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# REASONABLE PUMPING LIFTS FOR IDAHO

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# INTRODUCTION

## ANALYSIS OF THE PROBLEM

Pumping of ground water for irrigation has resulted in a number of water administration problems in Idaho. A recent estimate placed the annual irrigation pumpage of ground water from Idaho aquifers at 3.7 million acre-feet, a quantity approximately equal to the combined storage capacity of American Falls Reservoir, Palisades Reservoir, and all the other reservoirs on the upper Snake River (Ralston, 1968). Most of this development is located in the arid valleys of southern Idaho. In several of the basins combined artificial and natural discharge has exceeded recharge to the aquifer systems. The result has been a continuing decline of water levels as the excessive withdrawals are satisfied from water in storage in the underground reservoirs.

The responsibility for administrative control of problem areas such as these has been given to the Director of the Idaho Department of Water Administration (IDWA). Under this authority, four areas in southern Idaho have been declared critical to restrict future development of the ground-water resource. In several of these areas, the present stage of development is excessive and water levels are continuing to decline. A number of water right holders from these areas have indicated that water levels are reaching a depth from which they feel it is economically impractical to pump water for their farming operations. They have asked the Director of the IDWA to denote the "reasonable pumping lift" for their area, and to limit pumping by junior right holders to maintain this lift.

The responsibility of the IDWA is to utilize each of the legal tools provided by the State Legislature to effectively and fairly distribute water to its users. Thus, the Director of the IDWA has authorized this study of the feasibility of administering ground-water basins on the basis of reasonable pumping lift. He has also directed that, if possible, reliable estimates of the reasonable pumping lift for each ground-water basin should be calculated so that the water law as passed by the Legislature can be fully implemented.

## DUTIES OF THE DIRECTOR OF THE IDAHO DEPARTMENT OF WATER ADMINISTRATION

The Director of the IDWA has been given the responsibility for administering ground water by the Legislature. The following excerpts from the Idaho Code outline these duties with respect to protecting the rights of appropriators from depletion of the ground-water supply.

> *42-226. Ground waters are public water.—It is hereby declared that the traditional policy of the state of Idaho, requiring the water resources of this state to be devoted to beneficial use in reasonable amounts through appropriation is affirmed with respect to the ground water resources of this state as said term is hereinafter defined: and, while the doctrine of "first in time is first in right" is recognized, a reasonable exercise of this right shall not block full economic development of underground water resources, but early appropriators of underground water shall be protected in the maintenance of reasonable ground water pumping levels as may be established by the state reclamation engineer* (Director of the IDWA) *as herein provided. All ground waters in this state are*

*declared to be the property of the state, whose duty it shall be to supervise their appropriation and allotment to those diverting the same for beneficial use. All rights to the use of ground water in this state however acquired before the effective date of this act are hereby in all respects validated and confirmed.*

*42-23l. Duties of the state reclamation engineer* (Director of the IDWA)....*–It shall likewise be the duty of the state reclamation engineer* (Director of the IDWA) *to control the appropriation and use of the ground water of this state as in this act provided and to do all things reasonably necessary or appropriate to protect the people of the state from the depletion of ground water resources contrary to the public policy expressed in this act.*

*42-237a. Powers of the state reclamation engineer* (Director of the IDWA).*–g. To supervise and control the exercise and administration of all rights hereafter acquired to the use of ground waters and in the exercise of this power he may by summary order, prohibit or limit the withdrawal of water from any well during any period that he determines that water to fill any water right in said well is not there available. To assist the state reclamation engineer* (Director of the IDWA) *in the administration and enforcement of this act, and in making determinations upon which said orders shall be based, he may establish a ground water pumping level or levels in an area or areas having a common ground water supply as determined by him as hereinafter provided. Water in a well shall not be deemed available to fill a water right therein if withdrawal therefrom of the amount called for by such right would affect, contrary to the declared policy of this act, the present or future use of any prior surface or ground water right or result in the withdrawing the ground water supply at a rate beyond the reasonably anticipated average rate of future natural recharge....*

The above statutes appear to provide two methods of determining whether a basin is fully developed: (1) by limiting withdrawals to the estimated average annual recharge, and (2) by maintaining reasonable pumping lifts. However, the two methods are not independent. The method of limiting withdrawals to the estimated average annual recharge should be used to determine if an area should be closed to further ground-water appropriation. The method of reasonable pumping lift should then be used to determine the point at which mining of the water resource in the critical area must be stopped and the use of water by the junior right holders restricted. Thus, the two methods should be used in combination to effectively administer a ground-water basin.

**PURPOSE**

Although statutes pertaining to ground-water administration were adopted by the State Legislature in 1951 and 1953, the sections regarding reasonable pumping lifts have not been used as of this date for administering ground water. Neither the feasibility of determining reasonable pumping lifts nor the method of administrating a ground-water basin using a reasonable pumping lift have been evaluated in detail. However, reference to the statutes has been made in a number of recent court cases, and the continuing decline of the water level in some areas indicates that a method of controlling withdrawals in over-developed areas is now mandatory to maintain the rights of the prior right holders.

The purpose of this study is to determine values of reasonable pumping lift for each ground-water basin in Idaho in which significant ground-water development has occurred or is likely to occur. The values determined in this study are to be preliminary and serve as a guide for determining the necessity of detailed studies in basins in which the pumping levels are approaching the range indicated by this study.

## METHOD

The determination of reasonable pumping lifts is divided into its several interrelated problems. The problems are solved independently and the results are combined to estimate the reasonable pumping lift for each basin. The objectives of this study are to obtain reasonable solutions to each of the following sections of the reasonable pumping lift problem:

1. To delineate the hydrologic boundaries of the principal ground-water basins in the state, and to delineate areas within these ground-water basins having similar cropping practices and yields.

2. To estimate the capacity to pay for irrigation water of typical agricultural enterprises in each ground-water basin unit.

3. To estimate the cost of pumping a unit of water as a function of pumping lift.

4. To evaluate average irrigation water requirements under typical cropping practices for each ground-water basin unit.

The evaluation of each of these four objectives are presented in detail in the following sections of the report. The results obtained for each are combined to produce an estimate of reasonable pumping lift for each basin. The payment capacity per unit of water is calculated by dividing the capacity of the land to pay for water in dollars per acre by the irrigation requirement in acre-feet per acre. The payment capacity per unit of water (dollars per acre-foot) is compared to the cost of pumping an acre-foot of water as a function of pumping lift to determine a reasonable pumping lift for each basin.

## ASSUMPTIONS

A number of assumptions were made to facilitate estimation of reasonable pumping lifts and to restrict the results to a usable range. These assumptions are basic to the solution of each of the separate problems delineated in the objectives. Other assumptions required in the solution of particular problems are noted in the appropriate sections of the report.

The following assumptions apply to each section of the study:

1. The calculation of reasonable pumping lifts is based upon irrigation usage of water. It is assumed that persons using water for other purposes, such as industrial and domestic, can afford to pay more for each unit of water used.

2. The reasonable pumping lift is based upon cost per unit of water being the

limiting economic factor for an average or "typical" irrigator in each basin. The irrigator can be considered typical in that he grows the types of crops ordinary to his area, has average yields, applies irrigation water in a reasonably efficient manner, and pays an average price for each unit of water he pumps.

3. Administration of the use of ground water based upon reasonable pumping lifts is for the purpose of maintaining the water rights of the individual rather than maximizing profits on a community-wide scale (the general public).

4. Hydrologic, geologic, and water quality aspects are not the limiting factors in well yield or water usage. Among other considerations, this assumes that the aquifer thickness is sufficient to allow wells to obtain water at the reasonable pumping level for the area.

**DEFINITIONS**

1. **Pumping Lift** – The pressure, expressed in feet of water, against which the pump must operate. This is the sum of the lift from the well and any lift between the pump and the point of use. The pressure necessary to operate a sprinkler system is not included.

2. **Maximum Economic Lift** – The maximum distance water can be lifted by an irrigator using his full capacity to pay. Maximum economic lift is variable within a basin depending upon the payment capacity, total pumping cost, and quantity of water used for each farming unit.

3. **Reasonable Pumping Lift** – The distance water can be lifted by a typical irrigator for an economically-sized cropping unit. The quantity of water pumped, the payment capacity, and cost per unit of water are those for an irrigator assumed to be typical of the area.

4. **Payment Capacity** – The return after account has been made for all production costs except the cost of water at the farm headgate.

5. **Gross Income Ratio** – The ratio of weighted average gross income per acre of a county or basin to the weighted average gross income per acre of Canyon County.

6. **Regression Coefficient** – The rate of change of the dependent variable with respect to a unit change in the independent variable.

7. **Y-intercept** – The value of the dependent variable when the independent variable has a value of zero.

8. **Coefficient of Determination** – The fraction of the variation in the dependent variable attributable to regression of the dependent variable on the independent variable or variables.

9. **Standard Error of Estimate** – The variance of the dependent variable given the independent variable.

10. **Consumptive Use (or Evapotranspiration)** – The total quantity of water used by a crop and evaporated from adjacent soil with an adequate water supply at all times.

11. **Consumptive Irrigation Requirement** – The consumptive use of the crop less any water supplied from precipitation during the growing season.

12. **Irrigation Requirement (or Headgate Requirement)** – That amount of water which must be supplied at the farm headgate to provide for the consumptive irrigation requirement plus the application losses. It is evaluated as the consumptive irrigation requirement divided by an assumed field application efficiency.

13. **Field Application Efficiency** – The ratio of irrigation water consumptively used by the crop to the total quantity applied through irrigation.

14. **Weighted Average Irrigation Requirement** – The amount of water required per acre, assuming that the land is planted to various crops in the same proportion as those crops occur over the basin as a whole.

## PAYMENT CAPACITIES

### ASSUMPTIONS FOR CALCULATION OF PAYMENT CAPACITIES

The price that an agricultural enterprise can afford to pay for the water it requires is highly variable. The payment capacity is variable among basins, from farm to farm within a basin, and even from year to year for an individual farm. An optimum method of analyzing data with this degree of variability, at least from the administrator's point of view, is to analyze the budgets of enough existing farms in a basin to calculate a statistical distribution of payment capacities. This method would allow an administrator to know the percentage of farming operations affected by choosing as typical a particular value of payment capacity. However, this method requires a great deal of data, most of which is not readily available. An alternative method of analyzing payment capacities is to remove the variability by making assumptions that limit the range of the result and by using average or typical values for the basin. This latter method was chosen for this study because of limited data availability. The following assumptions were made to limit the range of the result and provide a common basis for evaluating payment capacities:

1. Payment capacities should be related to the ability to pay for water of a class of typical water users in each basin. The typical irrigator grows the crops most common to the area, with average yields, and average production costs.

2. Payment capacities are based upon economically self-supporting units having enough cropped acreage or animal production enterprises to provide full

employment for the family. This assumption is necessary to avoid confusing the results with data for pleasure and hobby farms too small to be considered economic by themselves.

3. Payment capacities are based upon costs of providing a full water supply. This assumption is necessary because some farms use ground water as a source of supplemental water. The value of the supplemental water can not be adequately determined using the same methods as those used for determining the value of a full water supply.

4. Payment capacities are calculated assuming that crop production is not possible without irrigation. No deductions are made from the gross farm income for income possible without irrigation.

5. Money invested should receive a reasonable interest return commensurate with the risk involved. Interest on investment is a valid charge against any enterprise because capital, if invested elsewhere, could be drawing interest. A return to management and compensation for family labor are also valid charges against a farm enterprise.

6. Increased profits resulting from pumping from levels above the reasonable pumping lift are not available in succeeding years.

7. Payment capacities are those for the better land classifications in each basin. It is assumed that the poorer lands will not support an economic farming unit without a substantial increase in farm size.

**FARM BUDGETS**

The capacity of each basin to pay for irrigation water was estimated using recently published estimates of the payment capacities for farming operations in seven areas of Idaho. These estimates were adapted to other basins for which payment capacities have not been recently estimated by assuming payment capacity to be related to the over-all productivity of the basin. This short-cut method was used instead of a detailed farm budget economic analysis for each basin because: (1) the data necessary for a farm budget analysis for each basin is not readily available, and time and expense make gathering of sufficient data for an adequate analysis of each basin impractical, (2) payment capacities determined by budget analysis methods are variable for an area depending upon subjective input values such as farm land values, interest rates, crop rotations and yields, machinery expenses, and return to management. This variability prohibits a precise determination of payment capacity by any method for even one farm size.

Payment capacity estimates were taken from U. S. Bureau of Reclamation (USBR) project reports for the following five areas of Idaho: East Greenacres (Kootenai County), Salmon Falls (Twin Falls County), Challis (Custer County), Lower Teton (Fremont and Madison counties), and Bear River (Bear Lake and Franklin counties). These reports include payment capacities calculated for family-sized irrigation operations typical of those that exist in each area or typical of those that would be developed in each area if adequate

irrigation water were available. The payment capacities were calculated using a standard farm budget analysis that included allowances for family labor return, interest on investment, and in most studies, a return to management. Data for the studies were obtained by interviewing operators of existing farms in the area and operators of irrigated farms in similar irrigated areas. A payment capacity meeting the requirements outlined in the assumptions of this report was selected from each study.

The selected payment capacities are listed in table 1. It should be emphasized that each of these payment capacities are the end result of a farm budget analysis performed by various individuals. Each budget was developed for a hypothetical enterprise that the USBR investigator felt would be reasonable and typical of those that would exist if the reclamation project came into being. Thus, many factors such as interest rates, family income, farm size, and return to management are not standardized in the various analyses. The fact that most of these items are not standardized can be rationalized by assuming that the investigator used values typical for the area. However, the returns to management allowed are extremely variable between the budgets and is, in fact, omitted from several of the analyses. A standard rate for management charges is difficult to establish because farm managers are usually the farm operators and do not allow themselves a fixed management salary (Lindeborg, 1970). Management services are available in Idaho at a rate of approximately 5 percent of the gross farm receipts. Therefore, to make the payment capacities as nearly comparable as possible, the return to management was adjusted to a standard 5 percent of the gross farm income. This adjustment results in the adjusted payment capacity listed in column 10 of table 1 for each project. These payment capacities are used as a basis for estimating payment capacities for these and other irrigated areas in Idaho.

The Agricultural Economics Department of the University of Idaho has conducted a number of studies concerning the capacity of farming operations to pay for irrigation water. The payment capacities of three sizes of farming operations were calculated for the Oakley Fan area of Cassia County (Cheline, 1968). Computer methods were used to optimize crop rotations for maximum returns using a linear programming technique. Data were obtained from personal interviews with farmers in the area. The results of this study are listed in table 2 including details on type of enterprise, farm size, and return to management. The payment capacity of the larger farms (600 acres) was found to be approximately double that of smaller units (200 acres).

The Agricultural Economics Department of the University of Idaho also studied the payment capacity of four areas in southern Idaho (Lindeborg, 1970). Each of the studies were for recently developed areas located along the Snake River. The areas studied were Dry Lake in Canyon County, the Minidoka area near Rupert, an area near Twin Falls, and the Oakley Fan area south of Burley. Data for the studies were obtained from interviews with the farm operators in each of the areas during the period 1962-1967. Most of the results reported in the study are for larger farming operations (320-640 acres); however, payment capacities for 200-acre farms were reported for the Oakley Fan area. Payment capacities for 200-acre farms in the Dry Lake area can be estimated from those listed for the larger farm sizes in the Dry Lake area. The payment capacities for the larger farm sizes were the only values listed for Minidoka and Twin Falls areas and are not comparable to those for the smaller acreage farms.

TABLE 1

SUMMARY OF U.S.B.R. PAYMENT CAPACITIES APPLICABLE TO THE

REASONABLE PUMPING LIFT STUDY

| (1) Project Name - | (2) County - | (3) Year Report Published - | (4) Type of Enterprise - | (5) Size of Enterprise - | (6) U.S.B.R. Land Class - | (7) Gross Farm Income (Rounded) $/Acre | (8) Standardized Return to Management (Rounded) $/Acre | (9) Return to Water and Management (Rounded) $/Acre | (10) Return to Water (Payment Capacity) $/Acre |
|---|---|---|---|---|---|---|---|---|---|
| East Green-acres | Kootenai | 1966 | Dairy | 120 Acres 36 Cows | 3 | 160.00 | 8.00 | 19.00 | 11.00 |
| Salmon Falls | Twin Falls | 1966 | Cash Crop | 140 Acres -- | 1 | 140.00 | 7.00 | 36.00 | 29.00 |
| Challis | Custer | 1964 | Dairy | 104 Acres 25 Cows | 2 | 95.00 | 5.00 | 10.50 | 5.50 |
| Lower Teton | Fremont-Madison | 1964 | Cash Crop | 150 Acres | 1 | 140.00 | 7.00 | 23.50 | 16.50 |
| Bear Lake | Bear Lake | 1969 (Preliminary) | Dairy | 75 Acres 20 Cows | 1 | 160.00 | 8.00 | 14.50 | 6.50 |

TABLE 2

SUMMARY OF THE PAYMENT CAPACITIES CALCULATED AT THE UNIVERSITY OF IDAHO FOR THE OAKLEY FAN AND DRY LAKE AREAS OF SOUTHERN IDAHO

| (1) Area and County | (2) Source and Date Published | (3) Type of Enterprise | (4) Size of Enterprise (Acres) | (5) Gross Farm Income $/Acre | (6) Standardized Management Return $/Acre | (7) U of I Calculated Pymt. Capacity $/A-F | (8) Ave. Irri. Req. for Rotation A-F/A | (9) U of I Payment Capacity $/Acre | (10) Return to Management Allowed by U of I $/Acre | (11) Return to Water and Management $/Acre | (12) Return to Water Pymt. Cap. $/Acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oakley Fan (Cassia) | Cheline 1968 | Cash Crop | 200 | 180 | 9 | - | - | 30.50 | 0 | 30.50 | 21.50 |
| | | | 400 | 200 | 10 | - | - | 50.00 | 0 | 50.00 | 40.00 |
| | | | 600 | 180 | 9 | - | - | 56.00 | 0 | 56.00 | 47.00 |
| Oakley Fan (Cassia) | Lindeborg 1970 | Cash Crop | 200 | 180 | 9 | 6.37 | 2.48 | 16.00 | 20 | 36.00 | 27.00 |
| | | | 400 | 200 | 10 | 13.79 | 2.51 | 34.50 | 20 | 54.50 | 44.50 |
| | | | 600 | 200 | 10 | 16.22 | 2.51 | 40.50 | 20 | 60.50 | 50.50 |
| Dry Lake (Canyon) | Lindeborg 1970 | Cash Crop | 200 | 265 (est.) | 13 | 12.45 (est.) | 3.07 | 38.00 | 20 | 58.00 | 45.00 |
| | | | 320 | 265 | 13 | 16.90 | 3.07 | 52.00 | 20 | 72.00 | 59.00 |
| | | | 640 | 265 | 13 | 20.22 | 3.07 | 62.00 | 20 | 82.00 | 69.00 |

Lindeborg's method was to calculate the "marginal value product" for each added increment of water used during the production of an optimal crop rotation for each area. "Marginal value product" was defined by Lindeborg as "the value of the increase in output obtained by adding an additional acre-foot of water to a fixed amount of other production factors" (Lindeborg, 1970, p. 4). This was assumed to be the price that could be paid for that increment of water. Because a finite quantity of water is required for production and a narrow range of values for the price of water is needed for administration, Lindeborg averaged the marginal value products up to the quantity of water required to grow the crop rotation at 60 percent field application efficiency. The value thus reported can be taken as the payment capacity for an optimal crop rotation. He repeated the calculation for several farm sizes to estimate the effect of farm size upon payment capacity (average marginal value product). The results for Dry Lake area and Oakley Fan are listed in table 2. The payment capacity for the 200-acre farm in Dry Lake was estimated from the values presented by Lindeborg for the 320 and 640-acre farms, assuming economies of size to be the same as for the Oakley Fan. Also listed in table 2 are average irrigation requirement and return to management for each farm budget. The payment capacities were published in terms of dollars per acre-foot of water used, and were converted to dollars per acre as shown in table 2. The adjusted payment capacity listed in column 8 was obtained by altering the return to management to the standard 5 percent of the gross farm income used in this report.

## DISCUSSION OF PAYMENT CAPACITIES

Although the methods of calculating payment capacity used by the University of Idaho is different than the method used by the Bureau of Reclamation, the results appear to be similar when compared on a standardized basis. Estimates of payment capacity for similar farm sizes allowing similar rates of return to management should be comparable. The only duplication by the two agencies are the Oakley Fan-Salmon Falls areas. Because the crops, climate, and soils of these areas are similar, payment capacities should be comparable. The adjusted payment capacity for the 200-acre farm in the Oakley Fan as calculated by Lindeborg (table 2) is $27.00 per acre. The adjusted payment capacity for the 200-acre farm in the Salmon Falls area as calculated by the Bureau of Reclamation (table 1) is $29.00 per acre. Thus, the results obtained by the two agencies do appear to be comparable.

The payment capacities as calculated by the Bureau of Reclamation for the Challis, Bear Lake, and East Greenacres projects were for 75 to 120-acre farms (table 1). The payment capacities for the other areas are for 150 to 200-acre farms. The increased payment capacity of larger acreages noted by Cheline and Lindeborg would appear to make comparing the payment capacities of the smaller farms to that of the larger farms unreasonable. However, the budgets of the smaller farms include livestock enterprises; while the budgets of the larger farms include only crop enterprises. The livestock operation allows full employment of the farm family to increase the gross income for the farm. This makes the payment capacities more directly comparable than an acreage comparison suggests.

## ESTIMATION OF PAYMENT CAPACITIES

**Data Availability** – Payment capacities for the areas described above varied from $5.50 to $45.00 per acre. A review of the characteristics which influence productivity of these basins reveal variations in climate, elevations, lengths of growing seasons, soils, and crop

rotations. Each of these factors has an effect on payment capacity and might be used to estimate payment capacities. However, gross income per acre reflects each of these factors and is a better estimator than any single characteristic. This relationship is used in this study to estimate payment capacities for those basins for which payment capacities have not been recently calculated. This approach simplifies data collection because data for the income side of a farm budget analysis is less detailed and more readily available than data for the cost side of the budget.

Data for determining gross farm income are available from several published sources. Crop yield data are available by county on a yearly basis for potatoes, wheat, and barley from the Statistical Reporting Service, USDA. The data reported included acreage planted, acreage harvested, and harvested yield. Information is not available on a county-wide scale for either distribution and range of yield or average prices received. Average yields for other crops are reported on a state-wide basis by the Statistical Reporting Service. Prices for all crops are reported as state-wide averages. The Census of Agriculture, taken at 5-year intervals, has acreages and total yields by counties for each principal irrigated crop. The most recent reports are for the 1959 and 1964 crop years. The average prices received for products are not presented. The USBR reports the average yields and prices received for agricultural products on each of its irrigation project developments annually. Data are available for eleven project areas in Idaho. Also included in the USBR data are estimates of average gross income per acre for the project areas.

The data used in calculation of the gross income per acre was chosen to provide consistent estimates from county to county. Of the data sources available, the average yield data provided by the Census of Agriculture is most complete. Yield averages are obtainable for every important irrigated crop except pasture for each county in Idaho for the years 1959 and 1964. The average yield data from the 1964 census were used in conjunction with average prices received per unit of crop as obtained from averaging the state-wide annual crop prices reported by the Statistical Reporting Service for the years 1964-69. Prices for several crops were not available from this source and were estimated from the other data sources.

**Calculation of Gross Income Ratio** – The average gross income per acre for each county with irrigated acreage in Idaho was calculated by obtaining the total dollar value resulting from the production of principal irrigated crops. The crops used were silage corn, grain corn, wheat, oats, barley, alfalfa, potatoes, dry beans, dry peas, and sugar beets. The total dollar value of these crops for the county was divided by the county acreage in these crops to give an average gross income per acre. The resulting value was placed in ratio form by dividing it by the gross income per acre of Canyon County.

A graph of payment capacity versus gross income per acre ratio (fig. 1) was obtained by plotting the adjusted payment capacities listed in tables 1 and 2, versus the calculated gross income ratio for an appropriate county. The resulting curve was used to estimate payment capacities for other counties for which the gross income ratio was known. The payment capacity for a county was then used as a basis for estimating the payment capacity for a similar ground-water basin. The gross income ratio and payment capacity for each irrigated county are listed in table 3, along with the ground-water basin of which the county is considered to be typical.

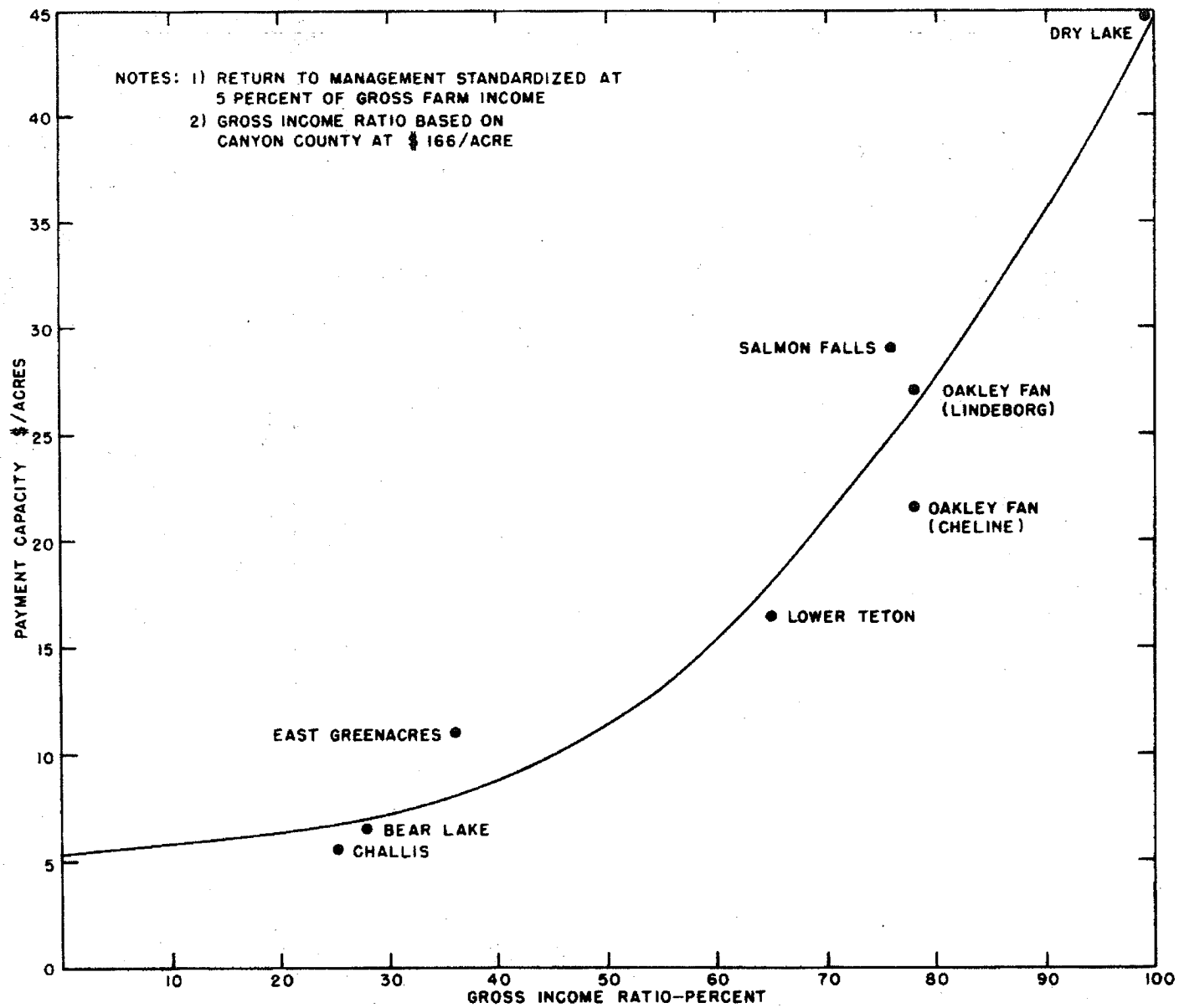


FIGURE 1. Relationship between payment capacity for water and the relative productivity of farming areas

TABLE 3

SUMMARY OF PAYMENT CAPACITY ESTIMATES

| Basin No.* | Basin Name | County | Ave. 1964 Gross Income Per Acre | Gross Income Ratio | Estimated Payment Capacity |
|---|---|---|---|---|---|
| - | - | - | $/Acre | - | $/Acre |
| 1 | Rathdrum | Kootenai | 60. | 0.36 | 8. |
| 2 | Weiser | Adams | 44. | 0.27 | 7. |
| 3 | Weiser River | Washington | 128. | 0.77 | 25. |
| 4 | N.F. Payette | Valley | 56. | 0.34 | 8. |
| 5 & 6 | Garden Valley, Stanley Basin | Boise | 41. | 0.25 | 7. |
| 7 | Payette | Payette | 92. | 0.55 | 14. |
| 8 | Payette | Gem | 86. | 0.52 | 12. |
| 9 | Boise | Canyon | 166. | 1.00 | 45. |
| 10 | Boise | Ada | 96. | 0.58 | 15. |
| 11 | Bruneau, Homedale, Murphy, Grand View | Owyhee | 118. | 0.71 | 22. |
| 12 | Mountain Home | Elmore | 158. | 0.95 | 40. |
| 13 & 14 | Salmon Falls, Sailor Creek | Twin Falls | 126. | 0.76 | 25. |
| 15 | Camas | Camas | 29. | 0.18 | 6. |
| 16 | Big Wood, Silver Creek, Little Wood | Blaine | 59. | 0.36 | 8. |
| 17 | Snake Plain | Gooding | 94. | 0.57 | 15. |
| 18 | Snake Plain | Lincoln | 73. | 0.44 | 10. |
| 19 | Snake Plain | Jerome | 127. | 0.77 | 25. |
| 20 | Snake Plain | Minidoka | 146. | 0.88 | 34. |
| 21 | Michaud Flat | Power | 154 | 0.93 | 37. |
| 22, 23 & 24 | Rock Creek-Goose Creek, Raft, Rockland Valley | Cassia | 130 | 0.78 | 26. |
| 25, 26, 27 & 28 | Malad, Arbon, Curlew-Black Pine, Pocatello | Oneida | 65. | 0.39 | 9. |
| 29 | Cache Valley | Franklin | 78. | 0.47 | 11. |
| 30 | Bear Lake | Bear Lake | 47. | 0.28 | 7. |
| 31 & 32 | Portneuf, Gem-Gentile Valley | Caribou | 77. | 0.46 | 10. |
| 33 | Snake Plain | Bingham, Madison, Bonneville | 127 | 0.77 | 25. |
| 34 & 35 | Lower Teton, Willow Creek | Fremont | 107. | 0.65 | 18. |
| 36 | Upper Teton | Teton | 52. | 0.32 | 7. |
| 37 | Mud Lake | Jefferson | 98. | 0.59 | 15. |
| 38 | Birch Creek | Clark | 53. | 0.32 | 7. |
| 39 & 40 | Big Lost River, Little Lost River | Butte | 73. | 0.44 | 10. |
| 41, 42 & 43 | Challis, Pahsimeroi, Lemhi River | Lemhi | 53. | 0.32 | 7. |

* Basin numbers refer to those shown in figure 8.

It is recognized that some care is necessary in applying the payment capacities as calculated. The payment capacity or the gross income ratio for a county may not be the same as that for a basin within the county. For example, Custer County includes several different ground-water basins. It includes part of the Big Lost River Basin which grows some crops adaptable to lower elevations, and the Stanley Basin area which grows crops adaptable to higher elevations. It would not be valid to utilize the payment capacity for Custer County for Stanley Basin because it would include the effects of part of the Big Lost River Basin. Therefore, it was necessary to use judgment in selecting gross income ratios that are representative of the basins to which they apply. Conversely, there are counties which have only one basin. For these, the payment capacity and the gross income ratio as calculated for the county are a good average for the basin.

There are a number of instances in which payment capacities or gross income ratios for adjacent counties differ greatly. For instance, the large variation between the payment capacity for Canyon County as compared to Ada County can be explained in part by differences in soils; however, part of the difference must be due to differing farm sizes and farming practices. The smaller farms in Ada County do not support the necessary specialized equipment for the higher value crops. An additional factor is that the gross income ratio does not reflect income from animal enterprises or pasture land. If the data were available so that these could be included, the payment capacities might be altered.

Estimates of payment capacities could be improved by additional sources of data. If data were available for basin units rather than county units, the judgment factor required in selecting a county which is representative of a given basin would be eliminated. If values for prices of crops were available for counties instead of on a state-wide basis, the gross income might be different. There is no way at the present time of getting reliable estimates of average prices paid for each of these ten crops during the year for a county or basin. The only price variation data readily available are for the differences in shipping costs to major terminals. The most recent data for yields were for 1964. It should be realized that changes in crop rotations and introduction of new crop varieties may have caused changes in payment capacities for various counties. For instance, new varieties of wheat and alfalfa have increased the expected yields. Counties in which feed crops are grown may thus be more competitive with those growing cash crops than the gross income ratio indicates. The estimates should be updated periodically as new data become available.

Additional refinement could be obtained in the estimates of payment capacity by calculating additional base payment capacities to increase the reliability of the curve in figure 1. Payment capacities calculated especially to establish this curve using consistent assumptions and methods on current data could provide a better basis than those now available. Ideally, the base payment capacities would be for a single farm size, and livestock operations would not be considered. The unstable economic conditions under which the available payment capacities were made reduces the reliability of making comparisons such as that made in figure 1.

Payment capacities for each basin were estimated to the nearest dollar from the curve of figure 1. Although the reliability of the data used to develop figure 1 does not warrant this degree of accuracy, it was felt that rounding should be delayed until the final result to avoid multiple rounding errors.

## COST OF PUMPING WATER

During the past decade, a number of studies have been conducted to determine the cost of pumping irrigation water. Several articles have been written especially for Idaho conditions as a result of research contracts between the University of Idaho and the Idaho Department of Water Administration. Those studies which have results that are directly applicable to the reasonable pumping lift study are summarized below.

### ANALYSIS OF COST BY ITEMIZING

The cost of pumping water in the Oakley Fan area near Burley was studied by Haynes in a companion thesis to that of Cheline's on payment capacities (Haynes, 1969). He collected field data on pumping system costs and irrigation practices from twenty-two farms in the area. Using a computer program, Haynes determined the cost of pumping water for 200, 400 and 600-acre model farms for a number of irrigation efficiencies. The number of wells on each size of farm was also a variable. The pumping costs were based upon electrically-powered systems and included both fixed and variable costs. His results indicated that the cost of pumping increased with the number of wells used per farm. The results also showed that a change from 50 percent to 65 percent in field application efficiency can result in a large change in the cost of pumping. Haynes combined his cost results with the payment capacities presented by Cheline to determine the range of economic lifts for each farm size. These varied from 389 feet to 437 feet for the 200-acre farm, depending upon field application efficiency; the range in lift varied from 670 feet to 894 feet for the 400-acre farm, depending upon efficiency and the number of wells used. His results for a 600-acre farm indicated a range from 767 to 1,081 feet depending again upon efficiency and the number of wells used.

Dickerson, Larsen, and Funk evaluated pumping costs from wells in Kansas (Dickerson, Larsen, Funk, 1964). Their data, obtained from well drillers, retail pump companies, and irrigators, were for systems of less than 300 feet total lift used for supplemental water supplies. The pump systems studied were powered by either natural gas, liquified petroleum (L.P.) gas, or diesel fuel. Charts giving total annual costs per acre-foot pumped versus total pumping lift and annual hours of operation are presented for each fuel type. These costs are related to expected increases in crop returns due to irrigation to obtain reasonable pumping lifts. Although the unit pumping costs given on the charts are not strictly applicable to Idaho, the results do emphasize the importance of maximizing annual pumping hours. Although each added increment of operating time has successively less effect, the number of pumping hours is shown to be one of the most significant factors determining unit pumping cost. Their results also indicate considerable difference in cost depending upon fuel type.

A study by Chen and Long of the cost of pumping irrigation water in New Mexico indicated that the volume of water pumped influenced the cost per unit of water more than the type of power used or the magnitude of lift; however, their study included only a narrow range of lifts (64 to 102 feet). Data were obtained by interviews with the irrigators of 31 farms who operated 52 wells. Their results indicated that the cost of pumping water ranged from $33.92 per acre-foot for wells pumping less than 50 acre-feet per year to $4.13 per acre-foot for wells pumping more than 200 acre-feet per year for the wells studied (Chen and Long, 1965).

## ANALYSIS OF COST BY STATISTICAL METHODS

Von Bernuth studied pumping costs for irrigation water, using a statistical correlation procedure (Von Bernuth, 1969). Data for his study were obtained from publications and previous surveys of wells located in five western states. Data were gathered for wells with pumps powered by both electricity and natural gas. The total pumping lift for these wells varied from 15 feet to nearly 600 feet. Data gathered included lift, discharge, pump horsepower, annual operating hours, volume pumped, and total investment as independent variables, and total annual costs per acre-foot and annual variable costs per acre-foot as dependent variables. Using a step-wise multiple regression technique, the relative effect of each independent variable on each dependent variable was determined. Data for the electrically-powered wells were analyzed separately from that for the natural-gas powered pumps. Regression equations were developed to estimate each of the dependent variables using selected combinations of the independent variables.

Von Bernuth developed five equations for determining total annual costs of pumping from wells using electricity. The coefficient of determination for these equations varied from .87 to .89, indicating that the equations accounted for 87 to 89 percent of variation in costs. These equations, along with the coefficient of determination and standard error of estimate for each, are shown in table 4. It should be noted that several of the equations having only a few variables are nearly as accurate as the more complex equations. Thus, these equations have the advantage of allowing costs to be determined without collecting data for each item involved in the total cost.

Von Bernuth's correlations indicated that the most significant factor determining total annual cost was investment divided by volume pumped, or dollars invested per acre-foot; and that the most significant factor affecting variable (or operating) costs was lift. Judged by simple correlation coefficients, the following variables, listed with their simple correlation coefficients, were most interrelated to total pumping cost: investment divided by yield (0.918), operating time (0.495), lift (0.458), and volume pumped (-0.452). He concluded that his equations should be useful for estimating costs.

## ASSUMPTIONS FOR DETERMINING THE COST OF PUMPING WATER

The cost of pumping water can take a wide range of values for any given value of lift because of the effect of other variables. Because the effect of lift on total pumping costs is the goal of this portion of the study, it is necessary to make some initial assumptions to limit the results to a range usable for administration of water rights. The following assumptions are intended to be related to and complementary to those made in calculating payment capacity.

1. Pumping costs should be representative of those for wells supplying economic-sized farming units. Cost for wells on small acreages or wells used supplementally should not be used. This assumption is necessary because of the large variability in unit pumping costs due to volume pumped.

2. Pumping costs should be based upon supplying the full irrigation requirement of typical crops grown in the basin at some reasonable irrigation efficiency.

## TABLE 4

## EQUATIONS TO PREDICT TOTAL IRRIGATION PUMPING COSTS AS DEVELOPED BY VON BERNUTH

(after Von Bernuth, 1969)

| Eqn. No. | Equation | Coefficient of Determination | Standard Error of Estimate (¢) |
|---|---|---|---|
| 1 | $Y_1 = 0.932L + 11.26I - 0.035E - 0.004F + 227$ | 0.88 | 135 |
| 2 | $Y_1 = 0.872L + 11.65I - 0.063P - 0.036E + 225$ | 0.88 | 136 |
| 3 | $Y_1 = 0.793L - 0.036Q + 0.429H - 0.083T + 0.0071Y + 11.01L - 0.216P - 0.016E + 0.006F + 394$ | 0.89 | 134 |
| 3* | $Y_1 = 0.753L - 0.057T + 11.09I + 263$ | 0.88 | 134 |
| 4 | $Y_1 = 0.666L + 12.74I + 129$ | 0.87 | 138 |
| 5 | $Y_1 = 0.779L + 11.78I - .044E + 244$ | 0.88 | 136 |

**Symbols**

$Y_1$ = Total annual water cost divided by well yield (¢/A-F)

L = Total lift in feet

I = Investment cost divided by well yield (¢/A-F)

E = Product of lift and discharge divided by nameplate horsepower

F = Product of lift, discharge, and operating time

Y = Total water yield in acre-feet per season

P = Product of lift and discharge

Q = Discharge rate in gallons per minute

T = Annual operating hours

H = Nameplate engine horsepower

This assumption is also necessary because of the variation in costs due to volume pumped.

3. Pumping costs should be based upon a single well supplying water to a main headgate for surface irrigation. Costs arising from distribution of the water beyond the main headgate are not included in the pumping cost value because they are included in the farm budgets used to estimate payment capacity. Surface irrigation was chosen because most of the payment capacities were based on this method of application. Also, the increased application efficiency of sprinklers tends to offset the increased investment and operating costs.

4. Pumping costs should be based upon electrically-powered pumps. Although there are other types of power used to pump water in Idaho, electrically-powered pumps predominate.

5. Pumping costs should be based upon the total water costs, not merely the operating or variable costs. The total cost will include depreciation and interest charges that are not always considered by owners but are necessary for a continuing operation.

6. The relationship between pumping costs and lift is not dependent upon the location of the well within the state. This assumption is necessary to allow data collection on a state-wide scale rather than a basin scale. A comparison of the unit pumping costs calculated in this report for the various areas of the state supports this assumption.

**METHOD OF COST ANALYSIS UTILIZED**

The short-cut method of estimating costs using key variables developed by Von Bernuth was selected for use in this study because of data collection difficulties and the desirability of calculating a statistically-sized sample. Utilization of any of Von Bernuth's regression equations requires the use of data similar to that from which the original equation was derived. Differences indicated by any of several statistical measures could cause the cost estimates to be in error. Several groups of data were collected to test the validity of using Von Bernuth's equations on data other than those used in deriving the equations. Data for five wells were obtained from the Boise District Office of the Bureau of Land Management (BLM). These data included all of the information required to estimate costs using Von Bernuth's equations No's. 3* and 4 for electrically-powered wells (table 4). Estimated annual pumping costs as calculated by a standard BLM procedure were also included in the data gathered. The BLM procedure for estimating pumping costs is similar to the itemizing procedure described by Dickerson, Larsen, and Funk, 1964. Von Bernuth's equation No. 4 was used to estimate pumping costs, and the resulting estimate was compared to the BLM estimate for the same well. Agreement within 10 percent was noted for each of the comparisons (fig. 2). It should be emphasized that the BLM cost values required assuming pumping time, power rates, and efficiency, and were only estimates of the true costs paid by the well owners.

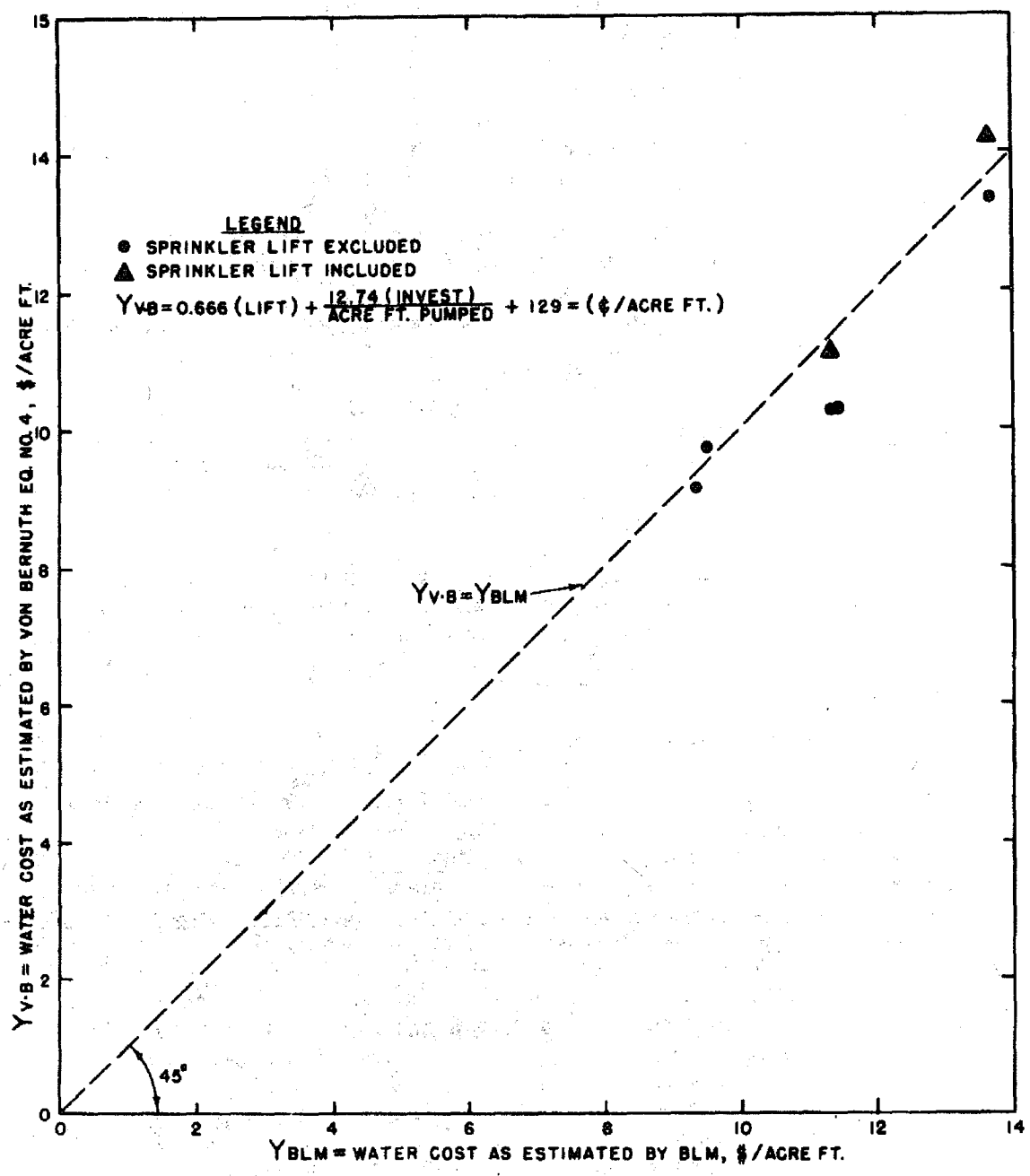


FIGURE 2. Comparison of water cost estimates obtained using the Von Bernuth short-cut method to water cost estimates for the same system obtained by an itemizing procedure