An analysis of pump water costs in central Arizona

AN ANALYSIS OF PUMP WATER COSTS IN CENTRAL ARIZONA

by

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ABSTRACT

Irrigation water is the limiting factor in Central Arizona's agricultural production. A substantial portion of the water used for irrigation is drawn from underground reservoirs. As a result of continual increases in pumping lift, changing technology and fluctuations in the various components of cost, farmers are faced with an ever changing pattern of pumping costs.

Reliable, current pumpwater cost data are needed by farmers to make decisions that will yield maximum profit. Agriculturally-oriented businesses and public agencies also need full and reliable information to be most effective. The purpose of this study is to provide this information.

Physical inventory, performance and operational information, and various cost data were obtained for farmer and irrigation district owned irrigation wells. Total cost was computed for all components contributing to the cost of pumping water. Factors which affect costs involved were examined with a view to determining where savings might be realized.

Information is provided which will allow farmers to estimate pumping costs peculiar to their own pumping situation. Data are also provided which will facilitate estimation of future pumping costs.

INTRODUCTION

This study pertains to pump irrigated farming areas within Maricopa and Pinal Counties of Central Arizona. These counties contain about two-thirds of Arizona's total irrigated acreage and constitute the state's major concentration of irrigation wells.

Problem Statement

Central Arizona has been historically characterized by irrigated agriculture. Water is the limiting resource in farm production in this area.

A substantial portion of the water used by farmers in Central Arizona is drawn from underground reservoirs. In order to withdraw sufficient water for the vast acreages, hundreds of irrigation wells have been installed. Resulting groundwater withdrawals in excess of recharge have caused continual and often rapid decline in groundwater levels in all major pumping areas.

As a result of continual increases in pumping lift, changing technology and fluctuations in cost components, farmers are faced with and ever changing pattern of pumping costs. Scarcity of reliable, current water cost data makes it difficult for farmers to make decisions that will yield maximum profit. While water cost data are of prime importance to individual farmers, they are also of considerable value to agriculturally oriented businesses and public agencies which are concerned with agriculture and need full and reliable information to be most effective.

Maximization of net revenue by farmers involves essentially three areas of concern in regard to pumping costs. The first pertains to the capital cost of the well and appurtenant equipment. When contemplating the purchase of a farm which already has an irrigation well installed, it is necessary to know the value of the well in order to accurately estimate the worth of the farm. Farmers that already own land and are confronted with installing a replacement well will also want to analyze costs involved to determine the profitability of such a venture. In such an analysis both capital expenditures and operating costs are involved. The analysis usually is made by comparing average annual costs with average annual returns which are expected to accrue during the life of the well. Depreciation of well and equipment is used to amoritize the capital expenditures involved.

The second area of concern involves operation of an established well. The decision here is whether or not it will pay to operate the well to provide water for a given crop. Once the well is installed, capital expenditures involved in drilling and equipping the well are "fixed". There is nothing farmers can do about them. Pertinent costs are those which accrue as a result of operation of the installed well. In economic terms these costs of operation are referred to as "variable costs". Operation of the established well will be profitable throughout that range where added costs do not exceed added returns which result through use of the additional water pumped.

The third area of concern involves operation of an established well from the long run point of view. In areas where declining ground-water levels are common, additional capital expenditures are periodically necessary in order to continue operation of the well. Considerations involved are similar to those outlined in discussion of the first question. Average annual added capital costs plus yearly operating expenses are compared with average annual returns expected to prevail during the useful life of the addition.

Review of Literature

Three previous studies on the cost of pumping water in Central Arizona have been conducted; one in 1891 (Stolbrand 1891), another in 1939 (Thompson and Steenberger 1939), and the most recent in 1951 (Rehnberg 1951). In light of changes which have occurred in the pumping situation and continual progress which has been made in techniques used by pump irrigators, none of the previous studies are felt to be pertinent to the present analysis of pumping costs. However, some information from the 1951 study may be interesting for purposes of comparison.

Rehnberg studied the cost of pumping water in Pinal County in 1951, using a random sample of 20 electric and 20 natural gas wells. Mean pumping lift for electric wells sampled in Pinal County at that time was 209 feet. Natural gas wells, which generally pumped from somewhat greater depths, had an average pumping lift of 250 feet.

Mean overall plant efficiency was 46 percent for electric wells. Natural gas installations, which are inherently much less efficient, had a mean overall plant efficiency of 10.4 percent.

On the average, electric and natural gas wells had comparable total hours operated annually. Mean hours operated for electric wells was 3600 hours and 3674 hours for natural gas installations.

Average replacement cost new (cost of drilling and equipping a similar new well) for electric wells was significantly lower than for natural gas installations. Mean capital investment was $16,140 for electric wells and $27,410 for natural gas.

Average replacement cost new for both electric and natural gas installations was depreciated over the same period of time. Well and casing costs were depreciated over an estimated life of 10 years. Estimated life for depreciation of the pump and power unit cost was 5 years.

Uniform power and gas rates were used to place all wells on an equal basis. Power costs were computed at one mill per KWH (kilowatt hour). The gas rate used was $.05 per MCF (thousand cubic feet.)

Mean total cost per acre foot for pumping water in Pinal County was estimated to be $13.50 for electric wells and $10.50 for natural gas. Rehnberg suggested that the cost advantage of natural gas over electricity as a source of power increased with deeper lifts.

The first part of the present study was conducted by Kleinman in 1963. The objective of the 1963 study was to ascertain the cost of pumping water for irrigation in various private pumping areas in Maricopa and Pinal Counties. The two-county area was divided into five geologically independent areas and samples were drawn from each. The result was a sample of 50 electric and 24 natural gas wells comprised of various subsamples randomly selected from each of the five geographically different areas.

An inventory of the presently operated well and installed equipment was taken and current replacement cost new computed. Various operational and performance data were gathered including repair costs. Actual fuel consumption and cost of energy to farmers were also obtained.

Data were tabulated and pumping costs compiled for each well and for each area. Weighted averages were used to construct representative well data for each individual area. No significant difference was found to exist between pumping costs of different areas. An average cost figure for the entire area, however, was not computed.

Even though no significant difference was found to exist between pumping costs of the various areas, wide variation in pumping costs of individual wells did exist. Moreover, the farm survey did not provide an adequate basis for estimating fixed costs since reliable life estimates of equipment needed for depreciation were not available.

Objectives and Scope of Study

The primary objective of this study is to derive the average cost of pumping irrigation water incurred by individual farmers in Maricopa and Pinal Counties and to show factors which influence this cost. Special emphasis is placed upon deriving a reliable schedule for depreciation, since the 1963 study was inadequate in this respect.

A secondary objective is to determine pumping costs for various irrigation district wells to substantiate the derived pumping cost estimates for the farm survey wells which are based upon a much smaller sample.

Cost components are grouped in three major categories: fixed, added capital, and variable. Fixed costs include those components of cost which are not affected by amount of water pumped. They are depreciation, interest on investment and property taxes. The capital investment in well and appurtenant equipment provides a basis for deriving fixed costs. In estimating capital investment, current costs of well and equipment are used to put all wells on an equal basis. Special emphasis is placed upon deriving a reliable schedule for depreciation.

Added capital costs are those incurred as a result of the declining groundwater table, i.e., costs of deepening the well, adding column and bowls and increasing the size of motor or engine to allow continued pumping from greater depths. While added capital costs are basically capital expenditures, they are variable costs of pumping water in that they could be avoided if no water were pumped.

Variable costs are those which vary with the amount of water pumped. They include the cost of energy, attendance, lubrication and repair to well and equipment.

Factors which affect costs involved in pumping water are examined with a view of determining where savings might be realized. Regression analysis was employed to facilitate this analysis.

Source of Data

Principal sources of data were individual farmers, corporate farms and irrigation districts, well drillers, pump companies and electric and natural gas suppliers.

The primary source of information was unpublished data taken from schedules collected for the study in 1963. Data were gathered for 50 electric and 24 natural gas pumping installations located within Maricopa and Pinal Counties. Physical descriptions of each well and existing equipment, performance data and certain operational information were obtained from this source.

In 1964 the author obtained similar information from the files of five major irrigation districts and two large corporate farms on a total of 607 electrically powered irrigation wells located in Maricopa and Pinal Counties. This portion of the study is subsequently referred to as the "district survey".

With the descriptive data for each of the wells obtained from the farmers and irrigation districts, well drillers and pump companies were contacted to obtain current replacement costs new of each item. This procedure was followed to provide a uniform and up-to-date cost base for all wells in the farm and district survey alike.

The quantity of electricity or natural gas used in 1963 by each farm survey well and also actual cost to the farmer of such power was obtained from various suppliers for the 1963 study. Fuel consumption for each well in the district survey was taken directly from district and corporate farm records.

Attendance, lubrication, repair and added capital costs for each well in the farm survey were obtained from the 1963 study. Such data were not available from district records on a per well basis, however, an aggregate cost figure for these items for all wells was obtained from each district. For both farm and district survey alike, added capital costs were an integral part of general repair to well and equipment and were not readily separated.

Methodology

Farm survey wells were grouped according to the type of fuel used since the 1963 Kleinman study indicated no significant difference among pumping costs of the various geographical areas surveyed. All wells in the district survey are electrically powered and thus have been further classified by individual district. The above classification gives the following breakdown: (1) farm survey electric -- 50 wells, (2) farm survey natural gas -- 24 wells, (3) district 1 --67 wells, (4) district 2 -- 36 wells, (5) district 3 --78 wells, (6) district 4 -- 47 wells, (7) district 5 -- 96 wells, (8) district 6 --53 wells, and (9) district 7 -- 230 wells. This makes a total of 657 electric wells and 24 natural gas wells.

The primary concern of this study is to determine costs incurred by individual farmers in pumping water and not to analyze pumping costs of various irrigation districts, thus the entire analysis is farm oriented. Replacement costs new are those which an individual farmer would experience and not those which accrue to irrigation districts which commonly receive substantial quantity discounts. Property taxes have been assessed as they would accrue to individual farmers. Power rates used are those which individual farmers pay.

Certain components of variable cost represent the only major exception to the above method of assigning costs. The cost of attendance, lubrication and repair of well and equipment for all wells in the district survey were obtained directly from individual district records. To the extent that repair costs which accrue to districts, many of whom maintain their own repair crews, are lower than similar costs of individual farmers, total variable costs for the districts will not be representative of the costs incurred by an individual farmer under a similar pumping situation.

DESCRIPTION OF PUMPING PLANT

Well and Casing

There are presently two methods employed for drilling irrigation wells in central Arizona. They are "cable tool" and "rotary" drilling. While "cable tool" drilling is the most common there appears to be no significant difference in costs between the two methods.

Size--Various types of casing and methods of perforation were encountered, however, most were found to be competitively priced. Generally, it was found that a well is cased its entire depth. The most frequent casing diameter was 20 inches (Table 1). In the farm survey mean casing diameter was 19.4 inches for electric wells and 19.2 inches for natural gas. Overall district mean casing diameter was 20.6 inches. Individual district means ranged from 19.8 to 21.6 inches.

Depth--Mean depth drilled for the farm survey was 949 feet for electric and 1,080 feet for natural gas wells (Table 2). Overall district mean depth drilled was 674 feet. Among districts mean depth drilled ranged from 361 to 983 feet.

Age--Mean age of wells in the farm survey was 10.1 years for electric and 8.6 years for natural gas, (Table 3). Mean age for all wells in the district survey was 15.3 years. Among districts, however,

Table 1. Casing Diameter of District and Farm Survey Wells

Diameter (inches)	1	2	3	4	5	6	7	Dist. Total	Farm Survey. Elec.	Farm Survey. Gas	Total All Wells
					Number of Wells						
12	-	-	-	-	-	-	3	3	-	-	3
14	-	-	-	-	-	-	-	-	-	-	-
16	4	-	2	-	2	-	2	10	7	5	22
18	-	-	-	-	2	-	7	9	1	1	11
20	59	35	61	44	39	28	150	416	42	17	475
22	-	-	-	-	-	-	1	1	-	1	2
24	-	-	-	-	28	19	53	100	-	-	100
Total	63	35	63	44	71	47	216	539	50	24	613
					Mean Diameter and Standard Deviation (inches)						
Mean	19.8	20.0	19.9	20.0	21.4	21.6	20.8	20.6	19.4	19.2	20.4
S	1.0	0.0	0.7	0.0	2.2	2.0	2.1	1.8	1.4	1.8	1.8

Table 2. Depth Distribution of District and Farm Survey Wells

Depth (feet)	District (all elec.) 1	2	3	4	5	6	7	Dist. Total	Farm Survey Elec.	Farm Survey Gas	Total All Wells
	Number of Wells										
Under 200	-	-	20	29	6	-	20	75	-	-	75
200-399	5	2	18	5	23	1	35	89	3	-	92
400-599	13	-	11	3	10	6	58	101	6	-	107
600-799	25	3	11	5	20	15	60	139	10	4	153
800-999	15	23	2	2	6	24	25	97	7	8	112
1000-1199	3	6	1	-	5	-	7	22	13	6	41
1200-1399	-	1	-	-	-	1	4	6	4	3	13
1400-1599	-	-	-	-	-	-	4	4	4	1	9
1600-1799	1	-	-	-	1	-	2	4	1	1	6
1800-1999	1	-	-	-	-	-	1	2	2	1	5
Total	63	35	63	44	71	47	216	539	50	24	613
	Mean Depth and Standard Deviation (feet)										
Mean	793	983	474	361	633	874	679	674	949	1080	713
S	274	175	259	272	306	184	313	320	427	386	332

mean well age ranged from 12.4 to 20.9 years. This variation is due at least in part to differences in the rate of increase in number of wells over time. Those districts which have experienced the largest proportional increase in number of wells in recent years (districts with the greatest relative number of new wells) will have a mean which is biased toward a younger age.

In the long-run situation a sample of irrigation wells would on the average be half "worn out". In other words the average age would reflect half the life a typical well had. In light of the above mentioned bias of some of the districts toward a younger age it is questionable that average age figures given above accurately reflect the half-life of irrigation wells in Central Arizona.

Since a reliable estimate of average age is needed in arriving at depreciation, a special analysis is made of the age of irrigation wells in district 7. District 7 is the oldest irrigation district in Central Arizona and contains roughly a third of the wells included in the entire seven-district survey.

The first irrigation replacement well in district 7 was drilled in 1926. Existing wells in the district at that time were, therefore, assumed to constitute a population of wells. It was assumed further that all replacement wells since that time replaced a well drilled prior

Table 3. Age Distribution of District and Farm Survey Wells

Age (years)	District (all elec.) 1	2	3	4	5	6	7	Dist. Total	Farm Survey Elec.	Farm Survey Gas	Total All Wells
					Number of Wells						
Under 5	4	-	10	4	-	4	19	41	9	8	58
5-9	11	3	8	8	7	10	31	78	15	5	98
10-14	23	13	2	13	26	7	85	169	15	3	187
15-19	17	16	3	13	15	16	35	115	8	3	126
20-24	6	2	-	-	16	7	21	52	-	2	54
25-29	-	-	20	5	2	2	-	29	-	-	29
30-34	-	1	19	1	4	-	10	35	-	-	35
35-39	-	-	-	-	-	-	6	6	2	-	8
40-44	-	-	1	-	1	-	6	8	-	-	8
Total	61	35	63	44	71	46	213	533	49	21	603
					Mean Age and Standard Deviation (years)						
Mean	12.4	15.1	20.9	14.0	16.7	13.8	14.9	15.3	10.1	8.6	14.6
S	5.5	5.1	11.8	7.3	7.4	6.4	9.3	8.7	7.2	7.3	8.5

to 1926. To the extent that replacement wells were used to replace wells drilled since 1926 this "adjusted average" will retain some its bias toward a younger age. Data, however, were not available to allow elimination of such wells from the analysis.

An average age was derived based upon the age of all wells drilled prior to 1926 which were still in operation in 1964 (21 wells) plus the age of all replacement wells (47 wells) in the district. The age derived by this procedure was 21.3 years which is comparable to the mean age of wells in district 3 of 20.9 years. Assuming mean age of wells to represent the half-life of wells surveyed, estimated well life for district 7 would be 42.6 years and 41.8 years for district 3.

Column

Size--Mean column diameter for the farm survey electric was 10.2 inches and 11.3 inches for natural gas wells as shown on Table 4. Overall district mean column diameter was 11.6. District means ranged from 11.3 to 12.4 inches.

In all the areas surveyed 12 inch column was found to be the most frequently used. For nearly all wells the diameter of discharge pipe and suction pipe where used, was found to equal the diameter of the column pipe.

Table 4. Diameter of Column in District and Farm Survey Wells

Diameter (inches)	1	2	3	4	5	6	7	Dist. Total	Farm Surv. Elec	Farm Surv. Gas	Total All Wells
					Number of Wells						
6	-	-	-	-	-	-	3	3	1	-	4
8	1	-	4	-	3	3	9	20	11	1	32
10	21	29	40	5	35	20	45	195	22	6	223
12	39	6	14	26	16	24	78	203	15	17	235
14	2	-	5	13	7	-	81	108	1	-	109
Total	63	35	63	44	61	47	216	529	50	24	603
					Mean Diameter and Standard Deviation (inches)						
Mean	11.3	10.3	10.6	12.4	11.5	10.9	12.1	11.6	10.2	11.3	11.5
S	1.1	0.8	1.4	1.2	2.2	1.2	1.9	1.8	1.7	1.1	1.8

<u>Length</u>--Mean length of column pipe in the farm survey was 415 feet for electric wells and 483 feet for natural gas wells (Table 5). The overall district mean was 303 feet. Mean length of column ranged from 104 to 471 feet among districts.

<u>Column length versus well depth</u>--In areas with declining groundwater levels the relationship of column length to well depth is important since it indicates how much bowls may be lowered before the well must be deepened. Differences were not computed for individual wells, however, useful information is provided by comparison of average well depths and average column lengths. The data are as follows:

	District Total	Farm Survey Elec.	Farm Survey Gas	Total All Wells
Well Depth (feet)	674	949	1080	713
Column Length (feet)	303	415	483	319
Difference (feet)	371	534	597	394

These figures indicate that on the average there still exists considerable opportunity for lowering bowls before well deepenings will become necessary (assuming a homogenous acquifer over the entire well depth). Variation among district and farm survey wells is thought to be a function of differences in expected rate of decline of groundwater levels for areas surveyed.

Table 5. Length of Column in District and Farm Survey Wells

Length (feet)	1	2	3	4	5	6	7	Dist. Total	Farm Survey Elec.	Farm Survey Gas	Total All Wells
							Number of Wells				
Under 100	-	-	-	10	-	-	-	10	-	-	10
100-199	-	-	14	34	24	-	27	99	-	-	99
200-299	13	-	26	-	43	1	55	138	8	1	147
300-399	24	8	20	-	3	4	106	165	12	1	178
400-499	26	21	3	-	-	22	27	98	14	12	124
500-599	-	1	-	-	-	19	2	22	13	9	44
600-699	-	5	-	-	-	-	-	5	3	1	9
Total	63	35	63	44	70	46	216	537	50	24	611
						Mean Length and Standard Deviaition (feet)					
Mean	367	453	253	104	211	471	310	303	415	483	319
S	73	78	86	22	53	68	83	120	115	75	118

Pumping Lift

Mean pumping lift for all irrigation districts combined was 267 feet with a standard deviation of 115 feet (Table 6). Mean lift among districts surveyed showed relatively wide variation. Means ranged from 95 to 425 feet. In the farm survey mean lift for electric wells was 378 feet while mean lift for natural gas wells was 435 feet. The standard deviation from the mean was 112 feet for the farm survey electric and 68 feet for natural gas wells.

Lift versus column length--It was found generally that farmers do not operate with much column in excess of pumping lifts. Table 7 shows mean excess column for district and farm survey wells. Mean column pipe in excess of pumping lift was 34 feet on the average. For the farm survey electric mean excess column was 37 feet and 48 feet for natural gas wells. District means showed somewhat greater variation. Mean column in excess of lift for districts ranged from 9 to 63 feet. It is felt that expected rate of decline in the level of groundwater is a major factor in determining the amount of excess column installed.

Bowls

The required capacity of the bowl assembly for any particular pumping situation is largely a function of (1) the estimated well production and (2) the "head" under which the pump will operate. Well

Table 6. Lift by District and Farm Survey Wells

Lift (feet)	District (all elec.) 1	2	3	4	5	6	7	Dist. Total	Farm Survey Elec.	Farm Survey Gas	Total All Wells
					Number of Wells						
Under 60	-	-	-	1	-	1	1	3	-	-	3
60-119	-	-	10	40	2	-	11	63	-	-	63
120-179	-	-	21	3	25	1	19	69	1	-	70
180-239	10	-	19	-	36	-	31	96	5	-	101
240-299	4	-	8	-	7	-	61	80	8	1	89
300-359	15	5	2	-	1	4	66	93	8	1	102
360-419	30	16	2	-	-	12	22	82	10	6	98
420-479	4	8	-	-	-	14	4	30	7	11	48
480-539	-	2	-	-	-	15	1	18	7	4	29
540-599	-	4	-	-	-	-	-	4	4	1	9
Total	63	35	62	44	71	47	216	538	50	24	612
					Mean Lift and Standard Deviation (feet)						
Mean	342	424	190	95	195	425	276	267	378	435	281
S	74	68	64	15	42	92	82	115	112	68	113

Table 7. Pumping Lift Related to Column Length

Area	Column Length (feet)	Pumping Lift (feet)	Length Minus Lift (feet)
District (all elec.)			
1	367	342	25
2	453	424	29
3	253	190	63
4	104	95	9
5	211	195	16
6	471	425	46
7	310	276	34
District Avg.	300	267	33
Farm Survey			
Elec.	415	378	37
Gas	483	435	48
Farm Survey Avg.	437	396	41
Overall Average	315	281	34

production and head can be estimated from discharge and draw-down tests which are normally performed in connection with the development of newly drilled wells.

Under the assumption of constant motor RPM (revolutions per minute) capacity of the bowl assembly is largely determined by two factors. They are (1) the number of stages which comprise the bowl assembly and (2) the size or diameter of the individual bowl stage. Thus there are two general methods for increasing capacity of the bowl assembly. Increased capacity may result either from addition of subsequent stages to the bowl assembly or from replacement of existing stages by similar ones of larger diameter. Bowl and empeller design, while minor determinants of capacity, are major factors in determining how efficiently any particular capacity is utilized.

Number and size--Mean number of bowl stages per well in the farm survey was 6.2 and 6.3 for electric and natural gas wells, respectively (Table 8). District means ranged from 2.1 to 6.2 with an overall district mean number of bowl stages per well of 5.1.

The district survey showed 15-inch bowls to be in the most frequent use. Data on bowl diameter were not available for farm survey wells. Overall district mean bowl diameter was 15.2 inches. Means ranged from 13.9 to 16.0 inches.

Table 8. Number and Size of Bowls Related to Column Size and Lift, District Wells

Item	District 1	2	3	4	5	6	7	All Districts
Number of Bowls per Well								
Mean	5.2	5.9	4.8	2.1	4.8	6.2	5.4	5.1
S	1.8	1.2	2.1	0.4	1.6	1.6	2.2	2.1
Bowl Diameter (inches)								
Mean	14.0	13.9	14.6	15.6	15.4	14.3	16.0	15.2
S	1.1	0.5	1.9	1.8	2.5	1.2	2.4	2.2
Bowl Dia. ÷ Column Dia.								
Mean	1.24	1.35	1.38	1.26	1.34	1.31	1.32	1.31
S	0.15	0.10	0.16	0.15	0.15	0.11	0.12	0.14
Lift per Bowl (feet)								
Mean	65.8	71.9	39.6	45.2	40.6	68.6	51.1	53.2
S	17.9	12.1	20.0	11.3	12.4	18.9	18.8	20.0

Bowl diameter related to column diameter--Bowl diameter as a percent of column diameter was found to be fairly consistent. The combined district mean bowl diameter divided by column diameter was 1.31. District means ranged from 1.24 to 1.38. The importance which the selection of size of column pipe plays in the pumping operation may be illustrated through the concept of "friction loss".

The head under which a pump operates (operating head) consists roughly of pumping lift plus the friction loss which occurs as a result of the passage of water through the column pipe to the surface. Friction loss for a given discharge is determined largely by the diameter of column pipe used. The smaller the column pipe used the faster the water must travel to maintain the same discharge and consequently the greater will be the friction loss. Likewise the larger the column pipe the smaller will be the resulting friction loss.

Lift per bowl stage--Mean lift per bowl stage in the farm survey was 61.0 feet for electric and 69.6 feet for natural gas wells. Overall district mean lift per bowl stage was 53.2 feet. District means ranged from 40.6 to 71.9 feet.

If differences in friction head (increased pumping head due to friction loss) per bowl stage are assumed negligible under the previously discussed condition of comparable bowl diameter-column diameter relationship, then lift per bowl stage for a given discharge becomes a fairly reliable indicator of relative bowl diameter. As previously stated, data on bowl diameter were not available for farm survey wells. Mean lift per bowl stage would suggest, however, that farm survey wells on the average would tend to have relatively larger bowl diameters.

Age--Mean age of bowls for farm survey electric wells was 3.9 years and 4.0 years for natural gas wells (Table 9.) Bowl age data in the district survey were available for district 1 only, which had a mean age of 2.3 years. A combined average of the above means produced an overall mean bowl age of 3.2 years.

Table 9. Age of Bowls in District 1 and Farm Survey Wells

Age (years)	District 1 (elec.)	Farm Survey Elec.	Farm Survey Gas	Total
		Number of Wells		
0 - 1	30	16	5	51
2 - 3	24	9	7	40
4 - 5	2	11	3	16
6 - 7	3	5	2	10
8 - 9	2	4	2	8
10 - 11	-	3	2	5
12	2	1	-	3
Total	63	49	21	133
		Mean Age and Standard Deviation (years)		
Mean	2.3	3.9	4.0	3.2
S	3.0	3.3	3.0	3.1

Electric Motors

Rated horsepower--Mean rated horsepower of electric motors as shown in Table 10 was 208 horsepower for the farm survey. Overall mean rated horsepower for district wells was 190 horsepower. District means ranged from 92 to 291 horsepower.

Rated horsepower compared to input horsepower--Input horsepower was found to be closely correlated with rated horsepower. The farm survey electric wells showed a correlation of .943. Perfect correlation would be expressed as 1.0 and a correlation coefficient of 0 would indicate complete lack of correlation. Correlation coefficients for the districts ranged from .763 to .934. Because of the high correlation which exists rated horsepower may be considered a reliable estimate of input horsepower and vice versa. This is substantiated by comparison of overall district mean rated horsepower and mean input horsepower of 190 and 201 horsepower, respectively. A similar relationship is indicated by the farm survey electric.

Speed of electric motors related to size--The most frequent RPM (revolutions per minute) of electric motors was found to be 1800 RPM (Table 11). There were roughly twice as many 1800 as 1200 RPM motors. The only motors encountered other than 1200 and 1800 RPM were in district 5 which had seventeen 1500 RPM electric motors. Generally, an inverse relationship between rated horsepower and RPM of motors is expected. As higher horsepower become more frequent, lower motor speeds are anticipated. Data presented in Table 11 show indications of this postulated relationship. Modal horsepower for 1800 RPM motors was 200 to 249 horsepower while the most frequent rated horsepower for 1200 RPM motors was 250-299 horsepower.

Age--Motor age data were available for farm survey wells only. Mean age of motors in the farm survey electric was 6.1 years (Table 12). Mean age of electric motors for various rated horsepower indicated an inverse relationship between motor age and rated horsepower, i.e., the greater the rated horsepower, the younger the mean age of motors. Such a relationship is to be expected where widespread decline in the level of groundwater continually increases average horsepower requirements.

Personal interviews with various dealers and pump companies suggested a much longer life estimate for electric motors than the above motor age would indicate. Since a reliable life estimate is needed in arriving at depreciation, a special analysis was made of the actual useful life of electric motors in district 7.

District 7 experienced a relatively constant inventory of wells over the past ten year period. There were 248 wells in 1953 and 246 wells in 1963. It was found that 68 new electric motors were purchased during this ten-year period. This would be an average of 6.8 motors per year. Under the assumption that all new motors were used to

Table 10. Size Distribution of Electric Motors

Rated HP	1	2	3	4	5	6	7	Dist. Total	Farm Survey Elec.	Total All Wells
					Number of Wells					
Under 50	-	-	1	-	-	1	6	8	1	9
50-99	-	-	12	21	1	-	8	42	5	47
100-149	1	-	24	19	29	1	18	92	5	97
150-199	25	1	14	4	20	5	38	107	7	114
200-249	18	14	10	-	15	8	55	120	16	136
250-299	19	20	1	-	-	6	52	98	6	104
300-349	-	-	-	-	4	13	24	41	6	47
350-399	-	-	-	-	2	-	12	14	2	16
400-449	-	-	-	-	-	7	-	7	-	7
450-499	-	-	-	-	-	1	-	1	-	1
500 & Over	-	-	-	-	-	5	3	8	2	10
Total	63	35	62	44	71	47	2 16	538	50	588
					Mean Rated HP and Standard Deviation					
Mean	194	227	127	92	161	291	209	190	208	192
S	44	28	47	25	58	114	83	86	113	89

Table 11. Speed of Electric Motors Related to Size

Rated HP	Revolutions per Minute 1200	1500	1800
		Number of Wells	
Under 50	1	-	8
50-99	28	-	19
100-149	26	9	62
150-199	17	8	89
200-249	29	-	107
250-299	41	-	63
300-349	22	-	25
350-399	14	-	2
400-449	-	-	7
450-499	-	-	1
500 & Over	1	-	9
Total	179	17	392

Table 12. Age of Electric Motors in Farm Survey by Rated Horsepower

Age (years)	Rated Horsepower Under 200	200-349	350 & Over	Total
	Number of Wells			
Under 5	6	13	2	21
5 - 9	8	8	2	18
10 - 14	2	4	-	6
15 - 19	3	1	-	4
Total	19	26	4	49
	Mean Age and Standard Deviation (years)			
Mean	7.3	5.5	4.25	6.1
s	-	-	-	4.5

replace old, "worn-out" units, an estimate of 36 years of useful life for electric motors is indicated.

Lack of consistency between the farm survey life estimate of 12.2 years (two times the average motor age of 6.1 years) and the 36 year life estimate derived from the special analysis conducted for district 7 is thought to be a function of continual increases in average horsepower requirements created by declining groundwater levels. As the individual farmer with one or two wells is faced with the demand for additional horsepower it becomes necessary to replace functional or partially worn out units. The districts, on the other hand, with numerous wells are able to meet the demand for additional horsepower by switching motors among district wells and are thereby able to maximize the useful life of each motor. The farmer's cost disadvantage, however, is slight since normally replacement costs are adjusted for a "trade-in" where the farmer is credited with the value of the remaining useful life of the old motor.

Natural Gas Engines

Rated Horsepower--Manufacturers continuous duty horsepower rating of natural gas engines in the farm survey ranged from 200 to 500 horsepower (Table 13.) Mean rated horsepower of natural gas engines was 364 horsepower. High correlation was also found to exist between rated horsepower and input horsepower of natural gas engines. The correlation coefficient of rated horsepower and input horsepower was

.898.

Age--Mean age of engines as shown in Table 14 indicated the same inverse relationship to rated horsepower as did motor age in the farm survey electric. Mean engine age was 4.0 years. With natural gas engines as with electric motors it is doubtful that the life estimate of 8 years (two times the average age of 4 years) accurately reflects the average life of gas engines. From personal interviews with various natural gas engine dealers a 15 year life was estimated. There were no data available, however, to substantiate this estimate.

It is felt that the increase in the number of natural gas pumping installations over time tend to bias the farm survey age data toward a younger mean age. Once again, however, data were not available to test this hypothesis. It was also found to be a common practice among farmers to trade-in partially worn but functional engines on new engines to minimize costly, time-consuming repairs.

Table 13. Size Distribution of Natural Gas Engines

Rated HP	Number of Wells
200-249	1
250-299	2
300-349	10
350-399	4
400-449	1
450-499	3
500-549	3
Total	24
	Mean Rated HP and Standard Deviation
Mean	364
S	84

Table 14. Age of Natural Gas Engines from Farm Survey by Rated HP

Age (years)	Rated Horsepower Under 300	300-449	450 & Over	Total
		Number of Wells		
Under 5	1	12	3	16
5-9	1	2	-	3
10-14	-	1	-	1
15-19	1	-	-	1
Total	3	15	3	21
	Mean Age and Standard Deviation (years)			
Mean	9.0	3.4	1.7	4.0
S	-	-	-	4.1

ANALYSIS OF OPERATIONS

The preceding section was devoted to a description of the items of equipment which physically comprise the well and pump installations. This section includes discussion of various physical aspects related to operation of the previously described wells.

Discharge in Gallons per Minute

Mean discharge for all district wells combined, as shown in Table 15, was 1810 gallons per minute. Among districts mean discharge ranged from 1204 to 2048 gallons per minute. Mean discharge in the farm survey was 1256 and 1585 gallons per minute for electric and natural gas wells respectively.

Efficiency

Overall efficiency of the pumping installation is computed by dividing water horsepower by input horsepower. Thus overall efficiency is a ratio of the theoretical power requirement (water horsepower) to the actual power requirement (input horsepower). Overall plant efficiences for electrically powered installations are not comparable to natural gas overall plant efficiencies since conversion from electrical to mechanical energy is inherently more efficient than conversion from chemical to mechanical energy.

Table 15. Discharge in Gallons per Minute by District and Farm Survey Wells

Discharge (gpm)	District (all elec.)							Dist.	Farm Survey		Total
	1	2	3	4	5	6	7	Total	Elec.	Gas	All Wells
						Number of Wells					
Under 500	-	-	1	-	-	-	6	7	10	-	17
500-999	6	2	22	1	10	6	19	66	7	4	77
1000-1499	32	20	25	6	19	9	28	139	15	5	159
1500-1999	24	11	10	8	11	13	63	140	10	10	160
2000-2499	1	2	4	16	12	14	41	90	5	4	99
2500-2999	-	-	-	8	7	3	39	57	2	1	60
3000-3499	-	-	-	5	-	2	8	15	1	-	16
3500-3999	-	-	-	-	10	-	7	17	-	-	17
4000-4499	-	-	-	-	2	-	4	6	-	-	6
4500-4999	-	-	-	-	-	-	1	1	-	-	1
Total	63	35	62	44	71	47	216	538	50	24	612
					Mean Discharge and Standard Deviation (gpm)						
Mean	1426	1456	1204	2187	2048	1775	2005	1810	1256	1585	1756
S	285	284	458	620	1003	624	820	778	752	553	768

Electrical plant efficiency--As indicated, overall efficiency is an expression of output divided by input. Output or water horsepower may be expressed as follows:

$$\text{Water Hp} = \frac{\text{gpm} \times \text{lift}}{3960}$$

Thus we see that water horsepower or the theoretical power requirement is a function of well production and the pumping lift under which this production is maintained.

Input horsepower or the actual power requirement necessary to satisfy the theoretical power requirement may be expressed as follows:

$$\text{Input Hp} = \text{K W} \times 1.34$$

KW is the kilowatt demand and 1.34 the conversion constant.

Overall efficiency may then be expressed as output (water horsepower) over input (input horsepower) or as follows:

$$\text{Overall Efficiency} = \frac{\text{gpm} \times \text{lift}}{3960\ (\text{KW})\ (1.34)}$$

The optimum production for a given well is largely uncontrolled. Actual measured discharge, however, is a function not only of possible well production but also of the physical condition of the installed pumping equipment. As equipment wear increases water is pumped less effectively. For similar input power requirements decreasing production or output results, hence, overall efficiency also decreases.

Declining groundwater levels also cause decreases in plant efficiency. Pumps are selected for specific lift and discharge conditions. As these conditions change the selected pump will necessarily operate less efficiently. Mean overall efficiency for all district wells combined was 58.7 percent (Table 16). Among districts, means ranged from 48.7 to 61.0 percent. Farm survey electric wells had a mean efficiency of 51.7 percent. Overall efficiency tended to be higher, on the average, for irrigation districts than for wells in the farm survey.

Natural gas efficiency--Water horsepower, discussed above, is the same regardless of type of power unit employed. The expression of input horsepower, however, will vary with type of fuel used. Input horsepower for natural gas engines may be expressed as follows:

$$\text{Input HP} = \frac{\text{MCF/min}}{.000{,}041}$$

MCF (thousand cubic feet) per minute measures the flow of chemical energy (natural gas) and .000,041 is the horsepower conversion constant.

Mean plant efficiency for natural gas installations in the farm survey was 13.2 percent with a standard deviation of 3.4 percent (Table 17). The range was from 4.9 to 19.7 percent. As previously mentioned plant efficiency for electric and natural gas wells are in no way comparable since maximum engine efficiency is approximately 23 percent as compared to 92 percent for electric motors.

Table 16. Overall Plant Efficiency of Electrically Powered Wells

Efficiency (percent)	District (all elec.) 1	2	3	4	5	6	7	Dist. Total	Farm Survey Elec.	Total Elec. Wells
					Number of Wells					
20.0 - 29.9	-	-	4	1	-	-	3	8	3	11
30.0 - 39.9	-	-	10	1	1	-	3	15	10	25
40.0 - 49.9	8	2	17	10	7	4	13	61	6	67
50.0 - 59.9	26	12	22	15	23	15	72	185	14	199
60.0 - 69.9	22	21	7	12	37	19	92	210	14	224
70.0 & Over	7	-	2	5	3	9	33	59	3	62
Total	63	35	62	44	71	47	216	538	50	588
				Mean Efficiency & Standard Deviation (percent)						
Mean	59.2	59.6	48.7	56.5	59.9	61.0	60.8	58.7	51.7	58.1
S	7.0	6.0	12.6	10.9	7.3	12.7	9.2	10.2	13.9	10.6

Table 17. Overall Plant Efficiency on Natural Gas Powered Wells

Efficiency (percent)	Farm Survey Gas
	Number of Wells
4.0 - 5.9	2
6.0 - 7.9	-
8.0 - 9.9	1
10.0 - 11.9	6
12.0 - 13.9	2
14.0 - 15.9	11
16.0 & Over	2
Total	24
	Mean Efficiency and Standard Deviation (percent)
Mean	13.2
S	3.4

Hours Operated Annually

The number of hours a pumping installation is operated annually will depend upon (1) the average discharge and (2) the water requirement of the particular installation. Average well discharge has been discussed previously. The water requirement for a given well will depend upon the number of acres the well serves and the cropping pattern employed.

It was found in the 1963 study that farm survey wells served an average of 212 acres per well. Wells surveyed in Pinal County were found on the average to serve 166 acres while in Maricopa County, where farm survey wells were generally higher yielding, the average was 335 acres.

Mean hours operated annually for all districts combined was 4,250 hours (51.6 percent of possible) as shown in Table 18. Individual district means ranged from 3,163 to 5,668 hours out of a possible 8,760 hours (allowing no "down time" for repair). Mean hours operated for farm survey electric wells was 3,763 hours (43.0 percent of possible) and 3,717 hours (42.4 percent of possible) for natural gas wells.

Many of the irrigation districts through supplemental use of surface water during peak irrigation periods are able to more fully utilize the potential production of district wells during periods of lesser water requirement. Differences which exist between district and farm survey mean hours operated annually are felt to be largely due to this fact. One notable exception is district 5 which has no supplemental surface water and still showed a mean of 5,329 hours operated annually.

Wells serving acres devoted entirely to production of cotton are used intermittently for about six months out of each year. On the other hand, cropping patterns which require greater amounts of irrigation water during slack winter months allow year-round irrigation and consequently greater utilization of the potential production of any well.

Acre Feet Pumped Annually

Acre feet of water pumped may be estimated by the following equation:

$$\text{Acre Feet} = \frac{\text{gpm x hrs. operated}}{450 \times 12}$$

One acre inch per hour is equal to approximately 450 gallons per minute.

Overall mean acre feet of water pumped annually per district well was 1558 acre feet (Table 18). Individual district means ranged from 782 to 2,047 acre feet. Mean production for farm survey electric wells was 870 acre feet and 1,084 acre feet for natural gas wells.

As indicated above, acre feet of water pumped is entirely dependent upon well discharge and the number of hours the well is operated. Generally acre feet pumped was found to be consistent with hours operated since mean well discharges among district and farm survey sells were not found to be significantly different.

Fuel Consumption

The amount of fuel consumed is a direct function of input over time. Input may be expressed either in units of energy (electrical or c hemical) or as horsepower. Input horsepower has previously been discussed and expressed as an energy input times the horsepower conversion constant. Another way of expressing input horsepower is as follows:

$$\text{Input Horsepower} = \frac{\text{water horsepower}}{\text{overall efficiency}}$$

Thus input horsepower is a function of thetheoretical energy requirement (water horsepower) and the efficiency with which the electrical or chemical energy is converted to mechanical energy. It is felt that economies of fuel consumption are largely a result of increased efficiency since pumping lift and optimum well discharge are largely uncontrollable and differences between possible and measured well production will be reflected by plant efficiencies.

Electric wells--Mean electrical energy consumed per acre foot of water pumped for all district wells combined was 477 KWH (kilowatt hours) as shown in Table 18. Among districts means ranged from 175 to 731 KWH. For farm survey wells the mean was 818 KWH. This wide variation is largely due to differences in pumping lift among areas surveyed.

When the above means are reduced to power consumed per acre foot per foot of pumping lift they become somewhat more comparable. Mean power consumed per acre foot for the district wells combined was 1.79 KWH. District means ranged from 1.61 to 2.14 KWH. A mean of 2.22 KWH was consumed per acre foot foot in the farm survey electric.

Natural gas wells--Mean fuel consumption per acre foot of water pumped was 105 MCF (thousand cubic feet) for farm survey gas wells.

This gives a mean fuel consumption per acre foot of pumping lift of .241 MCF.

Table 18. Hours Operated, Acre Feet of Water Pumped, and Fuel Consumption per Acre Foot and per acre Foot per Foot of Lift, for District and Farm Survey Electric and Natural Gas Wells

Item	District (all elec.) 1	2	3	4	5	6	7	Dist. Average	Farm Survey Elec.	Farm Survey Gas
Hours Operated (1963)										
Mean	3163	3644	3358	4286	5329	5668	4923	4520	3763	3717
S	1150	602	1288	1322	1564	1445	1389	1342	1329	1265
Acre Feet Pumped (1963)										
Mean	833	979	782	1749	2047	1880	1817	1558	870	1084
S	365	251	435	734	1258	851	921	845	572	513
Fuel Consumption										
KWH per AF[1]	606	717	406	175	315	731	461	477	818	
Mean	143	105	162	39	91	130	168	140	371	
S										
KWH per AFF[1]										
Mean	1.77	1.69	2.14	1.84	1.61	1.72	1.67	1.79	2.22	
S	.219	.195	.696	.428	.252	.343	.347	.385	.770	
MCF per AF[2]										
Mean										105
S										207.2
MCF per AFF[2]										
Mean										.241
S										.097

[1]Kilowatt hours per acre foot and per acre foot per foot of lift

[2]Thousand cubic feet per acre foot and per acre foot per foot of lift

CAPITAL INVESTMENT

The initial capital outlay associated with production of underground water is referred to as a capital investment. This initial capital expenditure includes drilling and casing the well and the purchase and installation of the equipment which comprise the pumping plant.

In the 1963 study, well drillers and pump companies were contacted in order to derive current replacement costs new representative of those incurred by individual farmers. These cost data, with slight supplementation by the author, were used to estimate average capital investment for district and farm survey wells (Appendix A).

Capital expenditures are broken into three major cost components. They are (1) well and casing costs, (2) pump components costs, and (3) power unit costs.

Capital Cost of Well and Casing

Capital costs associated with well and casing are those of drilling and casing the well, perforating the casing and developing and testing the newly drilled well. Average cost of well and casing for the farm survey was $16,504 for electric wells and $19,003 for natural gas wells (Table 19). Average capital expenditure for well and casing among districts ranged from $6,631 in district 4 to $17,295 in district 2.

Table 19. Average Capital Investment per Irrigation Well, for District and Farm Survey Electric and Natural Gas Wells, 1963.[1]

Area	Well & Casing[2]	Pump[3]	Power Unit[4]	Total
District 1	$ 14,578	$ 9,359	$ 5,732	$ 29,669
2	17,295	9,797	7,007	34,099
3	8,529	6,244	3,817	18,610
4	6,631	3,953	3,858	13,442
5	10,940	6,253	4,869	22,062
6	16,508	11,343	7,840	35,691
7	12,493	9,533	6,584	28,610
Farm Survey				
Electic	16,504	8,453	7,884	32,841
Gas	19,003	10,688	19,523	49,194

[1]Capital investment estimated from 1963 replacement costs new.

[2]Includes drilling, casing and perforating.

[3]Includes columns, bowls, head, discharge pipe, suction pipe and strainer where used.

[4]Includes motor, starter and electrical wiring for electric wells and engine, driveline, gearhead and water cooler for natural gas installations.

Capital Cost of Pump Components

Pump component capital costs are those resulting from the purchase and installation of the pump head, column assembly, bowls, discharge pipe, suction pipe and strainer (where used). Average capital expenditure for pump components in the farm survey was $8,453 for electric wells and $10,668 for natural gas (Table 19). Average district capital costs for pump components ranged from $3,953 for district 3 to $11,343 for district 6.

Capital Cost of the Power Unit

Capital costs associated with the power unit will vary with type of fuel used. Electrically powered installations include the cost of motor, starter and electrical wiring. Average capital cost of power units for electrically powered wells was $7,884 for the farm survey electric. District means ranged from $2,858 for district 4 to $7,840 in district 6. Cost of transformers was not included in the power unit costs since thransformers were furnished by the power suppliers for a majority of the farm survey electric wells.

Natural gas power units costs include purchase and installation of the engine, driveline, gearhead and water cooler. Average capital cost of natural gas power units was $19,523. Average capital costs for natural gas installations were considerably higher than corresponding costs for electric wells. This variation is largely due to differences in cost of electric motors and comparable natural gas engines. The installed cost of natural gas engines per rated horsepower is more than twice that of electric motors.

Total Capital Investment

Average total capital outlay for the complete pumping installation was $32,841 for farm survey electric wells and $49,194 for natural gas wells (Table 19). District average capital expenditures per well ranged from $13,442 in district 4 to $35,691 for district 6.

Average capital investment for any well is a function of the size of pumping installation and the lift under which it operates. Average capital costs per well were found to be closely related to pumping lift. Since, on the average, well equipment of comparable sizes were encountered, regardless of location.

Table 20 has been prepared to aid an individual in estimating the total capital costs associated with a particular pumping lift. Capital costs will vary with type of power unit selected, and in the case of electric motors, with RPM of motor, thus costs are tabulated for similar installations equipped with 1800 or 1200 RPM electric motors and for natural gas engines. Assumptions have been made in relation to size and type of equipment and to well performance. These assumptions are stated explicitly in the footnotes. Capital costs are given for a wide range of pumping lifts.

Table 20. Well and Equipment Requirements and Estimated Capital Investment for Pumping Irrigation Water from Different Lifts[1]

	Physical Requirements					Capital Investment (dollars)								
		Pump		Power Unit HP				Power Unit			Totals			
Lift (ft)	Well Depth (ft)	Bowl Stages[2]	Column (ft)[3]	Elec. Motor	Gas Engine	Well and Casing	Pump	1800 RPM Motor	1200 RPM Motor	Natural Gas Engine	1800 RPM Motor	1200 RPM Motor	Natural Gas Engine
200	560	2	250	100	150	10,420	6,977	1,807	2,592	9,000	19,204	19,989	26,397
240	632	3	290	150	225	11,716	8,027	2,809	3,951	12,375	22,651	23,694	32,118
280	704	3	330	150	225	13,012	8,907	2,809	3,951	12,375	24,728	25,870	34,294
320	776	4	370	150	225	14,308	9,957	2,809	3,951	12,375	27,074	28,216	36,640
360	848	4	410	200	300	15,604	10,837	3,867	5,538	16,500	30,308	31,979	42,941
400	920	5	450	200	300	16,900	11,887	3,867	5,538	16,500	32,654	34,325	45,287
440	992	5	490	200	300	18,196	12,767	3,867	5,538	16,500	34,830	36,501	47,463
480	1064	6	530	250	375	19,492	13,817	5,125	6,675	20,625	38,434	39,984	53,934
520	1136	6	570	250	375	20,788	14,697	5,125	6,675	20,625	40,610	42,160	56,110
560	1208	7	610	250	375	22,084	15,747	5,125	6,675	20,625	42,956	44,506	58,456
600	1280	7	650	300	450	23,380	16,627	6,022	7,745	22,500	46,029	47,752	62,507
640	1352	8	690	300	450	24,676	17,677	6,022	7,745	22,500	48,375	50,098	64,853
680	1424	8	730	300	450	25,973	18,557	6,022	7,745	22,500	50,551	52,274	67,029
720	1496	9	770	350	525	27,268	19,607	6,969	8,829	26,250	53,844	55,704	73,125
760	1568	9	810	350	525	28,564	20,487	6,969	8,829	26,250	56,020	57,880	75,301
800	1640	10	850	350	525	29,860	21,537	6,969	8,829	26,250	58,366	60,226	77,647
840	1712	10	890	400	600	31,156	22,417	7,961	10,006	30,000	61,534	63,579	83,573
880	1784	11	930	400	600	32,452	23,467	7,961	10,006	30,000	63,880	65,925	85,919

[1] Capital investment estimated from 1963 prices.
[2] Assumes 14 inch bowls, 1500 gpm production and 75% pump efficiency.
[3] Assumes 12 inch column
[4] Assumes normally aspirated natural gas engine loaded to 70% capacity.

Added Capital Costs

In addition to the initial capital investment, discussed above, farmers are confronted periodically with the requirement of further capital expenditures which accrue as a result of declining groundwater levels. These periodic capital outlays are known as "added capital costs." Added capital costs are similar to fixed costs in that the cost is due to declines in the groundwater level which take place whether the pump is operated or not. They differ from fixed costs, however, in that fixed costs are always present, whereas added capital costs can be avoided if the well is never operated.

Average added capital costs over time will be directly related to the rate of decline in the groundwater level for a particular area. Rate of decline in the groundwater level varies widely with location. Annual declines in Central Arizona range from almost static water levels to as much as 17 feet. Estimated declines for district and farm survey wells are shown in Table 21. Average estimated decline for farm survey wells was 9.0 feet per year. Estimates of average decline for district wells ranged from 3.0 feet for district 4 to 8.0 feet for districts 1 and 2. Overall estimated average decline for district wells was 5.5 feet, and for district and farm survey wells combined an average annual decline of 5.9 feet was estimated.

Average added capital outlays will depend not only upon rate of decline in groundwater levels but also upon size of equipment installed.

However, as previously noted, average size of equipment among district and farm survey wells is fairly consistent.

Table 21. Average Annual Rate of Decline (1963) in Groundwater Levels for District & Farm Survey Wells

Area	Decline (feet)
District 1	8.0
2	8.0
3	7.0
4	3.0
5	4.0
6	9.5
7	4.0
District Avg.	5.5
Farm Survey	
Electric	9.0
Gas	9.0
Farm Survey Average	9.0
Overall Average	5.9

Table 22 has been prepared to facilitate estimation of added capital costs which would accrue for a given rate of decline in the groundwater level. The assumption is made that sufficient well depth in excess of pumping lift exists to eliminate need for deepening well and casing. Other explicit assumptions as to size of well and equipment and to various performance data are stated in the footnotes. A wide range of pumping lifts are included, and it was found that average added capital costs generally increased with greater pumping lifts. Added capital costs per foot of increase in pumping lift ranged from \$38.00 to \$50.00 for electric wells and \$52.00 to \$73.00 for natural gas wells. Application of the appropriate added capital costs figure times the expected annual rate of decline will produce a fairly reliable estimate of annual added capital outlay to be expected for a given pumping installation.

Table 22. Estimated Added Capital Costs Related to Increased Lift

Lift (ft.)	Motor Hp[1]	Physical Plant: Engine Hp[2]	Physical Plant: Bowl Stages[3]	Physical Plant: Column (feet)[4]	Added Capital Cost of Pump (dollars): Bowls	Added Capital Cost of Pump (dollars): Column	Added Capital Cost of Pump (dollars): Installation	Added Capital Cost of Pump (dollars): Total	Added Costs, Elec. Wells (dollars): Total Elec.	Added Costs, Elec. Wells (dollars): Cost per ft. Decline	Added Costs, Gas Wells (dollars): Total Gas	Added Costs, Gas Wells (dollars): Cost per ft. Decline
240	150	225	3	290	170	880	216	1266	2093		4641	
280				330		880	248	1128	1129	37.83	1128	59.16
320			4	370	170	880	280	1330	1330		1330	
360	200	300		410		880	312	1192	2194		5317	
400			5	450	170	880	344	1394	1394	40.37	1394	66.39
440				490		880	376	1256	1256		1256	
480	250	375	6	520	170	880	408	1458	2516		5583	
520				570		880	440	1320	1320	44.65	1320	70.21
560			7	610	170	880	472	1522	1522		1522	
600	300	450		650		880	504	1384	2281		3259	
640			8	690	170	880	536	1586	1586	44.29	1586	52.44
680				730		880	568	1448	1448		1448	
720	350	525	9	770	170	880	600	1650	2597		5400	
760				810		880	632	1512	1512	48.53	1412	71.88
800			10	850	170	880	664	1714	1714		1714	
840	400	600		890		880	696	1576	2568		5326	
880			11	930	170	880	728	1778	1778	49.88	1778	72.87
920				970		880	760	1640	1640		1640	

[1]Assumes 1800 RPM and 75% pump efficiency
[2]Normally aspirated natural gas engine loaded to 70% capacity
[3]14 inch bowls
[4]12 inch column pipe

COST ANALYSIS

In the following analysis, total cost of pumping water has been broken into three major components. They are (1) fixed costs, (2) added capital costs and (3) variable costs.

Those costs which are not affected by amount of pumped water are referred to as fixed costs. Fixed costs include depreciation, interest on capital invested in well and equipment, and property tax.

Added capital costs are those incurred as a result of declining groundwater levels. They are costs of adding column and bowls, increasing size of motor or engine and other costs which accrue as a result of pumping from greater depths as the water levels decline.

Variable costs refer to those outlays which vary with amount of water pumped from the well. Variable costs include energy, attendence, lubrication and repairs to well and equipment.

Fixed Costs

Capital investment in well and appurtenant equipment, discussed previously, provide a basis for deriving fixed costs. In estimating capital investment, current replacement costs new as incurred by individual farmers are used to put all wells on an equal basis.

Depreciation--Depreciation was computed individually for each of the three major cost components because of differences in length of life estimates. The straight line method is used throughout.

Well and casing costs are depreciated over a 40-year expected life with no salvage value. This makes yearly depreciation 2.5 percent of current replacement cost new.

Estimated life of the pump is 15 years. Thus pump components are depreciated at an annual rate of 6.7 percent. Salvage value is considered negligible.

Electric motors are estimated to have a life of 35 years and will require one rewind during this period. Estimated life of the starting equipment is 10 years. Salvage value is considered negligible.

For gas wells depreciation of the power unit is based upon a total expected life of 15 years. This gives a yearly depreciation figure of 6.7 percent. Two major overhauls are anticipated during the 15 years. Salvage value after 15 years is considered negligible.

Interest on investment--Interest on capital invested in well and appurtenant equipment was computed upon one-half the current replacement cost new of each well at the rate of six percent per annum. It is assumed that, on the average, wells and equipment are half worn out.

Property taxes--Each pumping installation is subject to property taxes. Pumping units are valued on the basis of rated horsepower. The rate is uniform throughout at $40 per horsepower. The maximum horsepower assessable is 250 which in turn limits the maximum assessment to $10,000 per well. A tax rate per hundred dollar assessed value is applied to arrive at yearly taxes.

Tax rates vary with the particular school district in which the installation is located. In the 1963 study tax rates ranged from $4.02 to $11.92 per hundred-dollar valuation. A uniform rate of $8.00 per hundred is applied to this study.

Total fixed costs--A comparative breakdown of components of fixed cost and total fixed costs for irrigation districts and farm survey electric and natural gas is shown in Table 23. Mean total fixed costs among districts ranged from $.75 to $3.47 per acre foot of water pumped. Overall average total fixed cost weighted by amount of water pumped in each district was $1.77 per acre foot. Farm survey electric mean total fixed cost was $3.38 per acre foot and mean fixed cost for natural gas installations was $4.39 per acre foot.

It should be remembered that total fixed costs per acre foot are a function not only of the size of capital investment but also of the annual amount of water pumped. Thus, district 6 which had the largest average capital investment a mean total fixed cost of $2.00 per acre foot which is substantially lower than the mean total fixed cost of district 1 ($3.47 per acre foot) which had the third largest average capital investment. Mean total fixed costs were computed per acre foot of water pumped per foot of pumping lift since district and farm survey wells are operated under a wide range of pumping lifts. District means ranged from

Table 23. Estimated Fixed Costs of Pumping Irrigation Water per Acre Foot and per Acre Foot per Foot of Pumping Lift

Area	Depreciation: Well & Casing	Depreciation: Pump	Depreciation: Power Unit	Depr. Total	Interest	Taxes	Total Fixed Costs
District	Cost per Acre Foot (dollars)						
1	.4654	.7813	.2927	1.5394	1.1422	.7926	3.4742
2	.4541	.6734	.2944	1.4219	1.0744	.7629	3.2592
3	.3458	.6503	.2456	1.2397	.8981	.6435	2.7813
4	.1012	.1537	.0698	.3247	.2463	.1740	.7450
5	.1807	.2674	.1287	.5768	.4371	.3403	1.3542
6	.2475	.4463	.1881	.8819	.6353	.4798	1.9970
7	.1831	.3655	.1544	.7030	.5031	.3920	1.5981
Dist Avg.	.2200	.3927	.1654	.7781	.5683	.4271	1.7734
Farm Survey Electric	.4743	.6477	.3625	1.4845	1.1325	.7655	3.3825
Gas	.4383	.6561	1.2007	2.2951	1.3616	.7380	4.3947
District	Cost per AFF (dollars)						
1	.00136	.00228	.00086	.00450	.00334	.00232	.01016
2	.00107	.00159	.00069	.00335	.00353	.00180	.00768
3	.00181	.00342	.00129	.00652	.00473	.00339	.01464
4	.00107	.00162	.00073	.00342	.00259	.00183	.00784
5	.00093	.00137	.00067	.00296	.00224	.00175	.00695
6	.00058	.00105	.00044	.00207	.00149	.00113	.00469
7	.00066	.00132	.00056	.00254	.00182	.00142	.00578
Dist. Avg.	.00082	.00147	.00062	.00291	.00213	.00160	.00664
Farm Survey Electric	.00125	.00171	.00096	.00392	.00300	.00203	.00895
Gas	.00101	.00151	.00276	.00528	.00313	.00170	.01011

$.0047 to $.0146 per AFF (acre foot foot). Overall district mean total fixed cost weighted by acre feet pumped in each district was $.0066 per AFF. Mean total fixed costs for the farm survey was $.0090 and $.0101 per AFF for electric and natural gas wells, respectively.

Added Capital Costs

Available district and farm survey data did not allow distinction between added capital costs and certain components of variable cost since added capital outlays are generally accompanied by repair and often replacement of existing pumping equipment. It was desirable that they be reported separately because of differences in the nature of added capital costs and variable costs. Hence, added capital costs reported in this study have been estimated directly from Table 22 and deducted from total repair and maintenance figures reported by irrigation districts and individual farmers, which included added capital costs.

Estimated average added capital costs among districts ranged from $.07 to $.36 per acre foot (Table 24). District overall average added capital costs weighted by acre feet pumped was $.14 per acre foot. Farm survey wells, which on the average experienced more rapid declines (refer to Table 21), had substantially higher added capital costs. Estimated average added capital costs for farm survey electric wells was $.42 per acre foot and $.55 per acre foot for natural gas wells.

Added capital costs per acre foot are dependent not only upon rate of decline in the level of groundwater but will also be influenced by amount of water pumped. Added capital costs per acre foot for two wells which experience identical rates of decline may differ greatly if one pumps substantially more water than the other.

Added capital costs per AFF also showed wide variation. District averages ranged from $.0003 to $.0018 per AFF. District overall average added capital cost was $.0005 per AFF. Farm survey means were $.0011 per AFF for electric and $.0013 for AFF for natural gas wells.

Table 24. Estimated Added Capital Costs of Pumping Irrigation Water per Acre Foot and per Acre Foot per Foot of Pumping Lift

Area	Cost per Acre Foot (dollars)	Cost per AFF (dollars)
District		
1	.3643	.00107
2	.3300	.00078
3	.3395	.00179
4	.0651	.00069
5	.0741	.00038
6	.2040	.00048
7	.0835	.00030
Dist. Avg.	.1353	.00051
Farm Survey		
Electric	.4175	.00110
Gas	.5512	.00127

Variable Costs

Fixed and added capital costs do not vary with the amount of production. Thus as the amount of water pumped increases, fixed and added capital costs per acre foot will decrease. Total variable costs, on the other hand, will vary directly with production and variable cost per acre foot will remain nearly constant throughout the normal range of production.

Power costs--Power costs represent the only major exception to the above statement. If power costs were charged at one flat rate, average variable cost per acre foot would remain theoretically constant. It was found, however, that most electrical districts had a minimum charge and many had graduated power rates favoring greater consumption. Natural gas suppliers in particular were found to offer quantity discount rates. Both electric and natural gas wells in the farm survey typically consumed sufficient power to qualify for the most favorable rate. Since different rate structures are employed by electric and natural gas suppliers, the average rate paid by farmers in each area has been computed from farm survey data. Average rates paid by farmers surveyed to various power suppliers are found in Table 25. Mean fuel consumption per acre foot and per AFF for farm survey electric and natural gas wells was then used in estimating average power costs per acre foot and per AFF to farmers in each area.

Table 25. Power Costs per AF and per AFF by Electrical District and Natural Gas Suppliers

Supplier	Rates[1]	Fuel Consumption		Power Cost	
Electric	¢/KWH	KWH/AF	KWH/AFF	$/AF	$/AFF
ED-2[2]	.8093	818.08	2.2164	6.6207	.0179
ED-3	1.0260	818.08	2.2164	8.3935	.0227
ED-4	.7506	818.08	2.2164	6.1405	.0166
ED-5	.8015	818.08	2.2164	6.5569	.0178
SRPD[3]	.9614	818.08	2.2164	7.8650	.0213
APS[4]	1.0861	818.08	2.2164	8.8852	.0241
Natural Gas	¢/MCF	MCF/AF	MCF/AFF	$/AF	$/AFF
APS[4]	4.782	10.46	.0237	5.0020	.0113
So.W.[5]	3.854	10.46	.0237	4.0313	.0091

[1]Average rate paid by farmers surveyed for each district and adjusted to 1965 rates.
[2]Electrical district
[3]Salt River Power District.
[4]Arizona Public Service.
[5]South West Gas.

A uniform rate was used throughout this study to place all wells on a comparable cost basis since power rates for the electric and natural gas suppliers showed substantial variation. Power costs were assessed at the uniform rate of 9 mills per KWH for electric wells and $.04 per MCF for natural gas installations. Mean power costs for each district and for farm survey electric and natural gas appear in Table 26.

Note that natural gas power costs are substantially lower than corresponding costs for electrically powered installations. Since power cost represents the greatest single expense associated with pumping, substantial savings in energy cost accrue to natural gas operated wells.

Operations and Maintenance--Irrigation District data did not allow distinction between component costs of operating and maintaining the pumping installation, hence these costs have been reported aggregatively as total operations and maintenance cost. Such data were available, however, for farm survey wells and attendance, lubrication and repairs to well and equipment have been reported separately as component costs of general operation and maintenance of the pumping plant (Table 26).

Total variable costs--Average total variable costs for district and farm survey electric and natural gas wells are found in Table 26. Overall mean variable cost of pumping water for district wells, weighted by acre feet pumped was $4.96 per acre foot. Means, however, ranged from $1.75 to $7.15 per acre foot. Farm survey mean variable cost was $8.78 for electric wells and $6.19 for natural gas. Differences between total variable cost per acre foot for farm survey electric and natural gas may be attributed to the lower cost of fuel for natural gas

Table 26. Estimated Variable Costs of Pumping Irrigation Water per Acre Foot and per Acre Foot per Foot of Pumping Lift

Area	Fuel Cost[1]	Operations & Maintenance Attend.	Lub.	Repair	Total	Total Variable
District		Cost per Acre Foot (dollars)				
1	5.4558				1.6957	7.1515
2	6.4557				.5810	7.0367
3	3.6540				.4855	4.1395
4	1.5741				.1739	1.7480
5	2.8314				.3299	3.1613
6	6.5772				.5720	7.1492
7	4.1481				.7835	4.9316
Dist. Avg.	4.2973				.6582	4.9555
Farm Survey Electric	7.3627	.0782	.1291	1.2140	1.4213	8.7840
Gas	4.2886	.0924	.3759	1.4293	1.8976	6.1862
District		Cost per AFF (dollars)				
1	.01595				.00496	.02091
2	.01523				.00137	.01660
3	.01923				.00256	.02179
4	.01657				.00183	.01840
5	.01452				.00169	.01621
6	.01548				.00135	.01683
7	.01503				.00284	.01787
Dist Avg.	.01609				.00247	.01856
Farm Survey Electric	.01948	.00021	.00034	.00321	.00376	.02324
Gas	.00986	.00021	.00086	.00329	.00436	.01422

[1]Based upon 9 mills per KWH for electricity & $.04 per MCF for natural gas.

installations since gas wells on the average had higher operations and maintenance costs than other district or farm survey electric wells.

Variable costs become somewhat more comparable when examined on a cost per AFF basis. Overall average variable cost of district wells was $.019 per AFF. District means ranged from $.017 to $.021 per AFF. Mean variable cost for farm survey electric wells was $.023 and $.014 for natural gas wells. Once again the lower cost of natural gas wells is a result of lower fuel costs.

Total Cost of Pumping

Total costs of pumping irrigation water for district and farm survey electric and natural gas wells are shown in Table 27. The Overall cost of pumping for district wells was $6.86 per acre foot. Individual district means ranged from as low as $2.56 per acre foot in district 4 to $10.99 per acre foot in district 1. Mean total cost for farm survey electric wells was $12.58 per acre foot. The farm survey natural gas total cost was $11.13 per acre foot.

Numerous factors contribute to the apparent cost advantage enjoyed by natural gas operated wells. Natural gas wells, on the average, were pumping from greater depths and with generally higher production per well than corresponding farm survey electric wells. Greater pumping lift and increased production necessitate a larger capital investment and result in increased fuel consumption, both of which tend to increase pumping costs. On the other hand greater total production spreads fixed costs over a larger amount of water pumped and costs per acre foot decrease.

Significant savings in energy costs have already been mentioned to favor natural gas as a source of power. It should be pointed out, however, that all other cost components are higher for natural gas than for electrically powered installations. The capital expenditure associated with a natural gas engine is substantially higher than for a similar sized electric motor. Thus the depreciation on natural gas wells is higher than for electric. Similarly interest on the capital investment is greater. Since rated horsepower of the gas installation is substantially higher than for electric, the assessed value for taxes is also higher.

Because of the higher cost of a natural gas engine compared to an electric motor, added capital expenditures for natural gas wells were greater than for electric wells, even though the same rate of decline was generally experienced. Gas installations were found to require more attendance hours than electric wells and a substantially greater amount of lubricants are used in the operation of natural gas engines. Gas engines require a major overhaul approximately every five years while the life of an electric motor rewind is from 15 to 17 years. This and other factors contribute to the higher cost of repairs for natural gas wells.

Table 27. Total Costs of Pumping Irrigation Water per Acre Foot and per Acre Foot per Foot of Pumping Lift

Area	Fixed	Added Capital	Variable	Total
		Cost per Acre Foot (dollars)		
District				
1	3.4742	.3643	7.1515	10.9900
2	3.2592	.3300	7.0367	10.6259
3	2.7813	.3395	4.1395	7.2603
4	.7450	.0651	1.7480	2.5581
5	1.3542	.0741	3.1613	4.5896
6	1.9970	.2040	7.1492	9.3502
7	1.5981	.0835	4.9316	6.6132
Dist. Avg.	1.7734	.1353	4.9555	6.8642
Farm Survey Electric	3.3825	.4175	8.7840	12.5840
Gas	4.3947	.5512	6.1862	11.1321
		Cost per AFF (dollars)		
District				
1	.01016	.00107	.02091	.02718
2	.00768	.00078	.01660	.02506
3	.01464	.00179	.02179	.03822
4	.00784	.00069	.01840	.02693
5	.00695	.00038	.01621	.02354
6	.00469	.00048	.01683	.02200
7	.00578	.00030	.01787	.02395
Dist. Avg.	.00664	.00051	.01856	.02571
Farm Survey Electric	.00895	.00110	.02344	.03329
Gas	.01011	.00127	.01422	.02560

Summarizing, it can only be said that natural gas appears to hold a cost advantage over electricity as a source of power for irrigation. Further study, however, is warranted before definite conclusions are drawn.

Total costs are somewhat more comparable on an acre foot foot basis. Overall average total cost for district wells was $.0257 per AFF. Means ranged from $.0220 to $.0382 per AFF. Mean total cost for farm survey electric and natural gas wells was $.0333 per AFF and $.0256 per AFF, respectively. The apparent cost advantage of gas over electricity is emphasized by cost per AFF figures since gas wells had substantially higher pumping lifts.

SUMMARY AND CONCLUSIONS

This study pertains to the cost of pumping irrigation water in Central Arizona. A substantial portion of the water used by farmers in this area is drawn from underground reservoirs. As a result of this continual withdrawal, the groundwater table is steadily declining. Increasing lifts, changing technology and fluctuations in various components of cost result in continual changes in the cost of pumping water.

Reliable, current pumpwater cost data are needed by farmers to make decisions that will yield maximum profit. These data are also of considerable value to numerous agriculturally-oriented businesses and public agencies which are concerned with agriculture. The purpose of this study is to provide this information.

Basic inventory, performance and operational data on 50 electric and 24 natural gas wells, owned and operated by individual farmers, were obtained by Kleinman (1963). The author obtained similar data on 607 electrically powered irrigation district wells for the same period.

Well drillers and pump companies supplied current replacement cost data, and the capital investment for each well and appurtenant equipment was computed. Various electric and natural gas suppliers furnished information as to current rate structures for different areas.

Individual farmers and pump companies were contacted to obtain repair data for wells in the farm survey. Repair costs for district wells were taken directly from irrigation district records.

While pumping installations vary from farm to farm, irrigation wells and equipment were found to be fairly uniform throughout Central Arizona. A typical well is about 1000 feet deep with 20 inch casing. It has between 400 and 500 feet of 12 inch column and a six or seven stage, 14 inch bowl assembly. If electric power is used, the motor is around 200 horsepower. Typical gas installations have a 325 horsepower engine. The typical well operates about 3700 hours annually, produces from 1300 to 1500 gallons per minute and pumps around 1000 acre feet per year.

The average capital investment of a pumping installation (based on 1963 costs) is $33,000 for electric and $49,000 for natural gas. It is estimated that an additional capital expenditure of from $363 to $598 will be incurred annually as a result of continual increases in pumping lift.

Cost components are reported in three major categories: fixed, added capital and variable. Total fixed costs, which include depreciation, interest on investment, and taxes, amounted to $3.38 per acre foot for electric wells and $4.39 for natural gas wells per acre foot.

Added capital costs include the cost of additional column and bowls and increasing the size of power unit to allow continued pumping from greater depths. Added capital cost per acre foot was $.42 for electric wells and $.55 for natural gas.

Variable costs include the cost of energy, attendance, lubrication and repair to well and equipment. Total variable cost per acre foot was $8.40 for electric and $6.19 for natural gas. Energy is the most important single cost of pumping. In this respect, natural gas enjoys a considerable cost advantage over electricity. Energy costs were assessed at the uniform rate of 9 mills per KWH for electric wells and $.04 per MCF for natural gas. Energy cost per acre foot was $7.36 for electric and $4.29 for natural gas.

Total cost of pumping irrigation water was $12.58 per acre foot for electric wells and $11.13 per acre foot for natural gas installations. Numerous factors underlie the apparent difference in pumping costs, which accrue to electric and natural gas wells. Significant savings in energy costs have already been mentioned to favor natural gas as a source of power. All other cost components, however, are higher for gas than for electrically powered installations.

Basically, the question is whether savings which result from the reduced cost of energy for natural gas installations are sufficient to offset the increased cost of other components. Natural gas appears to hold a cost advantage over electricity as a source of energy for pumping. Further study, however, is warranted before definite conclusions are drawn.

The costs of pumping water were also computed upon the basis of acre foot per foot of pumping lift to adjust for cost differences caused by variations in lift. Cost per AFF (acre foot foot) for electric wells was $.0090 fixed; $.0011 added capital; and $.02324 variable. This makes a total cost per AFF for electric wells of $.03329. Cost per AFF for natural gas wells was $.0101 fixed; $.0013 added capital; and $.0142 variable. Total cost per AFF was $.0256 for natural gas installations.

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APPENDIX

APPENDIX A

Breakdown of Well, Pump and Power Unit Costs

	Diameter of Casing, Inches					
	12	14	16	18	20	24
Well and Casing (dol. per foot)						
Drilling well	8.00	8.50	9.00	9.00	9.00	9.00
Casing	4.00	4.80	5.60	7.00	8.00	9.00
Perforation	1.00	1.00	1.00	1.00	1.00	1.00
Total	13.00	14.30	15.60	17.00	18.00	19.00
Shoe (dol. per foot)	200	215	242	295	340	400

	Diameter, Inches					
	6	8	10	12	14	16
Column Assembly (dol. per foot)	9.00	12.00	16.00	22.00	25.00	28.00
Suction pipe (dol. per foot)[1]	3.00	4.70	6.50	9.50	13.25	14.85
Discharge pipe (dol. per foot)	3.00	4.70	6.50	9.50	13.25	14.85

	Outside Bowl Diameter, Inches					
	10	12	14	16	18	20
Bowl cost by make (dol. per stage)						
Johnson-1st stage	--	470	600	750	1000	1290
Each additional	--	160	200	315	420	545
Layne & Bowler - 1st stage	350	450	580	790	1050	1350
Each additional	120	150	195	290	450	600
Peerless-1st stage	340	400	510	640	900	1170
Each additional	100	125	170	230	325	425
Other makes-1st stage		440	565	725	985	1270
Each additional		145	190	280	400	525

	Horsepower								
	50	100	150	200	250	300	350	400	450
Electric Motor (dol. each)									
1200 RPM	1306	2592	3951	5538	6675	7745	8829	10006	11233
1500 RPM	--	2300	3400	--	--	--	--	--	--
1800 RPM	980	1807	2809	3867	5125	6022	6969	7961	8798
Automatic Starter (dol. ea.)	250	470	1360	1470	2570	2625	2653	3000	3100
Head (dol. each)									
1200 RPM	400	400	540	540	1000	1000	1000	1200	1200
1800 RPM	400	400	540	540	540	1000	1000	1200	1200

	Horsepower								
	100	150	200	250	300	350	400	450	500
Gas Engine (dol. each)	6000	9000	11000	13750	16500	19250	20000	22500	25000

[1]Strainer costs per well for various districts were: Districts 1, 3 &6, $18; District 2, $20, District 4, $44