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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.

42-231. 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)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Area and County	Source and Date Published	Type of Enterprise	Size of Enterprise (Acres)	Gross Farm Income $/Acre	Standardized Management Return $/Acre	U of I Calculated Pymt. Capacity $/A-F	Ave. Irri. Req. for Rotation A-F/A	U of I Payment Capacity $/Acre	Return to Management Allowed by U of I $/Acre	Return to Water and Management $/Acre	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.

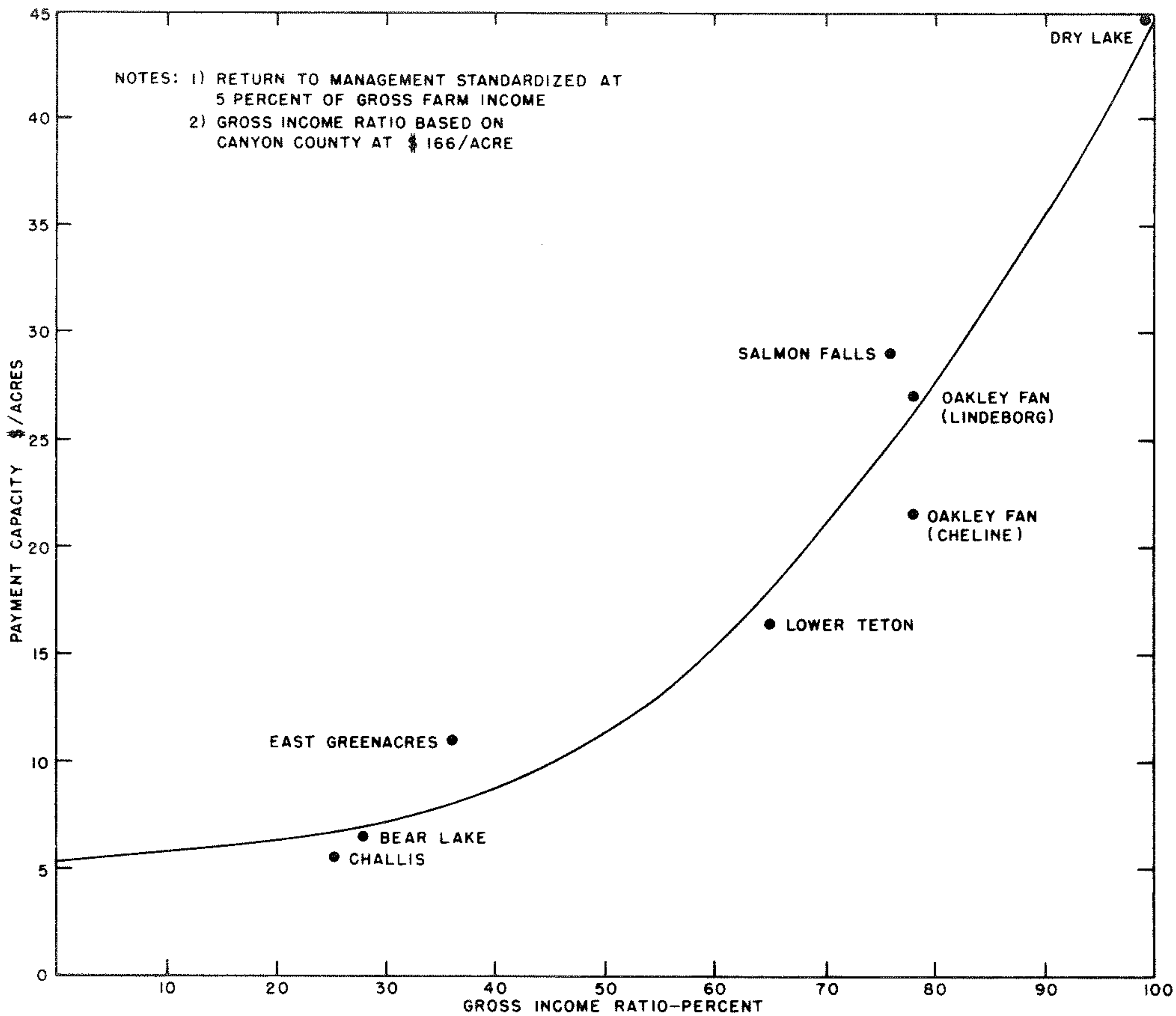

FIGURE 1. Relationship between payment capacity for water and the relative productivity of farming areas

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.

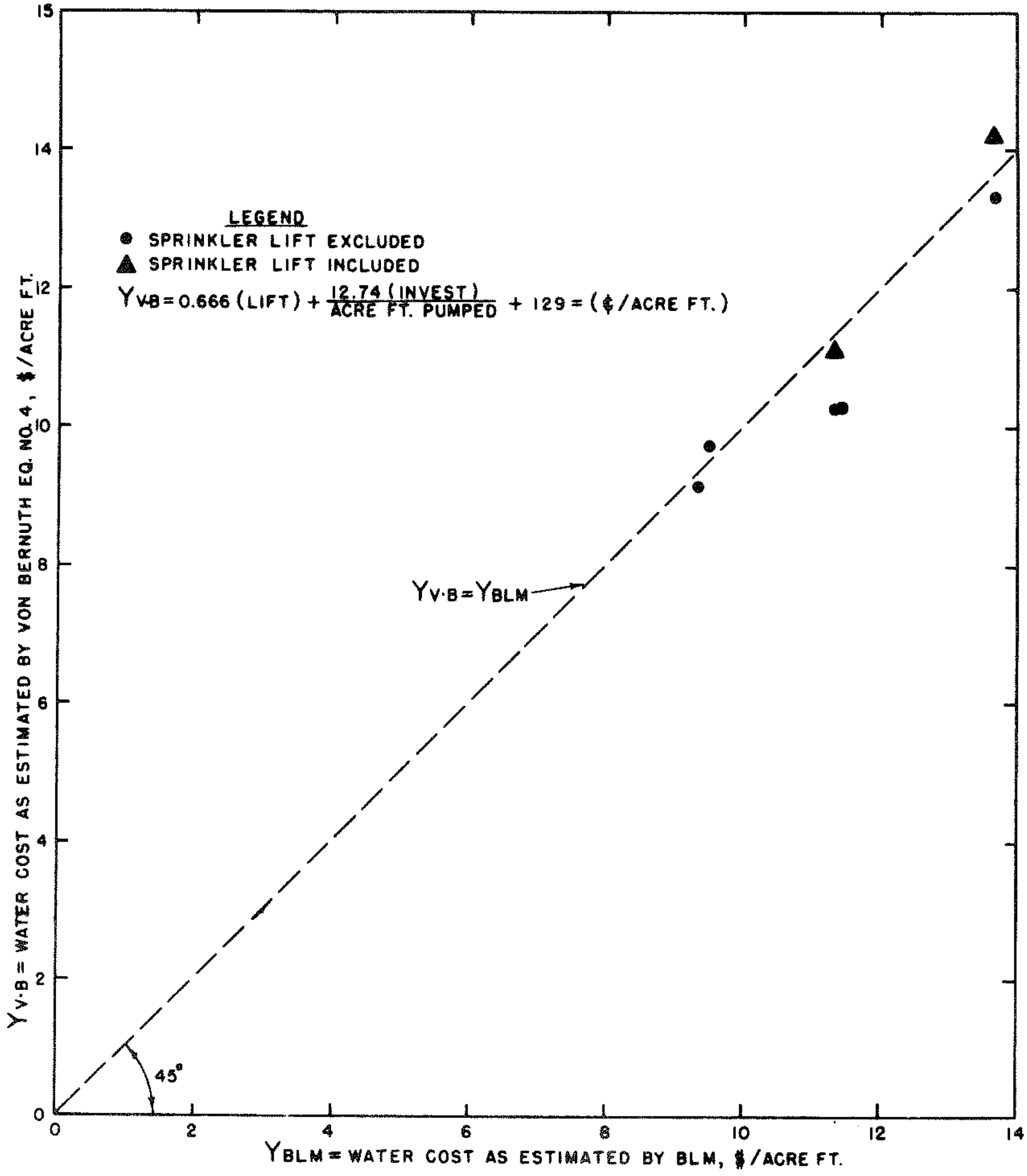

FIGURE 2. Comparison of water cost estimates obtained using the Von Bernuth short-cut method to water cost estimates for the same system obtained by an itemizing procedure

As a second check on the validity of using Von Bernuth's statistically-derived equations, the pumping cost values obtained by Haynes for the Oakley Fan (Haynes, 1969) were recomputed using his data in Von Bernuth's equation No. 4. The annual costs obtained by Haynes from itemizing costs for various systems ranged up to 14 percent higher than costs for the same system calculated using equation No. 4 (fig. 3). Part of this variation is due to the inclusion of annual costs for concrete head ditches, siphon tubes, and land leveling in the values calculated by Haynes while these costs were not included in the estimate obtained using equation No. 4. The greatest variation between the costs obtained by the two methods were for very high lift systems (800 to 1,081 feet). Better agreement was indicated for the lower lifts which are more commonly encountered.

Because power rates, interest rates, depreciation rates, and other cost influencing factors are variable, a better agreement between the estimates obtained using Von Bernuth's equation No. 4 and those obtained by an itemizing procedure could not be expected when using a single equation to calculate costs for pumping in all areas of the state. Therefore, Von Bernuth's equation No. 4 was used to estimate total annual water costs in this study.

DATA ACQUISITION

Data for well and pump characteristics are available from several sources: pump retail companies, well drillers, departmental records, and well owners; however, the well owner is the only source of data on the actual details of well operation. Because operating hours and volume pumped are such key factors in determining costs, a method of collecting data directly from the well owner was used. Questionnaires requesting the data needed for calculating pumping costs using Von Bernuth's equation No. 4 were mailed to approximately 500 well owners. Names were obtained from well driller's logs on file with the IDWA for wells drilled since 1965. Corrected addresses were obtained from licensing applications on these same wells. Data for recently drilled wells were requested so that the investment values would represent current replacement costs. A total of 165 usable questionnaires were returned. Many others were returned, but lacked some of the necessary information. Follow-up letters were sent to clarify doubtful information.

Several methods were used to estimate the accuracy of the reported data. The volume in acre-feet per acre that would be applied to the farmland using the data reported was compared to the irrigation requirement for alfalfa for the area (fig. 4). Many of the reported use values were lower than the expected requirement. This is possible either because of application efficiencies being better than assumed, all crops not being alfalfa, or the well was being used as a supplemental supply. Many of the points for which the reported acre-feet per acre use was higher than the expected irrigation requirement were for areas of coarse soil and may actually be necessary. However, it is likely that part of the variation of the reported water use from the expected water use is due to inconsistencies in the reported data. The reported water use was calculated using data for pump discharge, hours pumped annually, and irrigated acreage. The acreage values are probably accurate; however, the irrigator probably tends to overestimate the pump discharge and the annual hours of use. This overestimate of the yield of the system biases the result by making the cost per acre-foot pumped as calculated by the Von Bernuth equation lower than actually exists.

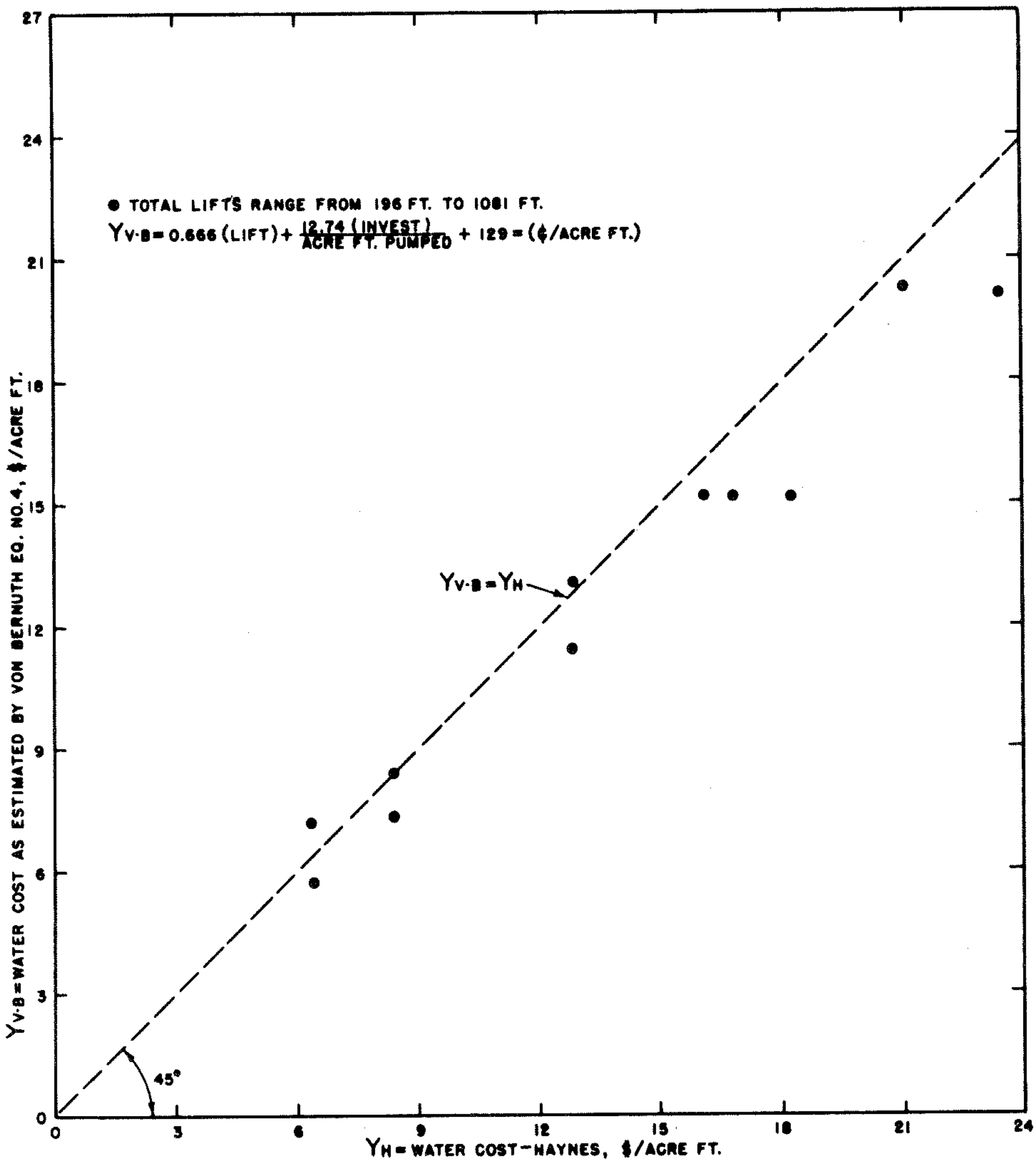

FIGURE 3. Comparison of water costs calculated using the Von Bernuth short-cut method to those for the same systems calculated by Haynes by itemizing

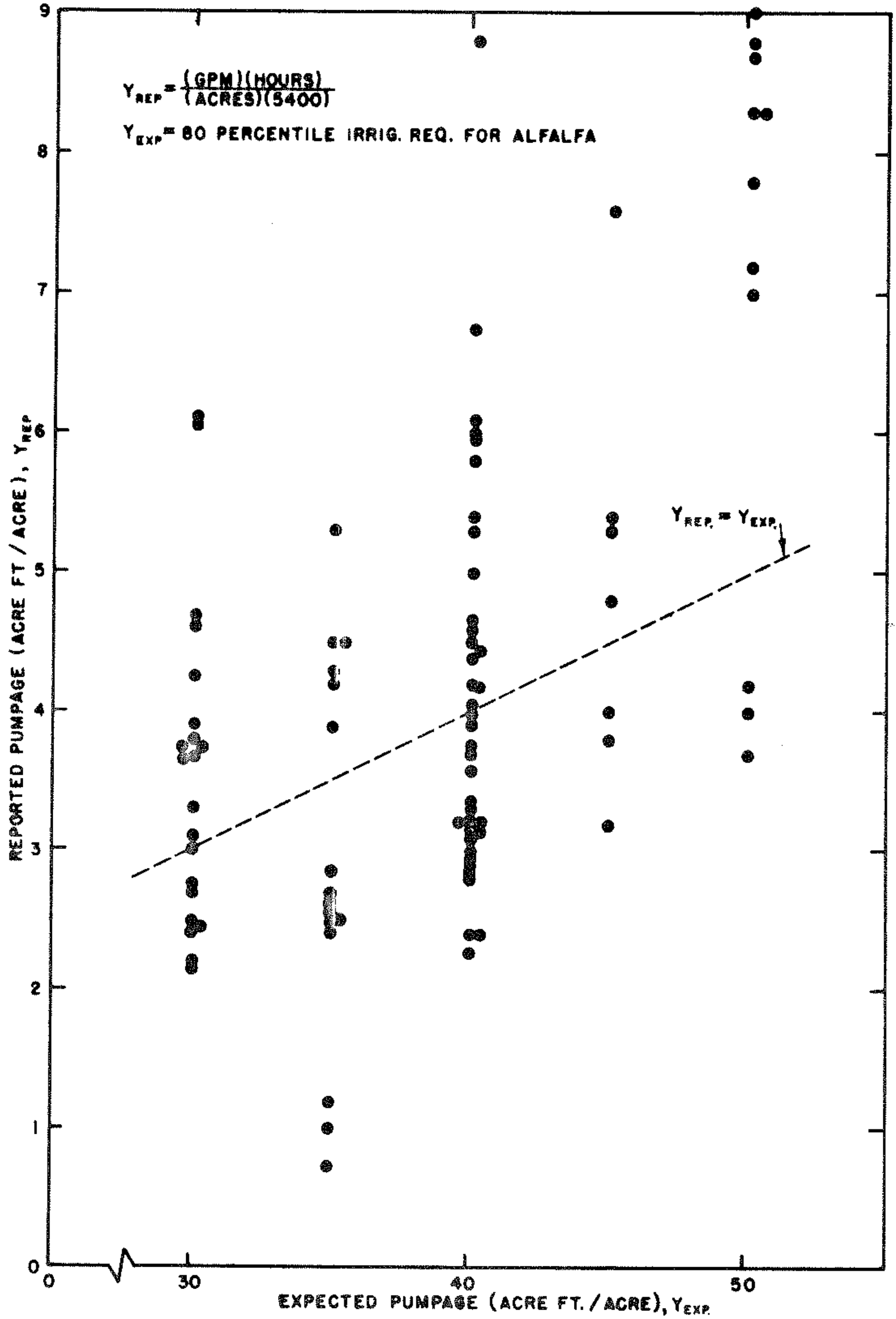

FIGURE 4. Comparison of reported water use to expected water use

Another method used to check the accuracy of the data was the comparison of the reported horsepower of the pump to that required to lift the reported discharge through the reported lift, assuming a reasonable efficiency (fig. 5). Again, considerable variation exists between expected values and calculated values. Part of the variation is due to the use of the single efficiency of 60 percent and the use of the same increase in lift for every sprinkler system. Part of the variation is undoubtedly due to inconsistencies in the reported data.

As a final check, the reported investment costs were compared to expected prices obtained from retail pump companies and well drillers. Although these checks are only general they indicate that the data, as a whole, are reasonable. The questionnaire data was used as reported in all cases.

CALCULATION OF PUMPING COSTS

A cost per acre-foot was calculated for pumping from each of the wells covered by the questionnaires using Von Bernuth's equation No. 4 for electrically-powered wells (fig. 6). At any given lift, a wide range of costs may be noted. Cost results as presented in figure 6 have been divided into groups on the basis of acre-feet pumped annually. It can be seen from this figure that costs per acre-foot decrease with volume pumped.

If it assumed that the returns represent a random sample of data for wells in Idaho, the costs should be good estimates of the cost of pumping irrigation water in Idaho.

ANALYSIS OF COST INFORMATION

The large range of costs that appear in figure 6 for each lift is the result of variation in two major factors: pumping time per season, and initial investment. Von Bernuth, in the development of his equation No. 4, divided the cost factors into two main groups: fixed or overhead costs and variable or operating costs. The variability of these costs with pumping time per season is important in explaining the range in results. As pumping volume per season increases, the fixed (overhead) costs tend to decrease per unit of water pumped because the costs are spread over more units of water. The variable (operating) costs remain approximately the same for each unit. The result is an over-all decrease in the total unit pumping costs as the volume pumped increases. This trend is intensified by power company contracts which specify a minimum yearly power cost up to a specified minimum number of hours and by rate schedules which reduce power rates as more electricity is used.

A well and pump system that is properly designed to produce the required volume of water for a farm will have a maximum number of operating hours per season. The number of operating hours per season will depend upon the length of the growing season, the availability of reservoir storage, the maximum irrigation demand rate, and the excess capacity desired for insurance in case of pump failure.

The other major factor which causes the variability in costs at a given lift is initial investment. A statistical correlation analysis of the well and pump data obtained from the questionnaires indicates a coefficient of determination between lift and initial investment divided by quantity of water pumped of only 0.019; that is, only 1.9 percent of the variation in the factor initial investment divided by quantity pumped is attributable to regression on

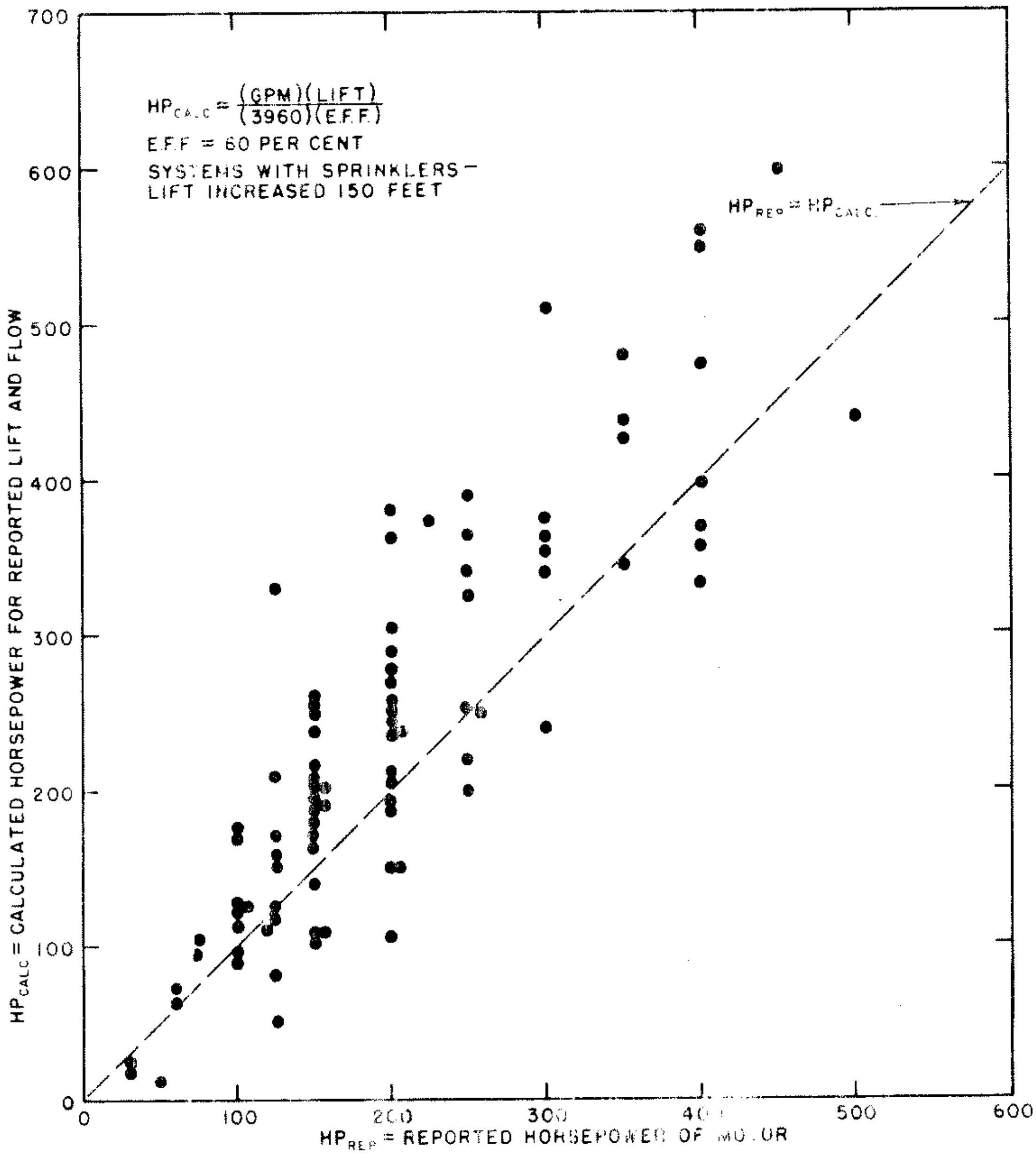

FIGURE 5. Comparison of power required for the reported lift and flow to the reported power of the pump motor

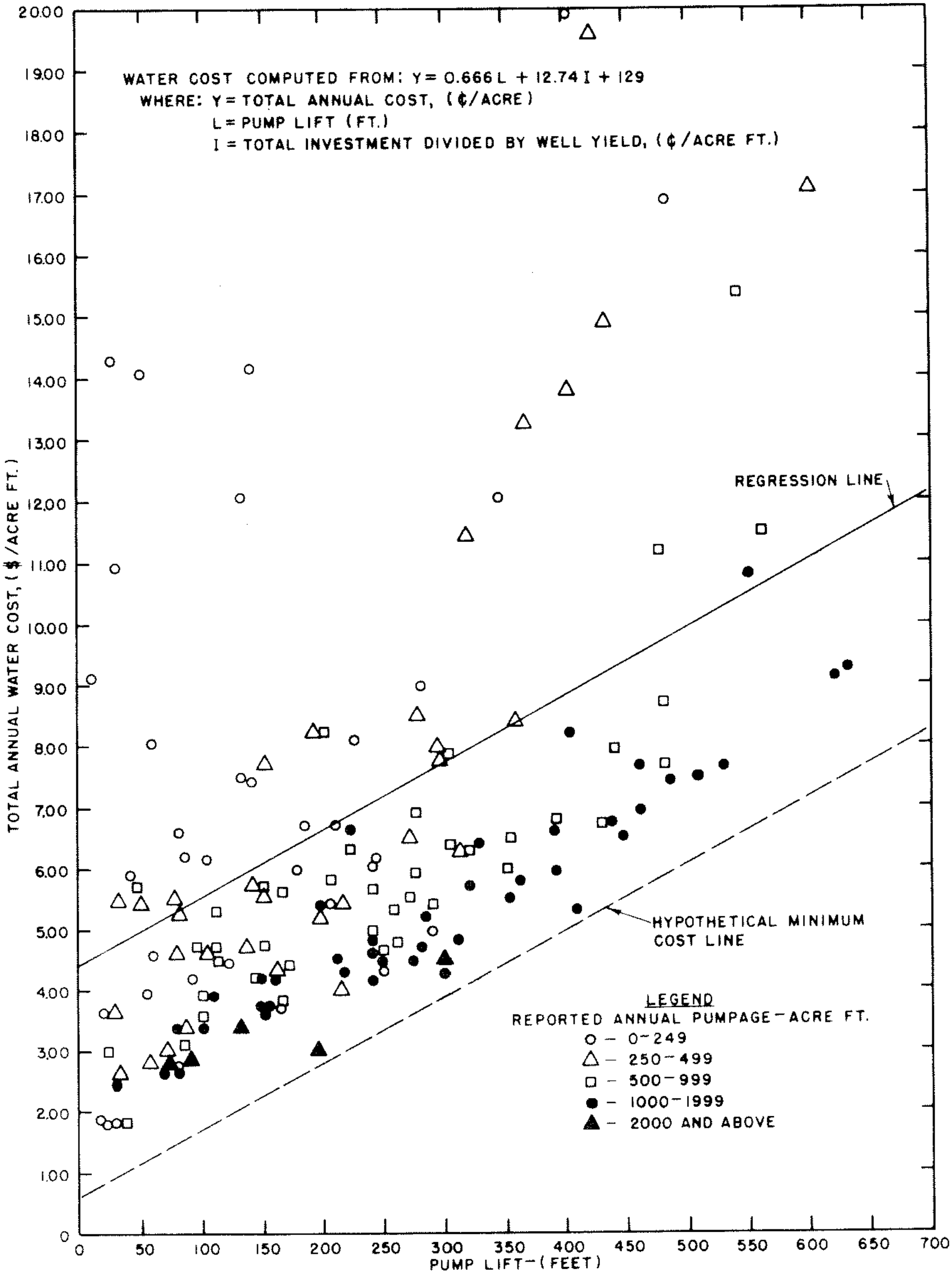

FIGURE 6. Relationship of pumping cost to pumping lift (all questionnaire data used)

lift. Part of this lack of correlation is caused by pumping time differences and discharge rates, and part by variations in initial investment. Wells do not have identical depths for the same pumping lifts. Differences in pumping drawdown, artesian lift, and the owner's decisions concerning extra depth for insurance against water-level decline can result in a large variation in well depth and drilling costs. Differences in well diameter can have a similar effect on costs. Von Bernuth's equations do not account for these variables directly; however, it can be assumed that on the average these differences are accounted for by the regression analysis used.

A cost calculated for a single set of well characteristics can be inaccurate because of variations in investment costs and operating conditions from farm to farm. This variation is shown by the scatter of costs for pumping water at any given lift shown in figure 6. Therefore, it is more accurate to calculate costs for a large number of wells and analyze the resulting data to determine more representative costs. This was accomplished statistically by calculating regression curves of calculated costs versus lift. The calculations were made using an IBM 360 Model 40 computer at the University of Idaho. Both a linear regression line and a second order curve were calculated for the data (table 5). The coefficients of determination indicate that very little of the variation in cost are attributable to lift (11.9 and 14.4 percent for the line and curve, respectively). It also indicated that the degree of improvement using curvilinear regression as opposed to a straight line regression was not significant.

TABLE 5
RESULTS OF REGRESSION ANALYSIS OF CALCULATED PUMPING COST AS A FUNCTION OF LIFT
(Unit pumping costs estimated using questionnaire data in Von Bernuth's equation No. 4)

Description of Well Data Included in Regression Analysis	Type of Analysis	Y Intercept	Regression Coefficient for Lift (L)	Regression Coefficient for L^2	Coefficient of Determination (r^2)
All Data	Linear	$4.51	0.0108	–	0.119
	Curvi-Linear	$5.97	−0.00405	0.0002643	0.144
Data for Wells on 10 Acres and More	Linear	$3.61	0.0128	–	0.250
	Curvi-Linear	$4.84	0.000436	0.0000217	0.275
Data for Wells Pumping 500 Acre-Feet and More Annually	Linear	$1.97	0.0137	–	0.82
	–	–	–	–	–

It was determined from an analysis of the data that the cost per acre-foot for wells used on small acreages were the highest values shown in figure 6. Regression equations, both linear and curvilinear, were calculated for data remaining after cost data for wells on acreages of 10 acres and less were eliminated (table 5). The coefficients of determinations were 25.0 and 27.5 percent for the linear and curvilinear equations, respectively. This was a considerable improvement because data for only 4 wells were eliminated.

It was felt, however, that to keep the pumping costs determination coordinated with the payment capacity calculation, it was necessary to base the cost only on wells pumping for economic-sized units. A 150-acre farm using water at 3.5 acre-feet per acre requires 525 acre-feet of water per year. Arbitrarily, data for wells producing less than 500 acre-feet per year were excluded. The linear regression line (fig. 7) for the data for the remaining 97 large wells had a coefficient of determination of 0.82; that is 82 percent of the variation in calculated cost was attributable to lift for these wells. The large degree of improvement in the correlation coefficient is somewhat inherent in the method of analysis used because only three independent variables, lift, volume pumped, and initial investment are included in Von Bernuth's equation No. 4. Restricting one of the variables, volume pumped in this case, is certain to help the correlation of the other variables with respect to the calculated dependent variable, cost. However, it is felt that this approach is reasonable and necessary because of the limiting assumption on farm size. The regression line shown in figure 7 is used to estimate pumping costs as a function of lift in this study.

The regression coefficient or slopes are small for all of the regression lines calculated. Total costs, thus, do not increase rapidly with lift. Since the slopes are little more than would be expected due to increased power costs, a compensating effect must also be in force. A compensating increase in efficiency with increased lift is believed to exist. This increase is obtained as a result of matching the well and pump system to the farm and by better operating efficiency. Farmers lifting water 500 feet are more likely to be conscious of the necessity for good design and efficient operation than farmers lifting water only 50 feet, assuming similar payment capacities.

A minimum pumping cost line is apparent from the plot in figure 6. A line drawn approximately parallel to the regression line for cost on lift and just below the lowest data points (this line is shown dashed), represents a minimum cost relationship which only efficiently designed and operated systems attain. By efficiently designed, it is meant that the size, depth, and price of the well and size, capacity, and price of the pump were minimized to result in a minimum initial investment and maximum operating time to produce the required volume of water. Such a well might be termed an ideal well. The only way to get a cost lower than the minimum cost line would be to get a bargain on the price of the well or pumping system. If this relationship were firmly established by actually designing ideal wells for a given lift for a number of sets of required volumes (farm sizes), it would be a valuable tool for evaluating efficiencies of design and operation of actual systems.

QUANTITY OF WATER REQUIRED

A number of sources of data are available for estimating the quantity of water required for various crops for many parts of the state. Estimates of water requirements are available

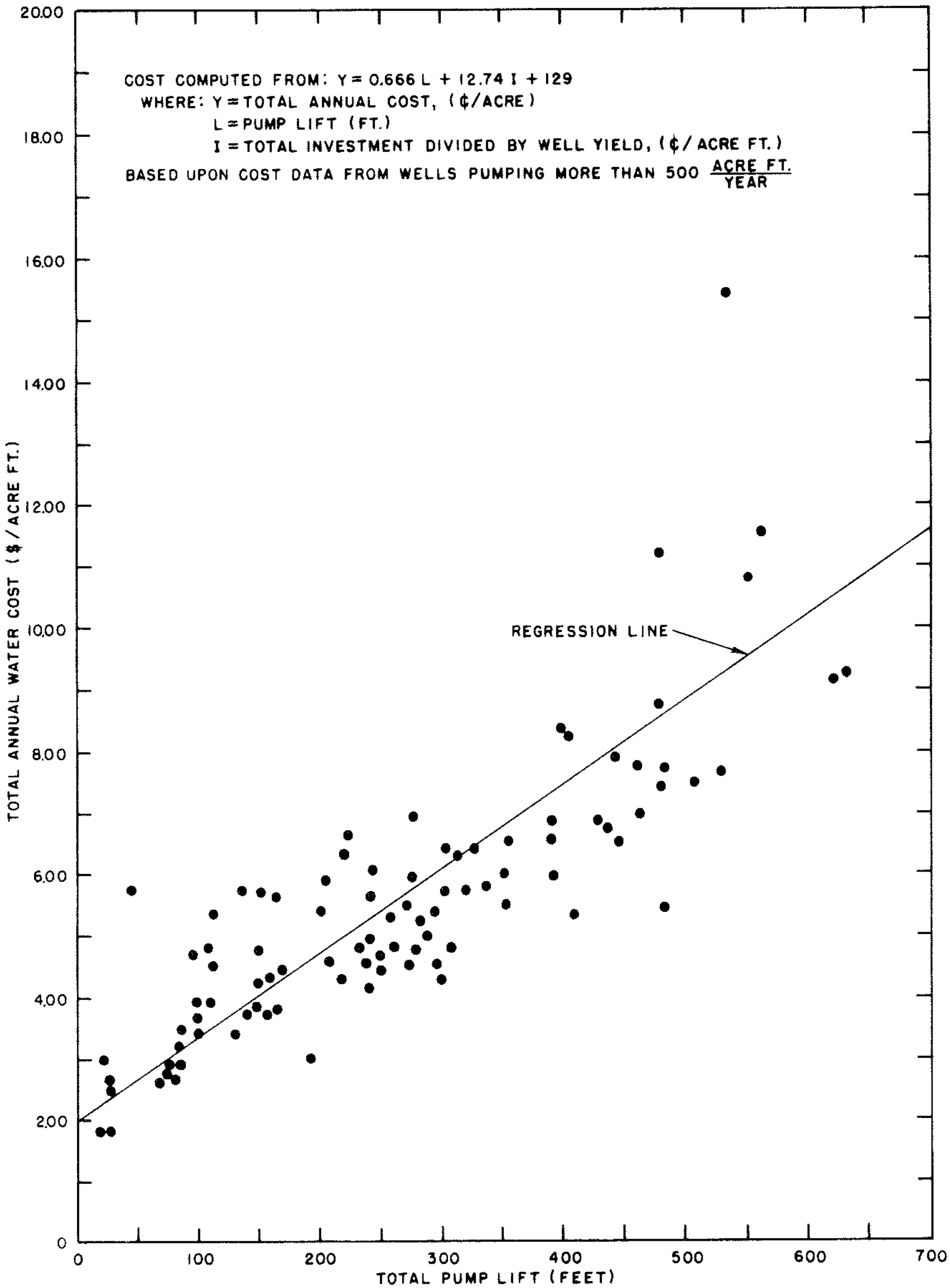

FIGURE 7. Relationship of pumping cost to pumping lift (large capacity well data only)

for particular areas in reports published by the U. S. Geological Survey, USBR, IDWA, University of Idaho, and other agencies. These data were developed using various equations and methods for estimating consumptive use. A bulletin published in 1952 by Jensen and Criddle, "Estimated Irrigation Water Requirements for Idaho", has been a standard guide for estimating water requirements by crop and area. These estimates are based upon the Blaney-Criddle consumptive use equation and climatic data for the area. Researchers at the University of Idaho, Department of Agricultural Engineering, have updated and extended the Jensen and Criddle bulletin by providing estimates of crop water requirement for each major agricultural area (Sutter and Corey, 1970). The water requirements were calculated for each crop using the modified Blaney-Criddle equation and climatic data from selected local weather stations. Consumptive use was calculated for each crop for each month of record at each station. Rainfall during the growing season was subtracted from consumptive use to give consumptive irrigation requirements. The resulting values were then reported in terms of percentiles for months requiring less than a certain value. This bulletin provides the most comprehensive source of data on irrigation water requirements available and is the basis for determining irrigation requirements used in this report.

DETERMINATION OF WEIGHTED AVERAGE IRRIGATION REQUIREMENT FOR EACH BASIN

A weighted average irrigation requirement was determined for each ground-water basin on the basis of the total water use by ten irrigated crops in a county representative of the basin. The total water use was calculated by summing the product of the number of acres of each crop grown in the county as reported in the 1964 Census of Agriculture and the corresponding 80 percentile consumptive irrigation requirement of the respective crops for a nearby weather station (Sutter and Corey, 1970). The 80 percentile requirement was chosen rather than the 50 percentile value because it is believed that reasonable pumping lifts should be based upon an adequate water supply. The 100 percentile value (the water capacity necessary to supply the crop requirements during the highest water use year on record) was not used because this value is affected by extreme years which do not occur frequently.

The weighted average irrigation requirement was obtained by dividing the total water use by the combined acreage of the ten crops in the county. The ten crops used in determining the average water use were the same ones as used in determining the gross income ratio for estimating payment capacity. The headgate irrigation requirement was obtained, assuming 60 percent field application efficiency, by dividing the weighted consumptive irrigation requirement by 60 percent. The field application efficiency used has been found to be reasonable for carefully applied surface irrigation. Irrigation requirements for basins were estimated by assuming the requirement to be similar to that for the county in which the basin is located or a county similar in climate and cropping patterns. The weighted average headgate irrigation requirement is listed in table 6 for each county used in this analysis and is shown by area in figure 8.

DISCUSSION OF CALCULATED WATER REQUIREMENTS

The actual water requirement is variable from farm to farm and from year to year. This variability requires making an administrative choice as to the water requirement that can be reasonably expected. Therefore, the 80 percentile values were used in order to insure an

TABLE 6

SUMMARY OF CALCULATION OF REASONABLE PUMPING LIFT ESTIMATES

(1) Basin No.*	(2) Basin Name	(3) County Used in Determining Payment Capacity	(4) Payment Capacity	(5) Weighted Ave. Irrigation Requirement	(6) Weather Station	(7) Payment Capacity	(8) Reasonable Pumping Lift Estimate
-	-	-	$/A	A-F/A	-	$/A-F	Feet
1	Rathdrum	Kootenai	8	2.73	Coeur d'Alene	2.95	75
2	Weiser	Adams	7	3.42	Council	2.05	0
3	Weiser River	Washington	25	3.48	Weiser	7.20	380
4	N.F. Payette	Valley	8	1.98	Cascade	4.05	150
5 & 6	Garden Valley, Stanley Basin	Boise	7	2.03	Cascade	3.45	110
7	Payette	Payette	14	3.27	Weiser	4.30	170
8	Payette	Gem	12	3.53	Caldwell	3.40	100
9	Boise	Canyon	45	3.45	Caldwell	13.05	800
10	Boise	Ada	15	3.49	Caldwell	4.30	170
11	Bruneau, Homedale, Murphy, Grand View	Owyhee	22	4.08	Grand View	5.40	250
12	Mountain Home	Elmore	40	3.60	Mountain Home	11.10	670
13 & 14	Salmon Falls, Sailor Creek	Twin Falls	25	2.87	Twin Falls	8.70	500
15	Camas	Camas	6	2.20	Fairfield	2.75	60
16	Big Wood, Silver Creek, Little Wood	Blaine	8	2.53	Hailey	3.15	90
17	Snake Plain	Gooding	15	3.14	Twin Falls	4.80	210
18	Snake Plain	Lincoln	10	3.07	Shoshone	3.25	90
19	Snake Plain	Jerome	25	2.94	Twin Falls	8.50	475
20	Snake Plain	Minidoka	34	3.08	Rupert	11.00	650
21	Michaud Flat	Power	37	3.05	Pocatello	12.15	740
22, 23 & 24	Rock Creek-Goose Creek, Raft, Rockland Valley	Cassia	26	3.12	Rupert	8.35	470
25, 26, 27 & 28	Malad, Arbon, Curlew-Black Pine, Pocatello	Oneida	9	2.90	Malad	3.10	80
29	Cache Valley	Franklin	11	2.77	Preston	4.00	150
30	Bear Lake	Bear Lake	7	2.12	Montpelier	3.30	100
31 & 32	Portneuf, Gem-Gentile Valley	Caribou	10	2.02	Grace	4.95	220
33	Snake Plain	Bingham, Madison, Bonneville	25	2.64	Idaho Falls	9.45	550
34 & 35	Lower Teton, Willow Creek	Fremont	18	2.00	Ashton	9.00	510
36	Upper Teton	Teton	7	1.91	Driggs	3.65	120
37	Mud Lake	Jefferson	15	2.54	Dubois	5.90	280
38	Birch Creek	Clark	7	2.48	Mackay	2.80	70
39 & 40	Big Lost River, Little Lost River	Butte	10	2.42	Mackay	4.15	160
41 & 42	Challis, Pahsimeroi	Lemhi	7	2.91	Challis	2.40	50
43	Lemhi River	Lemhi	7	2.61	Salmon	2.70	70

*Basin numbers refer to those shown in figure 8.

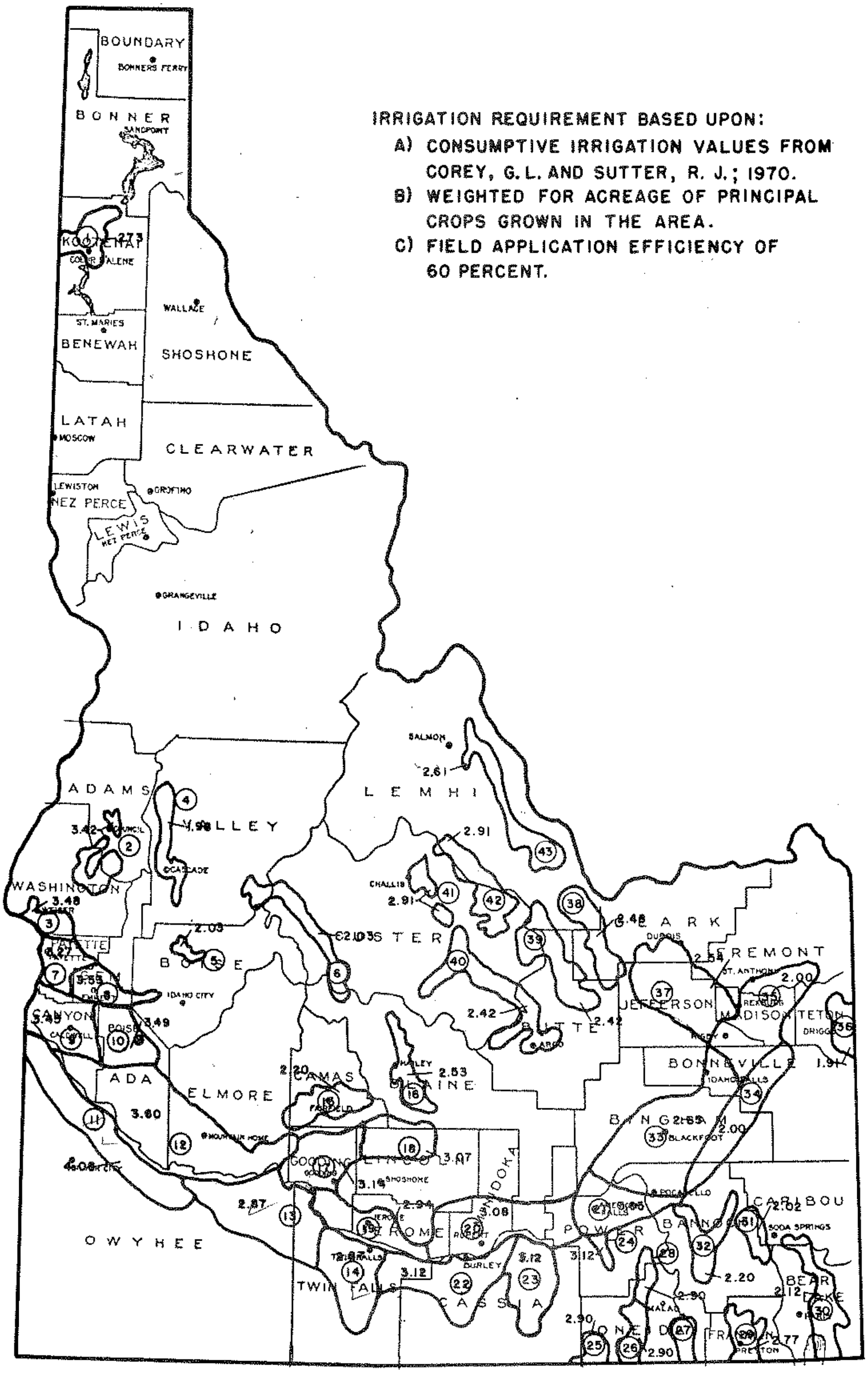

FIGURE 8. Weighted average irrigation requirement for ground-water basins in Idaho

adequate supply except on extreme years.

A potential source of error is apparent in deciding which county average should apply to which basin. The irrigation requirements as calculated are reasonably accurate for the station at which the data were collected; however, the station averages do not exactly fit each county or basin. The same problems were encountered here as in transferring the calculated gross income ratios for a representative county to a basin. The estimates are good when a county contains only the basin in question. However, a judgment factor is required when the county contains more than one basin or the basin extends over more than one county. Care was taken to insure that this judgment factor was as sound as possible by comparing basin and county elevations, climates, and cropping patterns.

On an individual farm basis the calculated weighted-average irrigation requirement will not always apply. It is doubtful that any farmer grows the rotation exactly average for the county. Consequently, a farmer growing crops with high water requirements (alfalfa, potatoes, sugar beets) will have a higher average farm water requirement than that listed for the basin. Such a farmer would be penalized with respect to a farmer growing low water requirement crops (grain, vegetables).

DELINEATION OF GROUND-WATER ADMINISTRATIVE BASINS

It is not possible to denote a single value of reasonable pumping lift for the state because of the wide variations in payment capacities and water requirements. A review of Section 42-237a of the Idaho Code makes it apparent that the Legislature intended for the reasonable pumping lift estimates to be determined for each individual hydrologic ground-water basin.

> ..., *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...*

Areas of common ground-water supply were determined by reviewing reports of previous hydrologic and geologic studies of ground water in Idaho. Ground-water basin boundaries in areas not previously studied in detail were estimated using geologic and topographic maps. Many of the hydrologic ground-water basins encompass areas of significantly varying elevations, climates, soil types, crop rotations, and crop yields. The reasonable pumping lift thus changes over the basin. Section 42-237a of the Idaho Code, quoted above, allows for the possibility of setting more than one reasonable pumping lift for a basin. For this study, boundaries were determined for areas within ground-water basins having similar payment capacities. This was necessarily accomplished only on a gross scale because data on crop yields are available only on a county-wide basis. The Snake Plain ground-water basin is basically an area of common ground-water supply, but changes in elevation, soil, and other factors cause the payment capacity to vary considerably from one end to the other. Therefore, the basin was divided into a number of subbasins and data for counties typical of these subbasins were used to determine reasonable pumping lifts for each of them. This procedure was used to subdivide each basin with areas of obviously varying payment capacities. It is realized that within each of these subbasins the reasonable lift varies widely. The process of subdivision of basins could be carried to the extent of saying that one field has a different reasonable pumping lift than another field on the same farm. Subdivision must be discontinued at some point, and it is felt that these subdivisions are adequate for the present estimates of reasonable pumping lifts. The administrative basins as subdivided are shown in figure 9.

REASONABLE PUMPING LIFT ESTIMATES

A reasonable payment capacity has been estimated for each county having significant irrigated acreage; a reasonable estimate of costs for pumping water from wells has been determined; and an estimate of the volume of water required to grow crops in each county has been made. Using these results, an estimate of the reasonable pumping lift can be made for each of the administrative ground-water areas that have been delineated. The details of determining reasonable pumping lift are shown in table 6. For each administrative basin the following data are listed: the county used in determining the payment capacity, the payment capacity in dollars per acre, the irrigation requirement, the payment capacity in dollars per acre-foot (column 4 divided by column 5), and the reasonable pumping lift (obtained from the pumping cost curve, fig. 7, using the payment capacity listed in column 7).

Based upon the values obtained in column 8, table 6, seven ranges of reasonable pumping lift have been delineated. Each ground-water basin has been assigned to the range indicated by the calculated value in column 8 of table 6. For basins having two or more counties, reasonable pumping lifts are assigned also to subareas within the basins (table 7). The reasonable pumping lift ranges are shown by areas in figure 9. Care must be exercised in applying the reasonable pumping lift estimates to individual farms or areas in any basin. The productivity values utilized in determining the payment capacities are county averages and may not apply to a particular area within a county.

The wide variations possible in each of the factors that determine an economic pumping lift for an operation make it imperative that any estimate of reasonable pumping lift for an area be qualified by the assumptions made in determining it. The reasonable lift values shown for each area (fig. 9) were estimated assuming a 150 to 200-acre farm growing crops typical of the basin with average yields. It was also assumed that the irrigation requirement was not excessive and that the pumping costs were similar to those shown in figure 7. As has been emphasized throughout the report, each of these factors is variable if a study is attempted on other than a gross scale. The reasonable pumping lift may be much less than that from which some irrigators can economically afford to pump. A farmer could have a larger payment capacity because of a larger farm size, lower production costs, higher value crops, better than average yields, or more efficient use of water. The same farmer could be paying less per acre-foot for water than is indicated by the administrative line in figure 7 if his pump system were efficiently designed and operated. The economic maximum pumping lift for such a farm could be several times greater than the reasonable pumping lift shown. On the other hand, a farmer with a low payment capacity because of a small acreage, poor soil, low value crops, below-average management, or high pumping costs because of inefficiently designed and operated pumping systems cannot afford to lift water nearly as far as the estimated reasonable pumping lift. Therefore, it is important to realize that the

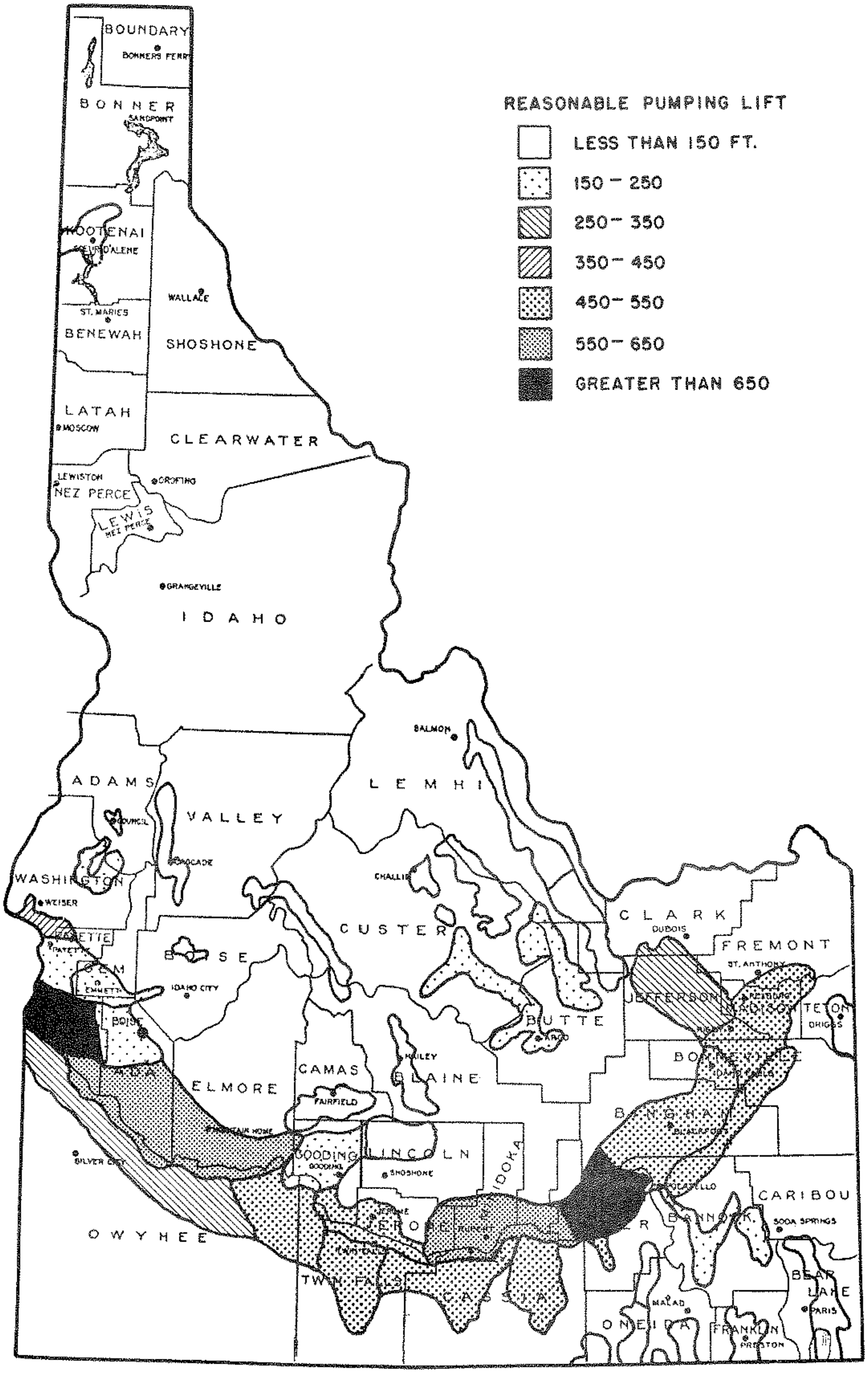

FIGURE 9. Ranges of reasonable pumping lifts for ground-water basins in Idaho

TABLE 7

REASONABLE PUMPING LIFT CLASSIFICATIONS

Depth Range	Basins Included
No. 1 (Less than 150 ft.)	Rathdrum Prairie, Upper Weiser River, N.F. Payette, Garden Valley, Stanley Basin, Camas, Big Wood, Silver Creek, Little Wood, Northwestern Snake Plain (Lincoln County), Malad, Arbon, Curlew-Black Pine, Pocatello, Cache, Bear Lake, Upper Teton, Birch Creek, Challis, Pahsimeroi, Lemhi River Valleys.
No. 2 (150-250 ft.)	Payette, Boise (Ada County), Western Snake Plain (Gooding County), Portneuf, Gem, Gentile, Big and Little Lost River Basins, Middle Weiser River.
No. 3 (250-350 ft.)	Bruneau, Grand View, Homedale, Murphy, Mud Lake.
No. 4 (350-450 ft.)	Lower Weiser River.
No. 5 (450-550 ft.)	Salmon Falls, Sailor Creek, Snake Plain (Jerome, Madison, Bonneville, Bingham Counties), Rock Creek-Goose Creek, Raft, Rockland, Willow Creek, Lower Teton.
No. 6 (550-650 ft.)	Snake Plain (Minidoka County).
No. 7 (Greater than 650 ft.)	Boise (Canyon County), Mountain Home, Michaud Flat.

reasonable pumping lift estimate is not necessarily reasonable for all ground-water users in a basin, but it is representative of economic-sized farms having reasonably efficient pumping systems.

Application of the reasonable pumping lift estimates will require consideration of pumping drawdowns, seasonal water-level changes, and well construction difference. Each of these factors is variable and should be evaluated for each basin to allow effective application of reasonable pumping lift values.

SUMMARY AND CONCLUSIONS

The Idaho Code charges the Director of the IDWA with the administration of the use of the water resources of the state. One method of ground-water administration provided by the code is the maintenance of reasonable pumping lifts. The purposes of this study are to evaluate the methods of determining reasonable pumping lifts and designate values for each ground-water basin in the state. The study is divided into four parts: determination of payment capacity, pumping costs, irrigation requirements, and ground-water administrative basins.

Payment capacities are based upon economically-sized family farms raising crops typical for the basin. It is assumed that a full water supply is available and necessary, and that the resulting crop yields are typical of those to be expected on the better land classifications in the basin. Payment capacity estimates for a number of areas are available from previous studies by various governmental agencies. These estimates are adjusted so that the rate of return to management (profits) are similar in each case. Payment capacities for basins not previously studied are estimated by interpolation from the known payment capacities assuming that a relationship exists between payment capacity and the over-all productivity of the area.

Costs for pumping irrigation water are estimated using data from 165 wells operating in Idaho using a statistically-derived equation (Von Bernuth's equation No. 4). Because the volume of water pumped and the initial investment often have a greater effect than does lift on the unit pumping costs, the cost analysis is limited to systems producing adequate water for economically-sized farms (500 acre-feet or more annually). A regression line that can be used for administration is calculated for costs versus lift. The slope of this line indicates that water costs increase $1.37 per 100 foot of lift.

Consumptive irrigation requirements are based upon providing an adequate supply 80 percent of the years in each area. Headgate irrigation requirements are then computed assuming 60 percent field efficiency. An estimate of average headgate requirement is obtained by weighting the average by the acreage of the principal crops grown in each basin in 1964.

Hydrologic ground-water basins are delineated and areas within these basins having similar reasonable pumping lifts noted. From the estimates of payment capacity, costs for pumping water, and irrigation requirement, reasonable pumping lifts are calculated and presented for each of these areas (tables 6 and 7 and fig. 9).

The variability of economic pumping lift due to factors such as farm size, management ability, soil fertility, efficiency of water use, volume of water pumped, and initial investment makes it necessary to base reasonable pumping lifts upon certain typical or average factors for each basin. Although a number of assumptions are necessary to limit the range of the result, the estimates should be valuable as a guide for administrating ground-water basins.

RECOMMENDATIONS

1. Accept the estimates of reasonable pumping lifts presented in table 7 and figure 9 as a guide for administration of the ground-water basins.

2. Initiate a detailed economic evaluation of basins in which the pumping lifts are

now approaching the preliminary estimate presented in this report.

3. Evaluate the outlined technique of pumping level determinations with respect to new methods and data being generated by research at Washington State University and the University of Idaho.

4. Develop a program of data acquisition to improve confidence in the estimated lifts.

   a. *Collect accurate data on well characteristics and costs as a part of* licensing for water rights.

   b. Encourage data-reporting agencies to collect data in a manner that can be presented as statistical distributions.

5. Encourage studies of pumping costs and payment capacities by statistical methods such as used by Von Bernuth to reduce the quantity of data collection required.

6. Initiate a new study of reasonable pumping lifts in several years including new *data and methods developed in* the intermediate period and the public acceptance, suggestions, and general reaction to the present study.

REFERENCES

Cheline, R.J., 1968, An Economic Approach to the Agricultural Use of Ground Water in the Oakley Fan Area of Cassia County, Idaho: University of Idaho, Moscow, Idaho. Unpublished master's thesis.

Chen, D. Y., and Long, R. B., 1965, Pump Irrigation Costs, Lea County: Agricultural Experiment Station Research Report III, New Mexico State University, University Park, New Mexico.

Dickerson, J. D., et al, 1964, Irrigation Water Costs Correlated With Total Pumping Lift: Progress Report No. 93, Agricultural Engineering Department, Kansas State University, Manhattan, Kansas.

Haynes, R. G., 1969, A Cost Analysis of Pumping From Irrigation Wells in Cassia County, Idaho: Department of Agricultural Engineering, University of Idaho, Moscow, Idaho. Unpublished master's thesis.

Jensen, M. C., and Criddle, W. D., 1952, Estimated Irrigation Water Requirements for Idaho: Agricultural Experiment Station Bulletin No. 291, University of Idaho, Moscow, Idaho.

Lindeborg, K., 1970, Economic Values of Irrigation Water in Four Areas Along the Snake River in Idaho: Bulletin No. 513, Idaho Agricultural Experiment Station, Moscow, Idaho.

Ralston, D. R., 1968, Ground-Water Development in Idaho - 1967: Water Information Bulletin No. 3, Idaho Department of Reclamation.

Sutter, R. and Corey, G. L., 1970, Consumptive Irrigation Requirements for Crops in Idaho: Agricultural Experiment Station Bulletin No. 516, University of Idaho, Moscow, Idaho.

U. S. Bureau of the Census, Census of Agriculture, 1964, Statistics for the State and Counties, Idaho: U. S. Government Printing Office, Washington D. C., 1967.

Von Bernuth, R. D., 1969, Factors Affecting Irrigation Pumping Costs: Department of Agriculture Engineering, University of Idaho, Moscow, Idaho. Unpublished master's thesis.