Selection of Pumping Equipment for Irrigation

Michael Fogel

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Selection of Pumping Equipment for Irrigation
DEFINITION OF TERMS

Irrigation Efficiency: The percentage of irrigation water pumped that is available in the soil for use by the crops.

Pump Capacity: The quantity of water a pump will deliver usually expressed in gallons per minute (gpm).

Total Head: The total head against which the pump operates consists of the following items:
   (a) Suction lift: Vertical distance in feet from the center line of the pump to the water surface.
   (b) Difference in elevation: Vertical distance from center line of the pump to the point of discharge.
   (c) Friction loss: Loss in head or pressure caused by the resistance to the flow of water through pipe and fittings.
   (d) Discharge pressure: The head or pressure required at the discharge nozzle. If the pump has a free discharge this will be zero.

Pump Efficiency: The ratio of the theoretical power, or water horsepower, to the actual power required to operate the pump.

Brake Horsepower: The actual power required to run the pump. It is directly proportional to the pump capacity and total head and inversely proportional to the pump efficiency.

Acre-inch: An acre-inch is the amount of water required to cover one acre one inch in depth.

CONVERSION FACTORS

1 cubic foot per second (cfs) = approximately 450 gallons per minute (gpm)
1 cfs = approximately 1 acre-inch per hour
1 acre-inch = 27,154 gallons
1 pound per sq. in. pressure = 2.31 feet of head
1 foot of head = 0.433 pounds per sq. in. pressure
1 horsepower = 0.746 kilowatts

ACKNOWLEDGMENT

The author wishes to thank the several commercial firms who generously supplied illustrations for this circular. He is also indebted to various state and federal agencies for furnishing some of the information herein.
A correctly designed pump irrigation installation, used under proper conditions and with good management, can be a profitable practice in most parts of South Dakota. It is the intention of this publication to briefly discuss the equipment that goes into a pumping plant. By so doing, potential users of this equipment will have some indication of the operating costs of the various units as well as the type of equipment that is best suited to his particular conditions.

The equipment, however, is just one phase in developing a pump irrigation system. Irrigation should be attempted only where both the soil and water are found to be suitable. The following are questions that should be answered before any equipment is purchased:

1. Is the soil adapted to sustained irrigation?
2. Is the quality of the water acceptable?
3. Is there enough water for irrigation especially at the time of the year when it is needed the most?
4. Is the type of water supply such that permission is required from the Water Resources Commission before it can be utilized for irrigation?

The answers to these questions are not always clear-cut. Technical assistance should be obtained to aid in the overall planning of a pump irrigation system.

If all conditions are found to be satisfactory for irrigation and the equipment is properly selected and laid out, there is still no assurance that irrigation will be a success. Soil-building practices should accompany irrigation since the food supply in the soils is removed at a rate faster than under dry-land farming. Selecting the method of irrigation that best fits the conditions, determining the amount, rate and time to apply water, are other factors that should be taken into consideration in order to obtain the maximum net benefits from irrigation.

**CAPACITY REQUIRED**

The basis for estimating the pump capacity in an irrigation installation is the amount of moisture crops use during the period they are growing most rapidly. This stage of crop growth is commonly referred to as the period of peak moisture use. Most crops in South Dakota will consume from 0.2 to 0.3 inches of moisture per day during their period of peak moisture use. To meet this critical demand, a continuous flow of from 3.8 to 5.7 gallons per minute per acre to be irrigated will be needed. This is based on the fact that a flow of 450 gallons per minute will supply one acre with one inch of water in one hour. If 30 per cent of the water pumped is lost to evaporation, to deep percolation be-
low the crop’s root zone, or to run-off, then the pump capacity will have to be increased to about 5½ to 8 gallons per minute per acre. Since this assumes a 24 hour pumping day which is seldom practical, consideration must be given to the number of hours the pump will operate each day.

As an example, let us assume a peak moisture use of 0.25 inches per day in estimating the pump capacity to irrigate 40 acres of alfalfa. This makes a daily use of 0.25 x 40 or 10 acre-inches of moisture. If the expected irrigation efficiency is 70 per cent, then the pump must be able to supply 10/0.70 or about 14 acre-inches of water per day. If the pump will be in operation 14 hours a day, then the pump capacity must be one acre-inch per hour, or 450 gallons per minute.

In most instances, irrigation efficiencies will vary between 55 and 75 per cent depending on such factors as the method of irrigation, soil type, and climatic conditions. Most sprinkler irrigation systems should apply water with an average efficiency of at least 70 per cent. A properly laid out and operated gravity system should also approach this figure. For an expected irrigation efficiency of 70 per cent, Table 1 can be used to estimate the quantity of water required to irrigate a given acreage. This will be sufficient pump capacity to meet peak moisture requirements of crops grown in South Dakota.

**POWER REQUIRED**

The actual power required to operate a pump is known as the brake horsepower. To determine this figure, it is necessary to know the quantity of water that will be pumped, the total head or pressure against which it will be pumped, and the efficiency of the pumping unit.

The total head usually expressed in feet of water, consists of the following factors:

1. **Suction lift** (vertical distance in feet from water level in well to center line of pump, drawdown included).
2. **Difference in elevation from pump center line to point of discharge**.
3. **Friction loss in pipe and fittings**.
4. **Discharge pressure**.

The values for friction losses and discharge pressures can be obtained from sprinkler irrigation companies. When pumping from surface water supplies, the suction lift is readily obtainable. In the case of pumping from
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wells, the well driller should furnish this information.

Manufacturers of pumping equipment can supply the user with the efficiency of their units. For estimation purposes, a figure of 65 per cent is often used.

Table 2 can be used to estimate horsepower requirements. It is based on a pumping plant efficiency of 65 per cent. The left-hand side of the table is for gravity irrigation while the right side can be used to estimate the power required to operate a sprinkler system. The table is based on the following formula:

\[ \text{BHP} = \frac{\text{GPM} \times \text{total head in feet}}{3960 \times \text{pumping plant efficiency}} \]

<table>
<thead>
<tr>
<th>Pump Capacity (Gallons per Minute)</th>
<th>For Gravity Discharge and Lifts of 50 Psi Discharge for Sprinklers and Lifts of 10 ft. 20 ft. 40 ft. 60 ft. 80 ft.</th>
<th>For Gravity Discharge and Lifts of 50 Psi Discharge for Sprinklers and Lifts of 10 ft. 20 ft. 40 ft. 60 ft. 80 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.4 0.8 1.6 2.4 3.1 4.9 5.3 6.1 6.8 7.6</td>
<td>0.4 0.8 1.6 2.4 3.1 4.9 5.3 6.1 6.8 7.6</td>
</tr>
<tr>
<td>200</td>
<td>0.8 1.6 3.1 4.7 6.2 10 11 12 14 15</td>
<td>0.8 1.6 3.1 4.7 6.2 10 11 12 14 15</td>
</tr>
<tr>
<td>300</td>
<td>1.2 2.4 4.7 7.0 9.4 15 16 19 21 23</td>
<td>1.2 2.4 4.7 7.0 9.4 15 16 19 21 23</td>
</tr>
<tr>
<td>400</td>
<td>1.6 3.1 6.2 9.4 12.5 20 21 25 27 31</td>
<td>1.6 3.1 6.2 9.4 12.5 20 21 25 27 31</td>
</tr>
<tr>
<td>500</td>
<td>2.0 3.9 7.8 11.7 15.6 25 27 31 34 39</td>
<td>2.0 3.9 7.8 11.7 15.6 25 27 31 34 39</td>
</tr>
<tr>
<td>600</td>
<td>2.4 4.7 9.4 14.0 18.7 30 32 37 42 46</td>
<td>2.4 4.7 9.4 14.0 18.7 30 32 37 42 46</td>
</tr>
<tr>
<td>800</td>
<td>3.1 6.2 12.5 18.7 25.0 39 42 49 54 61</td>
<td>3.1 6.2 12.5 18.7 25.0 39 42 49 54 61</td>
</tr>
<tr>
<td>1000</td>
<td>3.9 7.8 15.6 23.4 31.2 49 53 61 68 76</td>
<td>3.9 7.8 15.6 23.4 31.2 49 53 61 68 76</td>
</tr>
<tr>
<td>1200</td>
<td>4.7 9.4 18.7 28.1 37.4 59 64 73 82 91</td>
<td>4.7 9.4 18.7 28.1 37.4 59 64 73 82 91</td>
</tr>
<tr>
<td>1500</td>
<td>5.9 11.7 23.4 35.1 46.8 74 80 92 102 114</td>
<td>5.9 11.7 23.4 35.1 46.8 74 80 92 102 114</td>
</tr>
</tbody>
</table>

*Based on estimated pumping plant efficiency of 65 per cent.

pumps

Irrigation pumps usually are either of the horizontal centrifugal type or the deep-well turbine type. In most cases, there is no choice in their selection. That is, deep-well turbine pumps are used in practically all well installations and centrifugal pumps are used to pump water from surface water sources such as streams, lakes, and stock-water reservoirs. However, where the pumping level of the water in a well is close to the ground surface, centrifugal pumps are sometimes used.

The main reason for their use is that centrifugal pumps have a substantially lower initial cost and a longer life than do turbine pumps. As a general rule, the maximum practical suction lift, or the vertical distance between the water surface and the pump, for a centrifugal pump is about 15 feet. It is important that the suction lift includes the drawdown within the well when the water is being pumped at the required rate. The drawdown generally increases as the pumping rate increases. Sometimes pits are dug to reduce the suction lift so that a centrifugal pump can be used.

Centrifugal Pumps

Centrifugal pumps have to be primed before they will pump water. That is, they will not lift water unless the pump casing and suction line are both filled with water. The pump can
be damaged if it loses its prime and continues to run. Thus, it is advisable to install a pressure switch to shut off the power unit in the event the pump loses its prime.

There are several methods of priming a centrifugal pump. One method used in connection with internal combustion engines is by a device called an exhaust primer. The exhaust primer accomplishes its job by means of a rapidly-moving jet of engine exhaust gas. Centrifugal pumps can also be primed by using a foot valve placed at the end of the suction line and installing a gate valve in the discharge line. With the discharge valve closed, the suction line and pump casing are filled with water usually from an overhead tank or by using a hand pump located on top of the pump casing.

Even though centrifugal pumps run at a high efficiency over a relatively wide range of operating conditions, each pump has a certain head and discharge where it operates the most efficiently. If the head is either decreased or increased from this value, the efficiency will drop. Thus, in selecting a pump, the operating head, discharge requirements, and the lowest acceptable pump efficiency should be specified. In the larger pumps, pump efficiencies of between 70 and 75 per cent are readily obtained. These figures are somewhat high for the smaller pumps.
In buying a second-hand pump, the operating efficiency should be known. While the initial cost may be low this saving may be more than eaten up by a high operating cost due to a low pump efficiency. Reducing the pump efficiency by half will nearly double the operating cost.

A typical set of performance curves for a centrifugal pump is shown in Fig. 1. This pump was selected to deliver 450 gallons per minute against a total head of 160 feet. The curves also indicate that 25 horsepower will be required to run the pump.

The size of a centrifugal pump is commonly designated by the size of the discharge opening. Since friction loss in the intake line reduces the allowable suction lift, the intake fitting on the pump is often larger than the discharge fitting.

Fig. 2 Diagram of an electrically-driven deep-well turbine installation
Deep-Well Turbine Pumps

All types of pumps that are suspended by the discharge column, within which the drive shaft is located, are occasionally grouped under the heading of turbine pumps. Other pumps that are sometimes included in this classification are propeller, or screw pumps, and mixed-flow pumps. These pumps are designed to pump large quantities of water against low heads. In irrigation work turbine pumps are commonly called “deep-well turbines” because of their adaptability in pumping from deep wells. An electrically driven deep-well turbine installation is shown in Fig. 2.

For deep wells, or where additional pressure is required to operate sprinklers, more than one impeller or stage, may be needed. Impellers are housed in units called bowls and are placed one above the other. Since bowls are placed below the water level representing the lowest drawdown in the well, turbine pumps need not be primed.

power units

The choice of a power unit for a small irrigation pumping plant is usually limited to either an electric motor or an internal combustion engine.

Electric Motor

Electricity, when available at reasonable rates, is one of the most satisfactory sources of power for pump irrigation. The dependability and comparatively long life of an electric motor are two of the principal features that make this type of power desirable for pumping.

The most common type of motor used in pumping plants is the 60-cycle, 220-440 volt, three phase, squirrel cage induction motor. The speed of these motors under full load is nearly constant. It is important, therefore, that in direct connected units, the pump be selected that operates efficiently at the motor speed. Common speeds for motors operating on 60-cycle current are 860, 1160, 1760, and 3500 revolutions per minute. The 1760-speed motor is the one most commonly used where 60-cycle current is available.

Single-phase motors are often used for loads up to and including five horsepower even though a three-phase
motor would be more efficient. Above five horsepower, however, single-phase motors are not generally adapted to irrigation pumping.

The large motors are more efficient than the smaller ones. Since electric motors operate at a lower efficiency when they are not fully loaded, they should be selected so that they operate at around 90 to 95 per cent of a full load. Motor efficiency directly affects the cost of operation. For example, if a 20 horsepower motor is delivering its rated load at an efficiency of 90 per cent it is actually drawing 20/0.90 or 22 horsepower. Electric motors above five horsepower will generally have an efficiency of between 88 and 90 per cent.

Most squirrel cage induction motors will operate satisfactorily under a continuous overload of 10 per cent. In rare instances it may be more economical to slightly overload a motor than to install the next larger size. However, since overloading causes heating which tends to shorten the life of a motor, this practice is not recommended.

Electric motors should always be provided with protection against excessive heating due to overloading or undervoltage. In addition, the larger motors will require a starting compensator. It is advisable to check with the power supplier in the use of these motor controls and protective devices.

Standard motor sizes above five horsepower for three phase power are 7½, 10, 15, 20, 25, 30, 40, and 50 h.p.

Internal Combustion Engines

Gasoline engines are by far the most common source of power for irrigation pumping units in South Dakota. In many cases, however, the selection of another type of engine may be more economical in the long run. Other en-

Fig. 3. Electrically-driven centrifugal pumping unit
Engines being considered or used to a limited extent in this state are Diesel engines and propane-burning engines.

For a given set of conditions, the selection of the most suitable engine depends on such factors as the local cost of fuel, initial cost of the engine, the maintenance required for constant operation, and the length of time the engine is operated during the year.

Gasoline engines have two principal advantages over Diesel engines. They have a lower first cost and maintenance service is more readily available. On the other hand, Diesel engines operate at a higher efficiency resulting in a lower fuel cost and they have a longer engine life. The decision between gasoline and Diesel engines depends mainly on the average number of hours the pumping plant will be in operation each year and on the size of the engine. Thus, in areas where a limited amount of irrigation is practiced, Diesel engines may not be justified. This may also be true for the smaller pumping plants. As a rough guide, if an engine with a rating of at least 20 horsepower is to run more than 600 hours per year, serious consideration should be given to using Diesel engines rather than gasoline engines, as the source of power for pumping.

In many areas, the use of propane as a fuel may be more economical when compared to other fuels. Gasoline engines can be converted to burn propane or engines designed specifically to use this fuel can be purchased. The first cost of propane-burning engines may run from $100 to $150 higher than gasoline engines. To get the most economical results from propane engines, they should have a higher compression ratio than gasoline engines, a cool intake manifold as well as a propane carburetor and regulator equipment. While engines using propane will burn more fuel than gasoline engines, a savings of about 25 per cent in the cost of operation can be expected with propane as compared to gasoline. Inasmuch as propane engines have a higher life expectancy than do gasoline engines, appreciable savings are evident when pumping approximately 400 hours a year or more.

In many instances farmers are using their tractors as a source of power. An advantage of this practice is that only a small part of the depreciation would have to be charged against the cost of pumping. Oftentimes, however, the tractor has more power than is needed. In the case of gasoline engines, this would decrease the efficiency of the power unit since the engine is not operating under its rated load. It is also likely that the tractor will be required for other farm work. Thus, if at all possible, it is recommended that irrigation systems have their own sources of power.

In selecting an engine for a particular job, the continuous service rating should be used rather than the maximum rating. Overloading will result in reduced engine life while underloading will cause excessive fuel consumption. Where ratings are given for bare engines, further allowances should be made for operating such accessories as the fan, generator, water pump, etc. These accessories may consume as much as 10 per cent of the horsepower output of an engine. Thus, a heat exchanger, which is nothing more than a cooling coil, can be used in place of the conventional radiator and fan to bring about an approximate 5 per cent savings in horsepower. For pumping at the higher altitudes or
where higher temperatures are encountered, a still greater horsepower reserve should be allowed. When all these factors are taken into consideration, an engine should be loaded to about 60 or 70 per cent of its rated power. Used engines probably should not be loaded to more than 50 to 60 per cent of their rated power.

Since irrigation pumping plants operate long periods without supervision, safety controls should be installed which automatically shut the engine off if the oil pressure drops, if the coolant temperature becomes excessive, if the pump loses its prime, or if the discharge pressure drops.

Centrifugal pumps are generally direct-connected to the power unit. Figures 3 and 4 illustrate portable pumping units powered by an electric motor and a diesel engine, respectively. In the event a tractor is the source of power, the pump may be driven either from the belt or the power take-off of the tractor. A tractor-mounted, belt-driven centrifugal pump is illustrated in Fig. 5. When the tractor's power take-off is used (which is probably more satisfactory than using the belt), some type of speed increaser is needed as irrigation pumps commonly operate at three to four times power take-off speed. A trailer mounted PTO centrifugal pump is shown in Fig. 6. Inasmuch as a tractor will be under similar continuous heavy-duty conditions as a stationary engine, the same factors should be considered in their use. It is generally recommended that depending on the tractor's mechanical condition, 60 to 70 per cent of the available maximum belt horsepower be used for irrigation pumping.
Turbine pumps may be direct-driven, belt-driven, or driven through a 90 degree gear head. For electrical installations, the direct connection is the cheapest and most efficient type of drive. In installations where the water...
Selection of Pumping Equipment for Irrigation

level varies within wide limits, it may prove economical to use a variable-speed motor. These motors, however, are more expensive than constant-speed motors. Since most units have constant-speed electric motors, the discharge of the pump cannot be changed, and thus extreme care should be taken in selecting a pump.

The right angle gear drive (see Fig. 7) is the most dependable and efficient method of transmitting the power of a combustion engine to a turbine pump. The units are made in a variety of gear ratios to allow the pump and engine to operate at their most efficient speeds. A shaft with double universal joints, to take care of many changes or errors in alignment of pump and engine, is recommended to connect the engine to the gear head.

Belt drives, either flat-belt or V-belt, are cheaper than gear drives but are not as efficient. The efficiency of the various drives compare as follows: gear head—95 per cent or more, V-belt—90 to 95 per cent, flat-belt—85 to 90 per cent. A V-belt installation is slightly higher in cost than one using a flat-belt. An added advantage of V-belts, however, is that they can operate with the pulley centers much closer together than is permissible for flat-belts. Thus, they can be used in confined spaces. The recommendations of the manufacturer should be followed in selecting the size of the V-belt, number of belts, and pulley diameters.

Fig. 8 shows a flat-belt drive head for a deep-well turbine pump.

**estimating pumping costs**

The yearly cost of pumping water is generally divided into two groups: fixed costs and operating costs.

**FIXED COSTS**

Fixed costs may be considered as the overhead that is charged against the pumping installation. They consist of the following items:

- Depreciation of equipment
- Interest on investment
- Taxes and insurance

By far the item that represents the largest share of the fixed charges is depreciation of equipment. The expected useful life in years of the various components that make up a pumping installation is shown in Table 3. The annual depreciation, then, is the total of the amounts obtained by dividing the initial cost of each piece of equipment by its estimated useful life in years.

If we assume that equipment depreciates uniformly, then its average value is about one-half the initial cost. If we assume an interest rate of 6 per cent

![Fig. 7. A turbine pump installation using a right angle gear drive](image-url)
Table 3. Estimated Useful Life of Irrigation Equipment

<table>
<thead>
<tr>
<th>Item</th>
<th>Useful Life in Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>25</td>
</tr>
<tr>
<td>Pumps and gear drives</td>
<td>15</td>
</tr>
<tr>
<td>Power Units</td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td>15</td>
</tr>
<tr>
<td>Propane</td>
<td>12</td>
</tr>
<tr>
<td>Gasoline (water cooled)</td>
<td>10</td>
</tr>
<tr>
<td>Gasoline (air cooled)</td>
<td>5</td>
</tr>
<tr>
<td>Electric</td>
<td>25</td>
</tr>
<tr>
<td>Pipe</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>15</td>
</tr>
<tr>
<td>Steel, coated</td>
<td>10</td>
</tr>
<tr>
<td>Steel, galvanized</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 4. Estimating Annual Fixed Cost of a Pumping Installation

<table>
<thead>
<tr>
<th>Type of Power Unit</th>
<th>Annual Fixed Costs Expressed as Percentage of Initial Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>12</td>
</tr>
<tr>
<td>Propane</td>
<td>11</td>
</tr>
<tr>
<td>Diesel</td>
<td>10</td>
</tr>
<tr>
<td>Electric</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 5. Estimated Fuel Consumption of Irrigation Pumping Units

<table>
<thead>
<tr>
<th>Type of Engine</th>
<th>Fuel Consumption in BHP-Hrs./Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>13.5</td>
</tr>
<tr>
<td>Gasoline</td>
<td>10</td>
</tr>
<tr>
<td>Propane</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 6. Estimating the Cost of Operating a Pumping Installation

<table>
<thead>
<tr>
<th>Type of Power Unit</th>
<th>Unit Cost for Fuel or Power</th>
<th>Operating Cost per Acre-Foot of Water Pumped per Foot of Total Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>$0.20 per gal.</td>
<td>4\$/c</td>
</tr>
<tr>
<td>Propane</td>
<td>.12 per gal.</td>
<td>3\$/c</td>
</tr>
<tr>
<td>Diesel</td>
<td>.15 per gal.</td>
<td>3\$/c</td>
</tr>
<tr>
<td>Electric†</td>
<td>.02 per KWH</td>
<td>3\$/c</td>
</tr>
</tbody>
</table>

*Includes cost for fuel or power, lubrication and repairs but not for labor.
†Does not include demand or minimum charges.

and additional 1 per cent for taxes and insurance, then the average value of the equipment (one-half initial cost) is multiplied by .07 to give us the yearly charges for interest, taxes and insurance.

Table 4 can be used to obtain a quick estimate of the annual fixed cost of a pumping plant. A more accurate method would be to obtain a value for depreciation and for interest, taxes and insurance for each piece of equipment.

**OPERATING COSTS**

Operating costs will vary with the pump efficiency, total head, type and cost of fuel or power, and attention given the pumping plant. Included in this group of items are costs for:

- Fuel or power
- Lubrication
- Repairs
- Labor

The cost for fuel or power represents somewhere around three-fourths the operating cost of a pumping plant exclusive of labor. Table 5 can be used to estimate the fuel consumption for various types of internal combustion power units. By dividing the brake horsepower required to operate a pump (see Table 2) with the corresponding horsepower-hours per gallon shown in this table, the approximate fuel consumption in gallons per hour is obtained.
An estimate of the total operating cost (not counting labor) of an efficient pumping plant can be made by using Table 6.

**EXAMPLES**

The following example will illustrate the method for estimating the total annual cost of pumping water by using Tables 4 and 6:

- Acres to be irrigated: 80
- Total head in feet: 60
- Irrigation water to be applied per acre, inches: 18
- Total acre-feet of water pumped, 80 x 18/12: 120

**Initial cost of deep-well turbine installation:**
- Well and casing: $1,500
- Deep-well turbine pump: 1,400
- Gasoline engine: 1,000
- Right angle gear drive: 400
- Total: $4,300

**Annual cost of pumping:**
- Fixed cost: 12% of $4,300: $516
- Operating cost: Per acre-foot = $0.043 x 60 = 2.70
  Total = 1.20 x 2.70 = 2.70
  TOTAL $786
  or about $10 per acre

Supposing a sprinkler irrigation system were used to irrigate 80 acres with 15 inches of water, and this quantity of water (100 acre-feet) were pumped against a head of 180 feet. If the initial cost of the plant (well, pump, propane engine, drive) was $4800, the estimated cost of pumping would be:

- Fixed cost: 11% of $4800: $528
- Operating cost: Per acre-foot = $0.033 x 180 = 6.30
  Total = 100 x $6.30 = 630
  Total $1158
  or about $15 per acre

To find the total cost of irrigation, the cost of distributing the water together with the cost for labor must be added to the cost of pumping.
Consider these items . . .

Before You Buy
Pumping Equipment

1. Determine rate of flow of water required for irrigation.
2. Determine total head required.
3. Select pump with a high efficiency by using pump performance curves that meet discharge and total head requirements. In the case of direct connected units, pump speed is an added factor in making selection.
4. Determine brake horsepower required to operate pump either from pump performance curves or by using the following formula:
   \[ \text{BHP} = \frac{GPM \times \text{total head in feet}}{3960 \times \text{pump efficiency}} \]
5. When pump and power unit are not direct connected, correct brake horsepower for drive efficiency. (Divide BHP by 0.85 or 0.95 depending on drive used.)
6. For internal combustion engines, increase value obtained in part 4 or 5 by 40 to 50 per cent to obtain minimum rated horsepower required of the engine. For electrically-driven units, select motor that is equal to or slightly higher than the brake horsepower requirement.
7. Estimate the cost of pumping for at least two types of power units and make selection on basis of economy, availability of power or fuel, and dependability of dealer service.