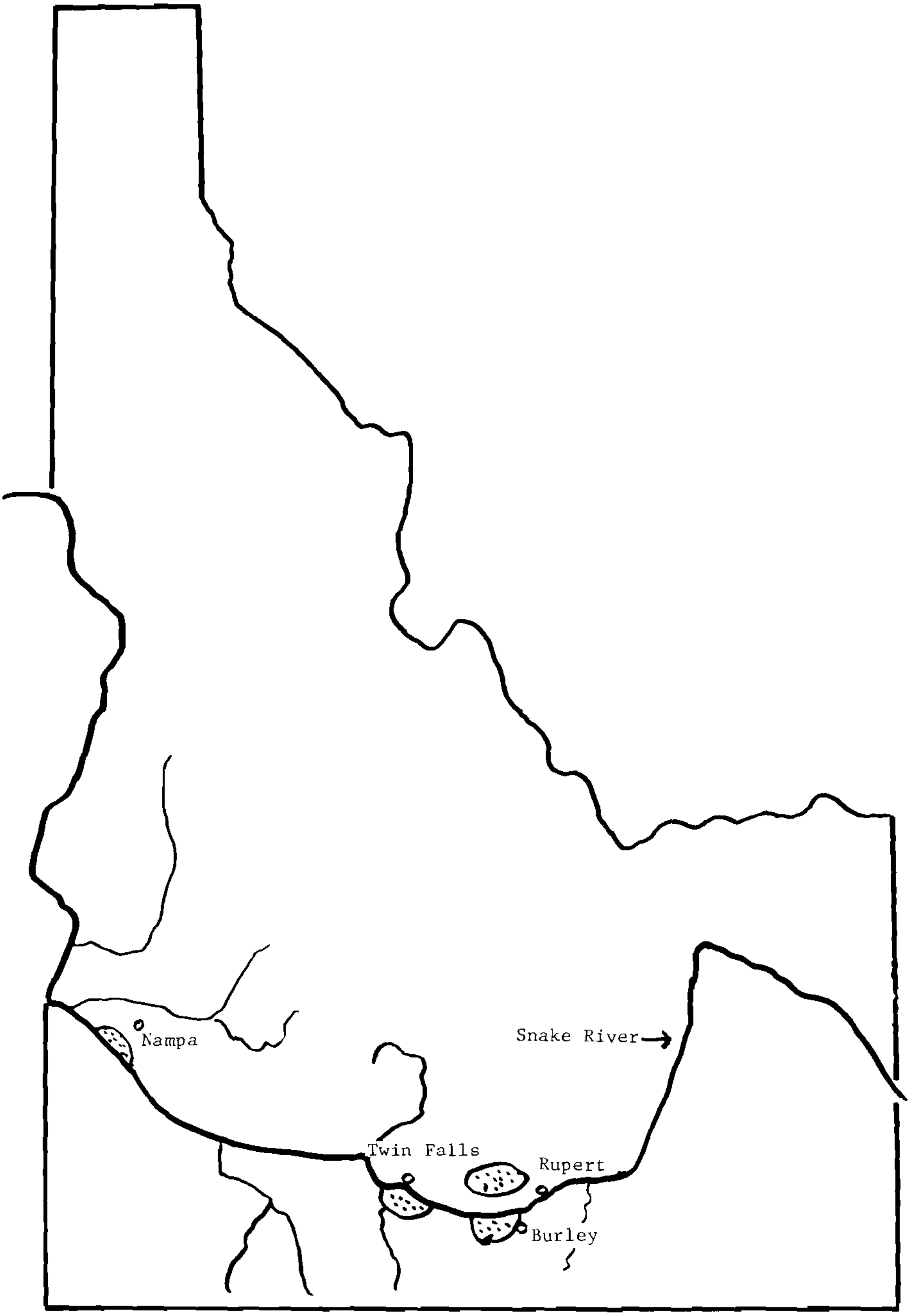

Fig. 1. Location of the study areas in southern Idaho.

Primary Data and Analysis

Primary data were collected in the different areas from 1962 to 1967 through personal interviews with farm operators. Farmers in the sample were selected in cooperation with the county agents.

Assumptions

Managerial abilities of all farm operators were assumed to be above the average of farmers in the areas. The farm manager must select the level of technology appropriate to his farm, the activity or combination of activities to be pursued, and the production technique to be followed for each activity. All these decisions must be made under conditions of uncertainty. Farmers must decide at the beginning of the year what crops they will produce, basing these decisions on the present and expected prices while a completely different set of prices may exist when they wish to market their product.

The conditions under which management makes decisions vary also from farm to farm. The many different ways in which farm managers make decisions are difficult to include in a common measurement. Therefore, the managerial abilities of all farm operators are held constant. This assumes that management on the farms is equal and that the managers' only objective is profit maximization. It also assumes that capital is available in unlimited supply, that the manager employs the production technique which is most efficient and appropriate for the resources at his disposal, and that average production costs are at a minimum. In other words, the farmers in this study are assumed to be growing the combination of crops which would maximize net revenue.

It is assumed that each farmer receives constant prices for each unit of product sold irrespective of the amount of each good he sells, and he pays the same price for every unit of any input he purchases. It is assumed also that the same production technique is employed on farms of approximately the same size within individual areas and that this is the optimum technique.

Soil productivity and climate conditions are assumed to be the same on all farms in each area. The only restrictions on total production for individual farms are available supplies of land and water.

Empirical Analysis

These assumptions are necessary because in each area representative enterprise budgets were developed by aggregation for farms with different resource supplies. Individual enterprise budgets on farms with similar resources were aggregated into a typical budget for a farm that approximates the real farms. Exact replicas of the representative farms may not exist in real life but the results from analyzing such a representative farm may be very useful.

The analysis is static in that it uses one given level of technology on each representative farm and does not consider advances in agriculture technology. Nor does the study allow for shifts in demand for agricultural products. With changes in consumer tastes, demand for

Table 2. Average prices received by Idaho farmers for agricultural products, 1957-1966.[1]

	Areas							
	Dry Lake		Minidoka		Twin Falls		Oakley Fan[2]	
Crop (unit)	Yield per acre	Price per unit	Yield per acre	Price per unit	Yield per acre	Price per unit	Yield per acre	Price per unit
Potatoes (cwt)	246	$ 1.30	250	$ 1.30	250	$ 1.30	250	$ 1.47
Sugar beets (tons)	25.7	13.60	16.5	14.14	16.5	14.14	17	14.30
Grain (bu.)	85	1.12	93	1.47	93	1.47	95	1.47
Alfalfa (tons)	4.5	19.83	5	19.83	5	19.83	4.5	20.75
Beans (cwt)	—	—	20.4	7.05	20.4	7.05	17.5	7.47

[1] U.S. Bureau of Census. 1967. Statistical abstract of the United States.

[2] U.S. Department of Agriculture. 1967. Agricultural statistics, 1967, average of 1959 to 1966.

individual crops may change disproportionately as the demand for new products arises. Therefore, the quantities purchased of some of the more important present-day crops would probably decrease while output of others will increase, and new crops will be introduced in response to consumer demand.

Grouping individual farms into various size groups and assuming that all farms within such groups may be represented by one farm also leads to inaccuracies. Such grouping relies on personal judgment. There is no quantitative method by which farms can be assigned to different size groups. Farms with smaller area and more intensive production methods may have greater total output than a larger farm and this may lead to difficulties in deciding to what size group such farms belong. Individual farms within a size group may not have identical input-output coefficients because of variations in land quality, managerial ability, skills, and preferences.

Representative farms were built up from sample farms using the same budget technique in all four areas. These representative farms contain a uniform approach to the computation of input-output coefficients in order to eliminate differences between farms. Seeding and fertilization rates were computed from the farmers' estimates and information obtained from dealers in the four areas. Prices of product were based on a 10-year average (1957-1966) for all areas except the Oakley Fan area which was based on an average of 1959-66 prices (Table 2).

Each budgetary cost was allocated to the enterprise on which it had been expended. Costs that could be identified with a given enterprise were allocated directly. An indirect allocation system was used for cost items of a joint nature. The figures for individual enterprises in the four areas are shown in Appendix Table 1.

Management and water costs were not included in the computed enterprise budgets.

Farm managers were usually the farm operators and did not allow themselves a fixed salary. Rather, they appropriated residual return after total farm costs had been paid.

The choice of a 5 percent return to land investment is an arbitrary one. Perhaps many farmers do not receive a return of 5 percent on their investment, but there are numerous opportunities for earning this much in alternative investments.

Since the object of this study was to estimate the value of irrigation water in different areas, water is assumed to be delivered free at the headgate of the representative farms. The cost of applying the water on the farm is included in the budgets.

When water is considered to receive its economic rewards according to its contribution to the total product, it is also assumed that all the input factors are priced according to their marginal value products.

Irrigation Water Requirements

Estimates of irrigation water requirements were computed from Station Bulletin No. 291 (3). Total irrigation water requirements include consumptive use plus application losses due to seepage. Irrigation efficiency is assumed to be 60 percent in all areas (4). This assumed value might be a little high in some areas. The water requirements by crops are presented in Table 3.

Estimating the Marginal Value Product of Water

In this study, linear and parametric programming are used to compute the price users can pay for an additional unit of water. All the complexities of land, water and rotational restraints are expressed as a linear mathematical model and net revenues are maximized on the representative farms subject to numerous acreage and water restraints. Because linear programming is a static analysis while agricultural production is a dynamic process, the optimal solution also is subjected to a form of sensitivity analysis. Parametric programming is used as a means for measuring the effects of change and uncertainty in the water supply.

Mathematically, the problem is stated as follows:

OBJECTIVE FUNCTION

$$\text{Maximize} \quad Z = \sum_{j=1}^{n} C_j X_j \qquad (j = 1, 2, \ldots n)$$

subject to restraints of the form

$$\sum_{j=1}^{n} a_{ij} X_j \ (\gtreqless) \ b_i \qquad (i = 1, 2, \ldots m)$$

$$\text{and} \quad X_j \geq 0$$

X_j = the quantity of the jth enterprise where there are **n** enterprises being considered.

C_j = the per unit contribution to Net Revenue of the jth enterprise, where there are **n** enterprises.

a_{ij} = the exchange coefficient of the jth enterprise in the ith restraint where there are m restraints and n enterprises.

b_i = the ith requirement where there are m requirements in all.

Z = Net Revenue

Table 3. Seasonal irrigation water requirements of crops grown in the four study areas.[1]

Crop	Acre-feet of water per acre: Dry Lake	Acre-feet of water per acre: Minidoka, Twin Falls, Oakley Fan
Alfalfa hay	3.83	3.33
Potatoes	2.88	2.78
Sugar beets	3.47	2.86
Small grains	2.26	2.23
Beans	1.98	1.99
Green peas	1.42	1.37

[1] Source: Jensen, Max C., and W. D. Criddle. 1952. Estimated irrigation water requirements for Idaho. Idaho Agr. Exp. Sta. Bull. 291, p. 11-12 (Areas 17 and 26).

The solution to a linear programming problem includes the "shadow prices" for the resources which limit the solution. These shadow prices or, as they are called in this study, Marginal Value Products, are computed under the conditions that all the input factors vary proportionally until the supply of the scarce resources is used up. Therefore, the Marginal Value Products are the Average Value Product of the total supply of the scarce resource, water. However, if a range of scarce resource supply quantities is taken, a demand function for water can be estimated.

Programming Models

Three linear programming models were formulated from the basic model. Structural changes are made from model to model in order to add greater realism to the analysis and to investigate the effects of change and uncertainty in the input-output relationships. The distinguishing characteristics of each model are presented in the following sections.

MODEL I — FIXED WATER SUPPLY

Representative farms for the Dry Lake, Twin Falls, and Minidoka areas were the basis for computation in this model. Each farm is 320 acres and represents a typical farm in the area in which it was developed. The possible crop enterprises in the three areas are potatoes, sugar beets, grain, and alfalfa hay with beans and peas grown only in the Twin Falls and Minidoka areas.

All possible crop enterprises were to be grown in each area because of rotational requirements. Therefore, upper and lower limits were placed on the level at which individual crop enterprises could enter the final solution. The model includes 16 real activities and 33 restraints (Appendix Table 2).

The water supply was considered limited but water could be interchanged between areas so that the enterprises which yielded the greatest economic returns would first satisfy their needs for water before any water was used for the less profitable enterprises in any area.

The objective function of the model was specified to maximize the total net revenue for the three areas combined. From the final solution of the model, the maximum total net revenue for each area was derived and is presented in Table 4. The solution indicates how many acres of the crop enterprises should be grown to obtain maximum income under the given rotational restrictions with a limited water supply.

The Marginal Value Product of water is $27.24 per acre-foot. This means that the last acre-foot of water applied had a price of $27.24. In general production theory, the variable resource is allocated to production until its additional contributing value (MVP) to the output is equal to its price. If a transfer of water rights were considered, then, the water would be used in the areas where its additional economic impact is the greatest. This does not mean that all water should be taken away from the areas with the lower economic values and transferred to the areas with the highest economic values. It does mean that water should be applied first within a given area to the enterprises with the highest returns before any water is allocated to the enterprises with very low returns.

The solution of this model indicates that the Marginal Value Product of water common for the three areas is $27.24 per acre-foot of water. Even though this figure is a good indication of the productivity of water for these areas, it would not help an administrator much in his job of allocating water between them. He does not have any indication of the effect a change in the water supply would have on the Marginal Value Products for the three areas or the different enterprises, because the range of water supply for which the $27.24 is valid is not given in this model.

Table 4. Optimum crop combination and total revenue on representative farms in three study areas.[1]

	Dry Lake		Minidoka		Twin Falls	
Crop enterprise	Acres	Per acre net revenue	Acres	Per acre net revenue	Acres	Per acre net revenue
Potatoes	50	$ 53.91	178	$84.52	140	$84.52
Sugar beets	180	143.44	20	38.35	20	39.65
Grain	50	35.57	30	48.47	30	55.03
Alfalfa hay	40	-6.42	25	-4.65	25	5.21
Beans	0	0	25	50.32	25	43.63
Peas	0	0	42	46.11	80	46.11
Total	320	$30,036.40	320	$20,339.13	320	$19,186.03

[1] Total net revenues include rewards to the input factors management and water.

The optimum total net revenue on the representative farm in the Dry Lake area was considerably larger than in the other two areas. One of the reasons for this is the much higher yield for sugar beets in the Dry Lake area.

The conclusion to be drawn from this model is that if the water supply was less than adequate to meet the demands of all three areas, return to water would be maximized by supplying the Dry Lake area with water before supplying the Twin Falls and Minidoka areas.

MODEL II — VARIABLE WATER RESOURCES

Water is still considered a scarce resource but this model reveals the effect of varying water from zero supply to an amount sufficient to satisfy the requirements for the crop enterprises in the optimum solution. Each step in the continuous solution reveals the opportunity cost of water in alternative uses among the crop enterprises. Therefore a demand function for water can be derived showing the amount of water which would be supplied at different water prices.

The linear programming matrix for Model II is similar to the matrix for Model I in all aspects of the rotational restraints. The solution is the same as presented in Table 4.

The crop enterprise combination which maximizes total net revenue depends on the amount of water available. The program indicates how much water would be needed to grow the different crops when no restrictions other than land and rotation would limit the total net income. The Marginal Value Product of water is $10.62 in the Dry Lake area, $8.82 in the Minidoka area, and $2.89 in the Twin Falls area. If the water supply was slightly less than water requirements for growing the crops, the farmer then would be willing to pay the prices indicated by the Marginal Value Products for an additional acre-foot of water.

The Average Marginal Value Product

The relevance of the Marginal Value Product as a means of pricing water in agriculture might be questioned. Some crops needed in the rotation have negative marginal values and would therefore be excluded from receiving water on a purely economic basis. Perhaps these negative-valued crops should be considered as a cost for the efficient crop enterprises, thereby reducing the economic returns for these enterprises.

If the farmers could grow any crop they desired in unlimited amount, they would grow the highest-valued crops. Under such a system the concept of the Marginal Value Product as the price of water would be perfect.

In analyzing the contribution each crop enterprise makes in maximizing total net revenue it is possible to derive a price of water which is more representative of the actual price producers can pay for water for the given enterprises. Such a price takes into account the amount of water used for each enterprise, not just the last acre-foot of water. This is theoretically not a measurement of the Marginal Value Product of water. It must be considered as an average Marginal Value Product, a weighted average of all the Marginal Value Products along a demand

Table 5. Marginal Value and Average Marginal Value Products of water at different levels of use on representative farms in three study areas.

Area	Water use	Marginal Value Product	Avg Marginal Value Product*
	(acre-feet)	($/acre-foot)	($/acre-foot)
Dry Lake	0- 625	$41.34	
	626- 769	17.70	
	770- 882	10.62	
	883-1036	-1.68	
	1037+	negative	$27.60
Minidoka	0- 58	$33.66	
	59- 553	30.40	
	554- 677	21.73	
	678- 727	20.25	
	728- 810	-1.40	
	810+	negative	$25.42
Twin Falls	0- 110	$33.66	
	111- 499	30.40	
	500- 567	21.47	
	568- 673	17.90	
	674- 756	1.56	
	756+	0	$25.14

*If the cost of management is assumed to be $20 per acre, $6.22 should be deducted from the price of water, making the values $21.38, $19.20, and $18.92, respectively, for the three areas.

curve for water for a given area. This price of water would be the price administrators should consider in allocating water between regions.

The Marginal Value Products computed by parametric programming are presented in Table 5. Quantities of water for which the Marginal Value Products are valid are shown by area. Thus in the Dry Lake area the Marginal Value Products range from $41.34 to $17.70 to $10.62 to zero. If the Average Marginal Value Products of an acre-foot of water are considered as the price of water for each area, then the price of an acre-foot of water would be $27.60 for the Dry Lake area, $25.42 for the Minidoka area, and $25.14 for the Twin Falls area.

The demand schedules for water and the level at which each enterprise enters the solution are shown in Figs. 2, 3, and 4.

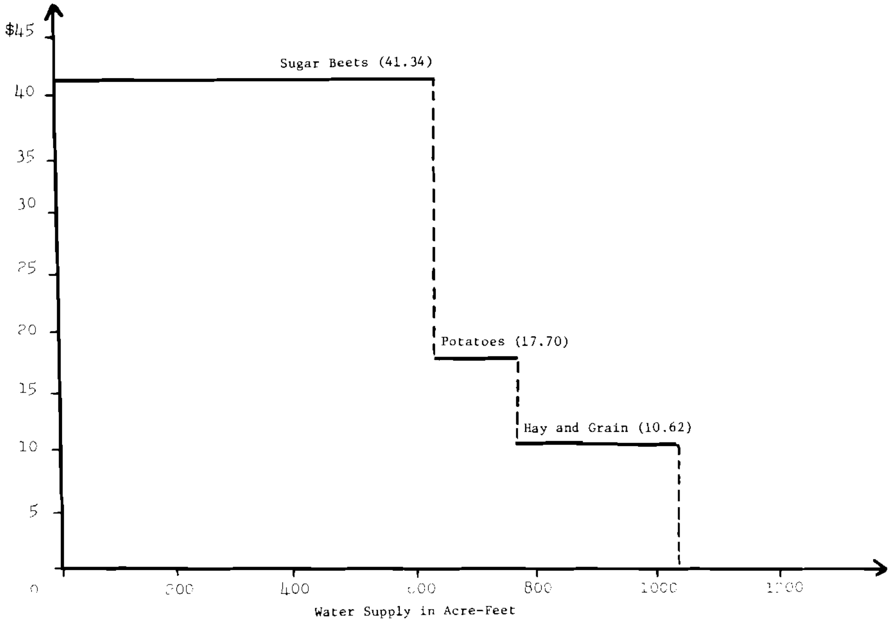

Fig. 2. Discontinuous demand curve for water for representative farm in Dry Lake area.

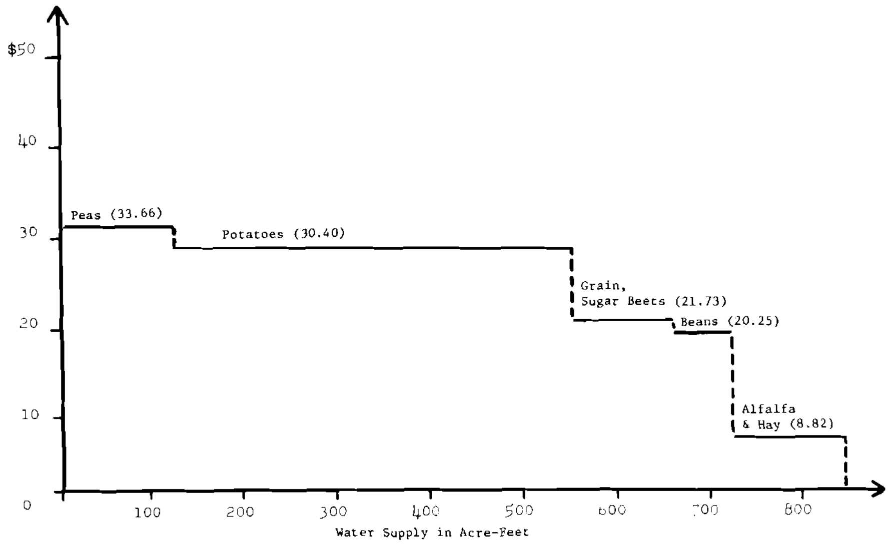

Fig. 3. Discontinuous demand curve for water for representative farm in the Minidoka area.

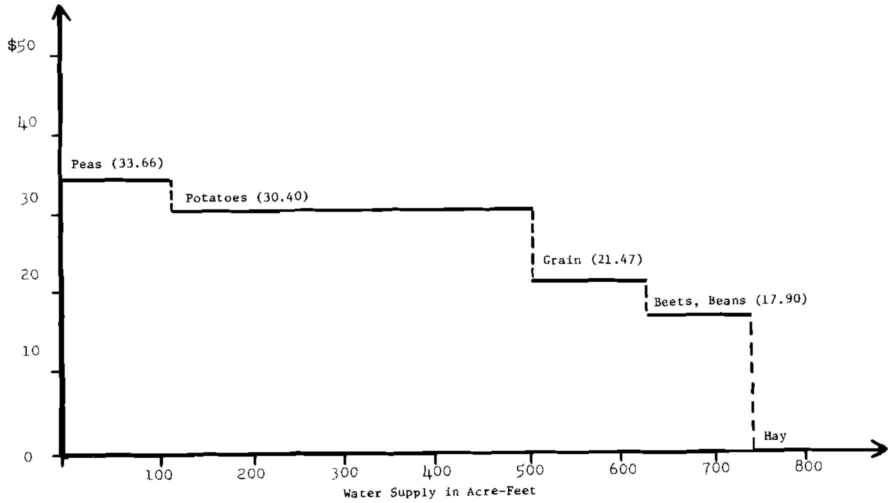

Fig. 4. Discontinuous demand curve for water for representative farm in the Twin Falls area.

Marginal Value Products for Varying Farm Sizes

In the previous sections the price of water was estimated for representative farms kept at a constant 320 acres in size.

In this section two sizes of model farms are developed from data gathered in the Dry Lake irrigation area. The data were very accurate but unfortunately the number of farms was not as large as desired.

To estimate the farmers' ability to pay for irrigation water, net revenues were computed for two farm size groups (Table 6). Prices and input-output data are the same as for Model I. The only crops that could be included in the program were potatoes, sugar beets, grain, and alfalfa hay. The rotation restrictions were as given in Tables 7 and 8.

Because of rotation requirements, the grain and alfalfa hay enterprises were forced into the final solution. The alfalfa hay enterprise was the last activity entering the program for all farms so it used the last unit of water and determined the Marginal Value Product of water on each farm. And since this enterprise had a negative net revenue on all farms, the Marginal Value Product of water would not be a good indicator of the price of water on these farms.

Table 6. Net revenues by farm size in the Dry Lake area.[1]

Crop enterprise	Farm size 320 acres	 640 acres
Potatoes	$ 53.91	$ 74.19
Sugar beets	143.44	144.49
Grain	35.57	45.14
Alfalfa hay	-6.42	-5.42

[1] Net revenues include returns to management and water.

Table 7. Acreage restrictions for crop enterprises on two farm sizes in the Dry Lake area.

	Farm size			
	320 acres		640 acres	
Crop enterprise	Minimum	Maximum	Minimum	Maximum
Potatoes	40	180	80	360
Sugar beets	40	100	80	200
Grain	60	180	120	360
Alfalfa hay	40	—	80	—

Table 8. Optimum crop combination and total revenue on two farm sizes in the Dry Lake area.[1]

Crop enterprise	Farm size 320 acres Acres	 320 acres Per acre net revenue	 640 acres Acres	 640 acres Per acre net revenue
Potatoes	120	$ 53.91	240	$ 74.19
Sugar beets	100	143.44	200	144.49
Grain	60	35.57	120	45.14
Alfalfa	40	-6.42	80	-5.42
Total for farms	320	$22,690	640	$51,687

[1] Net revenues include returns to management and water. Land values were estimated to be $400 per acre. This could be a rather low estimate. If the land values were $800 per acre an additional interest charge of $20 per acre should be deducted from the net revenue of each enterprise leaving $16,290 on the 320-acre farm, and $38,887 on the 640-acre farm to pay for water and management.

Table 9. Marginal Value and Average Marginal Value Products of water at different levels of use on two farm sizes in the Dry Lake area.

Farm size	Water use	Marginal Value Product	Avg Marginal Value Product*
	(acre-feet)	($/acre-foot)	($/acre-foot)
320 acres	0 - 347	$41.34	
	348 - 692.6	18.72	
	692.7 - 828.2	15.74	
	828.3 - 981.4	-1.68	
	981.5+	negative	$23.12
640 acres	0 - 694.0	$41.64	
	694.1 -1385.2	25.76	
	1385.3 -1656.4	19.97	
	1656.5 -1962.8	-1.41	
	1962.9+	negative	$26.44

*With this combination of enterprises the weighted average of water use is 3.21 acre-feet per acre. If $20 per acre management is subtracted from the returns, the Average Marginal Value Product become $16.90 for the 320-acre farm and $20.22 for the 640-acre farm.

When the contribution of each crop enterprise toward the total net revenue for each size group is considered, Average Marginal Value Product of water would be a more realistic estimate of the price of water. These figures are given in Table 9.

In connection with another study (2), information from 21 farmers in the Oakley Fan area was collected for the crop years 1965, 1966, and 1967. The input-output data were broken down into detailed information for each crop enterprise. Representative farm budgets were developed for each farm size and a linear programming model was applied to obtain the crop combinations which would maximize total net revenue on each representative farm (Table 10).

The optimum combinations of crop enterprises for the three size groups are presented in Table 11. The Marginal Value Products do not indicate the productivity of the area because the ranges in which they are valid are not given. In the 200-acre group, alfalfa hay has a negative net return per acre. Forcing alfalfa hay into the production plan decreases the possible optimum net revenue in proportion to the difference in net revenue for the enterprise which alfalfa hay replaces. See Table 12.

Again the Average Marginal Value Products give a more valid estimate of the price of water on these three farm sizes. The values are \$12.59, \$20.01, and \$22.44, respectively.

These results compare favorably with the results obtained in the Dry Lake area. The relationship between farm size and price of water is presented in Figure 5.

The prices of water in Tables 9 and 12 are too high because management costs were excluded from the initial computations. If it is assumed that management costs \$20 per acre, then \$6.22 should be deducted from the price of water making the values \$6.37, \$13.79, and \$16.22 for the Oakley Fan area, and \$16.90 and \$20.22 for the Dry Lake area.

The main reason that higher prices can be paid for water in the Dry Lake area is that sugar beets yield 10 tons per acre more there than in the Oakley Fan area.

Table 10. Net revenues by farm size in Oakley Fan area, 1965-67.

	Farm size (acres)		
Crop enterprise	200	400	600
Potatoes	\$73.58	\$92.64	\$100.46
Sugar beets	10.52	24.33	31.34
Grain	40.22	49.19	55.18
Alfalfa hay	-4.94	4.36	8.34
Beans	12.90	24.76	31.39

Table 11. Optimum crop enterprise combinations for the three size groups in the Oakley Fan area.[1]

	Farm size groups					
	200 acres		400 acres		600 acres	
Crop enterprise	Acres	Per crop net revenue	Acres	Per crop net revenue	Acres	Per crop net revenue
Potatoes	30	$73.58	96.7	$92.64	140	$100.46
Sugar beets	30	10.52	40	24.33	60	31.34
Grain	80	40.22	183.3	49.19	280	55.18
Alfalfa hay	20	-4.94	40	4.36	60	8.34
Beans	35	12.90	40	24.76	60	31.09
Total	195	$6,097.69	400	$20,112.32	600	$33,761.00

[1] Total net revenues include returns to the input factors management and water.

Table 12. Marginal Value and Average Marginal Value Products of water at different levels of use on three farm sizes in the Oakley Fan area.

Farm size	Water use	Value Product	Avg Marginal Value Product*
	(acre-feet)	($/acre-foot)	($/acre-foot)
200 acres	0 - 83.4	$26.47	
	83.5 - 261.8	18.03	
	261.9 - 332.1	6.48	
	332.2 - 417.9	3.73	
	418.0 - 484.5	-1.48	
	484.6+	negative	$12.59
400 acres	0 - 269.0	$33.32	
	269.1 - 677.7	22.06	
	677.8 - 757.3	12.44	
	757.4 - 871.7	8.51	
	871.8 -1004.9	1.31	
	1005.0+	0	$20.01
600 acres	0 - 389.2	$36.14	
	389.3 -1013.6	24.74	
	1013.7 -1133.0	15.62	
	1133.1 -1304.6	10.96	
	1304.7 -1504.4	2.50	
	1505.0+	0	$22.44

*If a $20-per-acre management cost were to be included in the analysis, the Average Marginal Value Products become $6.37, $13.79, and $16.22, respectively, for the three farm sizes.

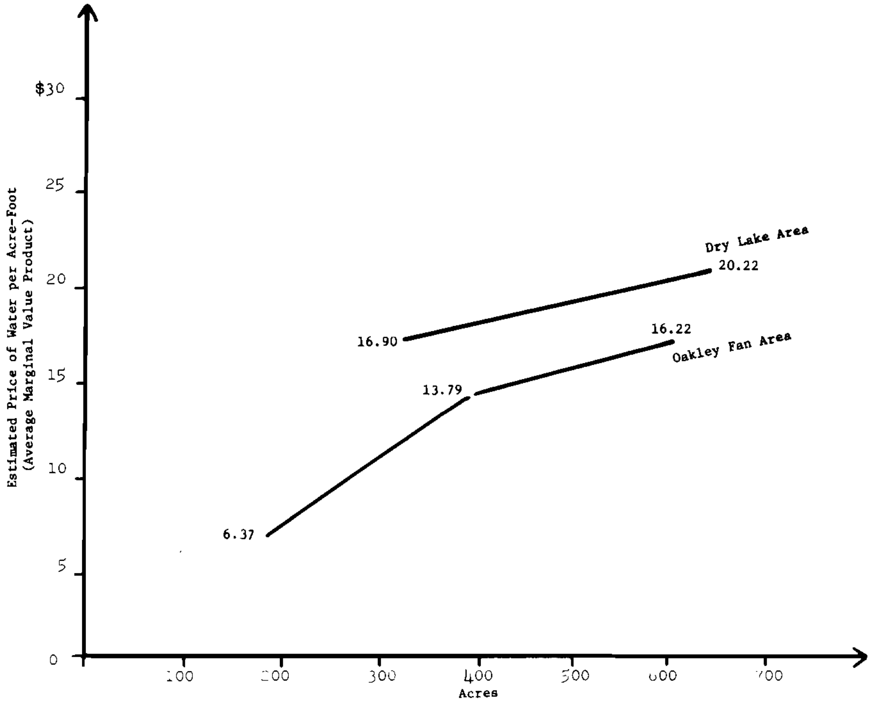

Fig. 5. Relationship of farm size and price of water in the Dry Lake and Oakley Fan areas.

Effect of Water Transfer on Estimated Price of Water

In evaluating water values between different areas, the full effect of an acre-foot of water should be considered. If water is to be taken from previous users and transferred to another region, then irrigation efficiencies of the areas must be taken into account as well as price. Water is not used up completely in irrigation. The water which escapes consumptive use and evaporation might through percolation be used over and over again.

Take, for example, an area in which water is used at an efficiency ratio of 60 percent and the remaining 40 percent percolates and is used again within the irrigation area. The process will follow a geometric progression of the following form:

$$S_n = a\frac{1-q^n}{1-q}$$

where: S_n = sum of the n terms

a = the first term (MVP)

q = the common ratio (40%)

when **n** approaches infinity the equation becomes:

$$S_n = \frac{a}{1-q}$$

Applying this formula to the Average Marginal Value Products, a more meaningful value of water emerges.

The adjusted Average Marginal Value Products for the three study areas are presented in Tables 13 and 14.

The first column of Table 13 indicates the price farmers can afford to pay for an acre-foot of water based on water requirements for crops currently being raised. All expenses have been deducted. The second column indicates the economic effect of an acre-foot of water over time when water is taken away from the area without considering any other economic externalities.

Columns one and three of Table 14 show the prices farmers can afford to pay for an acre-foot of water. These are the prices water administrators would look at in case productivity of an area was being considered. Columns two and four indicate the economic effect of an acre-foot of water if water were diverted from the area. This additional effect is only valid when water is being used to less than 100 percent irrigation efficiency. This concept might not be valid for other water uses.

Table 13. Price of water in three study areas, adjusted for irrigation efficiency of 60 percent.

Area	Avg MVP* per acre-foot	Adjusted Avg MVP* per acre-foot
Dry Lake	$21.38	$35.63
Minidoka	19.20	32.00
Twin Falls	18.92	31.53

*Average Marginal Value Product

Table 14. Price of water for different farm sizes in two areas, adjusted for irrigation efficiency of 60 percent.

Farm Size (acres)	Oakley Fan area		Dry Lake area	
	Avg MVP* per acre-foot	Adjusted Avg MVP* per acre-foot	Avg MVP* per acre-foot	Adjusted Avg MVP* per acre-foot
	(1)	(2)	(3)	(4)
200	$ 6.37	$10.62	—	—
320	—	—	$16.90	$28.17
400	13.79	22.98	—	—
600	16.22	27.03	—	—
	—	—	20.22	33.70

*Average Marginal Value Product

Summary and Conclusions

Four areas in Southern Idaho were included in the study. Information collected by personal interviews from the four areas included physical as well as economic data pertaining to input and output of the main crop enterprises on the farms.

The economic models used in estimating the value of water for the different crops and different areas were based on partial farm budgeting and linear programming. Representative farms were developed from the sample farms in each area and were assumed to represent typical farm organization in that particular area. Included in the economic models were variables of farm size, farm organization, water supply, and restraints on acreage.

The first linear programming model was designed for a fixed water supply for three representative farms of 320 acres each. The price of water common to the three areas was $27.24 for the last acre-foot of water.

Even though this price is a good indicator of the productivity of water, it does not have much meaning for an administrator who is responsible for the allocation of water among its highest uses.

A second parametric programming model was designed for a variable supply of water. The restraints were the same as in the first model. The results of this model were a range of Marginal Value Products for each of the crop enterprises in each of the three areas. Since this range in water prices would not be easy to use in decision making, an average was estimated, weighted by the amount of water used for each crop. This **average** Marginal Value Product would indicate the price farmers could afford to pay for an acre-foot of water.

A third parametric model was used for different-sized farms in two areas. The results showed an increasing ability to pay for water with increasing farm size.

In the growing controversies over transfer of water from one region to another, it is not fair to the agricultural industry to compare only the Marginal Value Products of the two regions. Consideration should also be given to the additional effect water has when the irrigation efficiency is relatively low.

Acknowledgments

The author wishes to acknowledge financial contributions and other support from the following sources:

The Office of Water Resources Research, U.S. Department of Interior

Regional research funds from Western Regional Technical Committee W-81, administered through the Idaho Agricultural Experiment Station.

Department of Reclamation, State of Idaho

The Bureau of Land Management was also very helpful in supplying information in the initial part of the study.

References

1. Blaney, Harry F., and W. D. Criddle. 1962. Determining consumptive use and irrigation water requirements. U.S. Dept. of Agriculture ARS Tech. Bull. 1275. Government Printing Office, Washington.
2. Cheline, R. J. 1968. An economic approach to the agricultural use of ground water in the Oakley Fan area of Cassia County, Idaho. M.S. thesis, Univ. of Idaho.
3. Jensen, Max C., and W. D. Criddle. 1952. Estimated irrigation water requirements for Idaho. Idaho Agr. Exp. Sta. Bull. 291.
4. Tyler, C. L., G. L. Corey and L. R. Swarner. 1964. Evaluating water use on a new irrigation project. Idaho Agr. Exp. Sta. Res. Bull. 62.

Appendix

Appendix Table 1. Total revenue, total costs and net revenue for representative farms in four areas in Idaho.

Crop enterprises	Total revenue	Total costs	Net revenue
Dry Lake Area			
Potatoes	$ 325.00	$ 271.09	$ 53.91
Sugar beets	349.50	206.06	143.44
Grain	124.95	89.38	35.57
Alfalfa hay	89.23	95.65	-6.42
Minidoka Area			
Potatoes	$ 319.80	$ 235.28	$ 84.52
Sugar beets	233.31	194.96	38.35
Grain	136.71	88.24	48.47
Alfalfa hay	99.15	103.80	-4.65
Beans	143.96	93.64	50.32
Peas	144.86	98.75	46.11
Twins Falls Area			
Potatoes	$ 319.80	$ 235.28	$ 84.52
Sugar beets	233.31	193.66	39.65
Grain	136.71	81.68	55.03
Alfalfa hay	99.15	93.94	5.21
Beans	143.96	100.33	43.63
Peas	144.86	98.75	46.11
Oakley Fan Area			
Potatoes	$ 367.50	$ 293.92	$ 73.58
Sugar beets	243.10	232.58	10.52
Grain	139.65	99.43	40.22
Alfalfa hay	93.37	98.31	-4.94
Beans	130.73	117.47	13.26

Appendix Table 2. Basic linear programming model used in the study.

		POT1	POT2	POT3	BEET1	BEET2	BEET3	BEAN2	BEAN3	GRAN1	GRAN2	GRAN3	HAY1	HAY2	HAY3	PEAS2	PEAS3	RHS1
OBJ	N	B	B	B	C	B	B	B	B	B	B	B	−A	−A	A	B	B	
TOLD1	E	1			1					1			1					C
TOLD2	E		1			1		1			1			1		1		C
TOLD3	E			1			1		1			1			1		1	C
TOWT	E	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D
POTLDA1	L	1																C
POTLDB1	G	1																B
POTLDA2	L		1															C
POTLDB2	G		1															B
POTLDA3	L			1														C
POTLDB3	G			1														B
BETLDA1	L				1													C
BETLDB1	G				1													B
BETLDA2	L					1												C
BETLDB2	G					1												B
BETLDA3	L						1											C
BETLDB3	G						1											B
BENLDA2	L							1										C
BENLDB2	G							1										B
BENLDA3	L								1									C
BENLDB3	G								1									B
GRNLDA1	L									1								C
GRNLDB1	G									1								B
GRNLDA2	L										1							C
GRNLDB2	G										1							B
GRNLDA3	L											1						C
GRNLDB3	G											1						B
HAYLD1	G												1					B
HAYLD2	G													1				B
HAYLD3	G														1			B
PEALDA2	L															1		B
PEALDB2	G															1		B
PEALDA3	L																1	B
PEALDB3	G																1	B

Appendix Table 2, continued.

```
             COLUMNS
                      POT1     OBJ          53.91000   TOLD1         1.00000
NAME                  POT1     TOWT          2.88000   POTLDA1       1.00000
ROWS                  POT1     POTLDB1       1.00000
 N  OBJ               POT2     OBJ          84.52000   TOLD2         1.00000
 E  TOLD1             POT2     TOWT          2.78000   POTLDA2       1.00000
 E  TOLD2             POT2     POTLDB2       1.00000
 E  TOLD3             POT3     OBJ          84.52000   TOLD3         1.00000
 E  TOWT              POT3     TOWT          2.78000   POTLDA3       1.00000
 L  POTLDA1           POT3     POTLDB3       1.00000
 G  POTLDB1           BEET1    OBJ         143.44000   TOLD1         1.00000
 L  POTLDA2           BEET1    TOWT          3.47000   BETLDA1       1.00000
 G  POTLDB2           BEET1    BETLDB1       1.00000
 L  POTLDA3           BEET2    OBJ          38.35000   TOLD2         1.00000
 G  POTLDB3           BEET2    TOWT          2.86000   BETLDA2       1.00000
 L  BETLDA1           BEET2    BETLDB2       1.00000
 G  BETLDB1           BEET3    OBJ          39.65000   TOLD3         1.00000
 L  BETLDA2           BEET3    TOWT          2.86000   BETLDA3       1.00000
 G  BETLDB2           BEET3    BETLDB3       1.00000
 L  BETLDA3           BEAN2    OBJ          50.32000   TOLD2         1.00000
 G  BETLDB3           BEAN2    TOWT          1.99000   BENLDA2       1.00000
 L  BENLDA2           BEAN2    BENLDB2       1.00000
 G  BENLDB2           BEAN3    OBJ          43.63000   TOLD3         1.00000
 L  BENLDA3           BEAN3    TOWT          1.99000   BENLDA3       1.00000
 G  BENLDB3           BEAN3    BENLDB3       1.00000
 L  GRNLDA1           GRAN1    OBJ          35.57000   TOLD1         1.00000
 G  GRNLDB1           GRAN1    TOWT          2.26000   GRNLDA1       1.00000
 L  GRNLDA2           GRAN1    GRNLDB1       1.00000
 G  GRNLDB2           GRAN2    OBJ          48.47000   TOLD2         1.00000
 L  GRNLDA3           GRAN2    TOWT          2.23000   GRNLDA2       1.00000
 G  GRNLDB3           GRAN2    GRNLDB2       1.00000
 G  HAYLD1            GRAN3    OBJ          55.03000   TOLD3         1.00000
 G  HAYLD2            GRAN3    TOWT          2.23000   GRNLDA3       1.00000
 G  HAYLD3            GRAN3    GRNLDB3       1.00000
 L  PEALDA2           HAY1     OBJ           6.42000   TOLD1         1.00000
 G  PEALDB2           HAY1     TOWT          3.83000   HAYLD1        1.00000
 L  PEALDA3           HAY2     OBJ           4.65000   TOLD2         1.00000
 G  PEALDB3           HAY2     TOWT          3.33000   HAYLD2        1.00000
                      HAY3     OBJ           5.21000   TOLD3         1.00000
                      HAY3     TOWT          3.33000   HAYLD3        1.00000
                      PEAS2    OBJ          46.11000   TOLD2         1.00000
                      PEAS2    TOWT          1.37000   PEALDA2       1.00000
                      PEAS2    PEALDB2       1.00000
                      PEAS3    OBJ          46.11000   TOLD3         1.00000
                      PEAS3    TOWT          1.37000   PEALDA3       1.00000
                      PEAS3    PEALDB3       1.00000
             RHS
                      RHS1     TOLD1       320.00000   TOLD2       320.00000
                      RHS1     TOLD3       320.00000   TOWT       2600.00000
                      RHS1     POTLDA1     180.00000   POTLDB1      40.00000
                      RHS1     POTLDA2     180.00000   POTLDB2      25.00000
                      RHS1     POTLDA3     180.00000   POTLDB3      25.00000
                      RHS1     BETLDA1     180.00000   BETLDB1      50.00000
                      RHS1     BETLDA2     160.00000   BETLDB2      20.00000
                      RHS1     BETLDA3     160.00000   BETLDB3      20.00000
                      RHS1     BENLDA2     120.00000   BENLDB2      25.00000
                      RHS1     BENLDA3     120.00000   BENLDB3      25.00000
                      RHS1     GRNLDA1     180.00000   GRNLDB1      50.00000
                      RHS1     GRNLDA2     180.00000   GRNLDB2      30.00000
                      RHS1     GRNLDA3     180.00000   GRNLDB3      30.00000
                      RHS1     HAYLD1       40.00000   HAYLD2       25.00000
                      RHS1     HAYLD3       25.00000   PEALDA2      80.00000
                      RHS1     PEALDB2      15.00000   PEALDA3      80.00000
                      RHS1     PEALDB3      15.00000
             ENDATA
```