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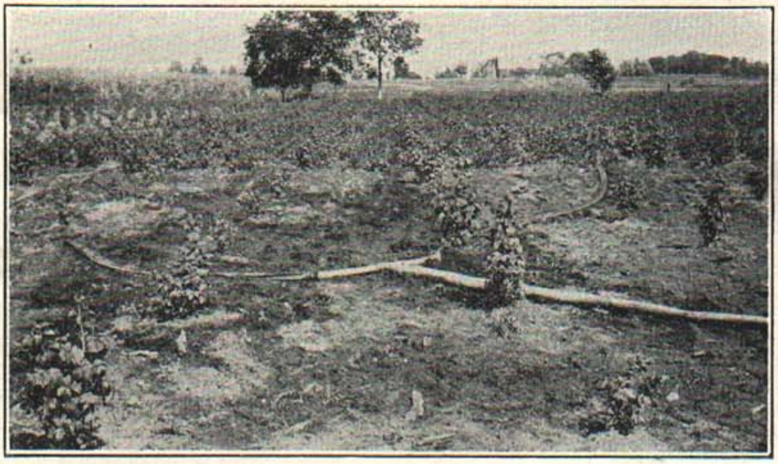
O. E. ROBEY



Irrigating small fruit with porous hose.

MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

EXTENSION DIVISION

R. J. Baldwin, Director

Michigan State College and U. S. Department of Agriculture co-operating.
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DEFINITIONS

A gallon of water weighs 8.36 lbs. and equals 231 cu. in.

A cubic foot of water weighs 62.5 lbs. and equals 7.48 gals.

An acre inch of water is the amount necessary to make a layer of water 1-in. deep on an acre. It requires 27,154 gallons to make an acre inch.

Pounds pressure and feet of head are terms used to indicate the pressure of a column of water. For instance, a tank of water 10 ft. high will create a certain amount pressure on a gauge at its base. The size of the tank is immaterial; the height of the tank is what determines the pressure. A column of water 2.3 ft. high will produce one pound of pressure per square inch; a column 23 ft. high will produce 10 pounds pressure per square inch.

POROUS HOSE IRRIGATION

O. E. ROBEY

Experiments conducted during the past two summers by the Agricultural Engineering Department have proved that the porous hose method of irrigation can be profitably used on a number of Michigan crops. Furthermore, demonstrations have shown its usefulness in meeting special situations where soil conditions, crop grown, ground contour, or capital investment would not warrant the use of other types of irrigation.

In this newer method of irrigation a porous hose is used for distributing the water. The hose may be made of canvas or other fabric with a tight weave. The water is pumped into one end of the hose and the other end is

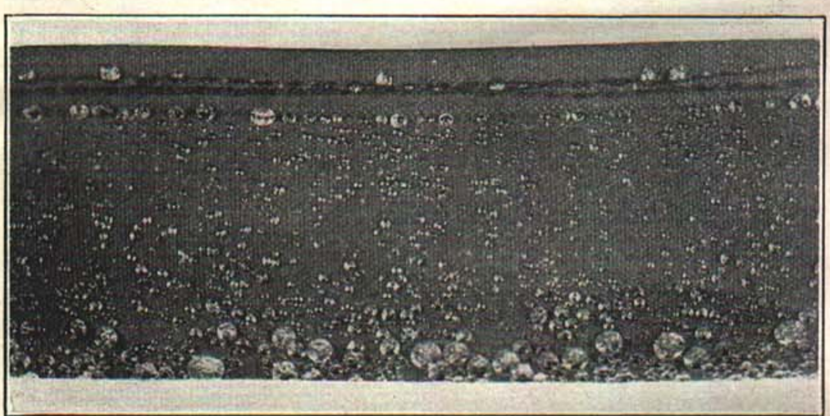

Fig. 1.—The irrigation water is forced through the hose in small drops; it does not spray.

closed; when the hose becomes filled with water and a slight pressure has been developed, the water begins to leak out through the pores. Owing to the fineness of the weave, the water does not spray, but merely passes through the fabric in small drops, Figure 1. This method of applying the water prevents eroding the ground or injuring the plant by wetting the leaves and foliage.

Porous hose irrigation has been successfully used for potatoes, strawberries, celery, garden truck, small fruits, and orchards,* Figure 3. It has also been found convenient for irrigating lawns and shrubbery, Figure

***If you are especially interested in orchard irrigation, write for Agricultural Engineering Department, Series Pub. 12.**

4. Another advantage of this method of irrigation is its adaptability to land which, owing to its irregular surface, is not readily irrigated by flooding. The porous hose will conduct the water over variations of elevation of two or three feet with fairly uniform results.

Fig. 2.—Irrigating potatoes with porous hose.

Need for Irrigation

Michigan has an annual rainfall of about 32 inches a year. It has generally been considered adequate for proper crop growth, but a careful study of the annual rainfall over a number of years reveals that there has been considerable variation in the distribution of the rainfall during the growing season. By referring to Chart No. 1, it will be seen that during the 69 years represented by the chart, 23 years had less than 10 inches of rainfall during

Fig. 3.—Porous hose has been successfully used in orchards where irregular ground makes flooding impractical.

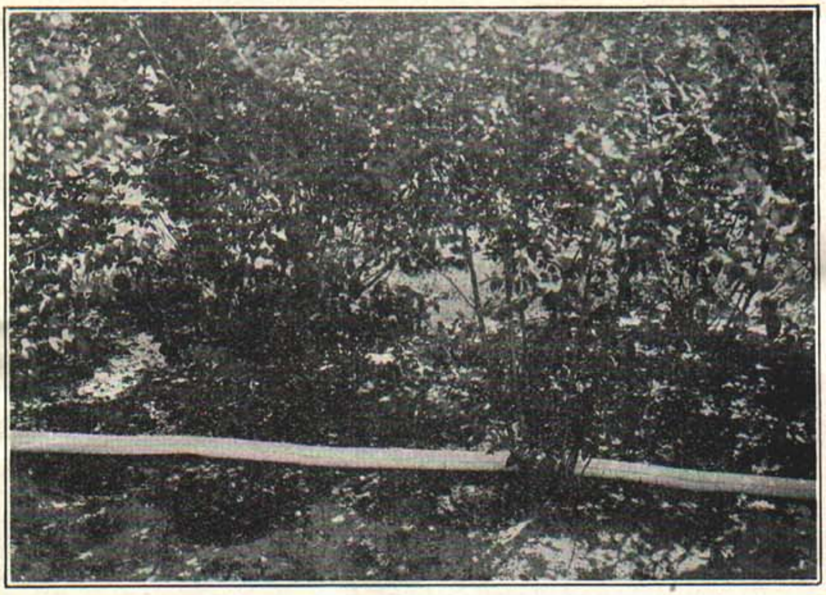

Fig. 4.—When porous hose is used for irrigating shrubbery it may be left near the roots until the ground is thoroughly saturated without spraying the leaves.

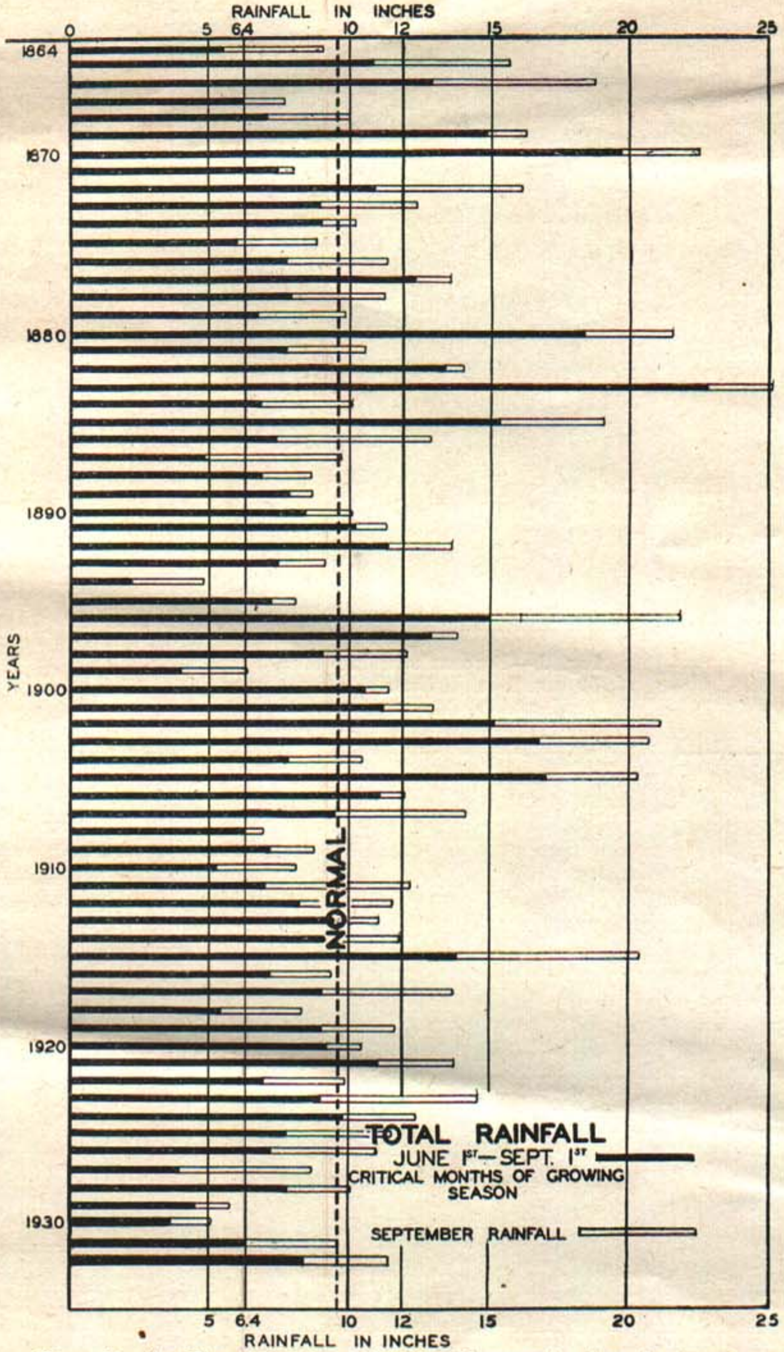

Chart No. 1.—The summer rainfall for 69 years is given in the above chart. The solid portion of each line represents the rainfall during May, June, July, and August. The open portion, September rainfall. Data from U. S. Weather Bureau, East Lansing Station.

the months of June, July, August, and September, while 56 years had less than 15 inches. Chart No. 2 indicates that at least 19 inches of water is desirable during this period.

A more careful analysis of the distribution of the rainfall during the summer months would show that there are several periods of from 10 days to a month during each summer when there is very little or no rainfall. The frequency of these periods is given for a 10-year period in Table No. 1. Rains of 0.2 of an inch or less have been omitted from this Table.

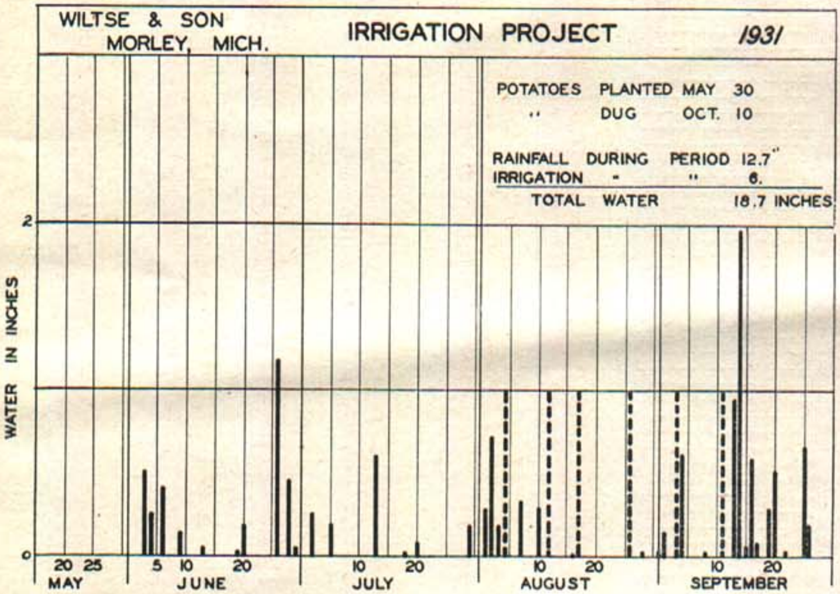

Chart No. 2.—This chart shows the distribution of rainfall and irrigation water on one of the potato irrigation plots. Solid lines represent rainfall, broken lines irrigation water. Adding 6 inches of water increased the yield 122 bushels per acre.

It should also be remembered that the character of the rains have considerable influence on the benefits secured from them. A dashing rain, though amounting to three-fourths of an inch or more has a high percentage of run-off and little penetration on the high land where it is most needed. However, a gentle rain of one-fourth of an inch or less does not have volume enough to penetrate sufficiently to be of much value to the plants. It is evident that the total number of inches recorded by the Weather Bureau does not always indicate whether irrigation is needed or not.

The value of irrigation is not measured entirely by increased yields. It usually has beneficial effects upon quality and may be used in either prolonging or hastening the harvesting period in order to meet better market conditions.

The Porous Hose Method of Applying Water

In applying water for irrigation purposes by the porous hose method, it is necessary to convey the water to the field through metal pipe or by

Table 1.—Distribution of rainfall at East Lansing during June, July and August from 1923-1932.

	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932
June 1										
2			.70							.24
3									.73	
4					.38					
5						1.25		.80		
6				.72					.97	
7	.73									
8		.49								
9										
10										
11										
12		.51			(17 days)	(13 days)	.75			
13										
14										(23 days)
15				1.73						
16								.97		
17			.44						(19 days)	
18										
19		1.36				.65				
20							(14 days)			
21	1.03				.51					
22										
23						.48				
24		.71								
25										.33
26			.32					.69	.8	
27							.74			
28	.86	1.79		(23 days)	(14 days)	.57			.58	
29										
30							.37			
July 1										
2										
3										1.49
4										
5									.59	
6			(18 days)		.44	(15 days)	(12 days)			
7	3.28									.34
8		.55								
9				.51						
10	.45									.28
11										
12										
13					.55	.35				
14							.59			
15			1.14							
16										
17										
18	(16 days)						.68			(16 days)
19						.45			(27 days)	
20										
21					.79					
22			(15 days)	.91		.71				
23		.43								
24										
25										
26										.87
27	.32									
28		1.64						(66 days)		
29										
30										
31			1.56							
Aug. 1				2.37						
2									.54	.46
3						.55				
4										
5	.54								.68	
6		1.75								
7			.90							
8										
9										
10					(42 days)		(49 days)			
11						(17 days)				
12			.75	.34						
13	(15 days)									
14										
15										(27 days)
16										
17										
18										
19		(25 days)							(26 days)	
20			.44	.34						
21	.37					.46				
22										
23										
24										
25										
26										
27										
28						1.14				
29										**2.56**
30										
31										

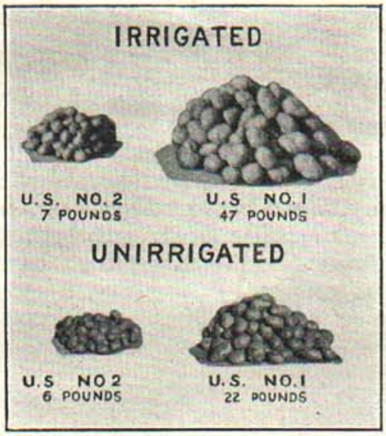

Fig. 5.—Irrigation improves quality as well as increases the yield.

some other means which will permit a pressure of 15 to 20 pounds per square inch in the distributing hose line. Where the lift is not too great, old fire hose or impervious canvas tubing may be used in place of the iron pipe.

The pipe line should be extended along one side of the field to act as

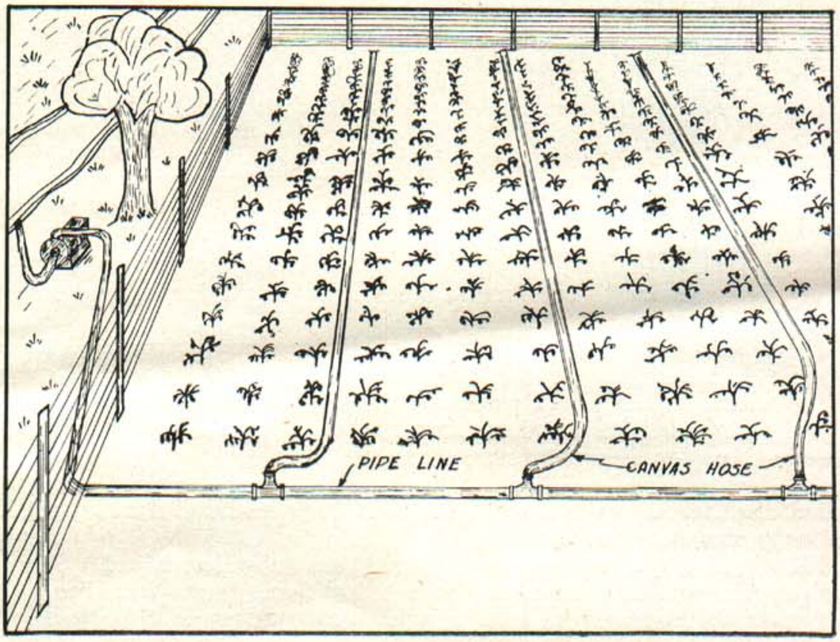

Fig. 6.—A typical layout for a porous hose system of irrigation.

a header for attaching the porous hose, Figure 6. Tees should be used for connecting the lengths of pipe and a plug used for closing the side outlet. When attaching the hose, the plug is removed and a short piece of pipe is inserted to provide places for the attachment of the hose.

It is preferable to have the header extend along the high side of the field. While the porous hose will conduct the water up-hill, a better distribution can be secured by extending the hose lines down grade or on the level.

Hose lines have been satisfactorily used up to 660 feet in length. In long lines of hose and when irrigating on irregular ground, it was found that more even distribution could be secured if the lines of hose were made up of different weights of canvas. Heavy weight canvas was used nearest the pipe line and in going up-grade. When going down a rather steep grade

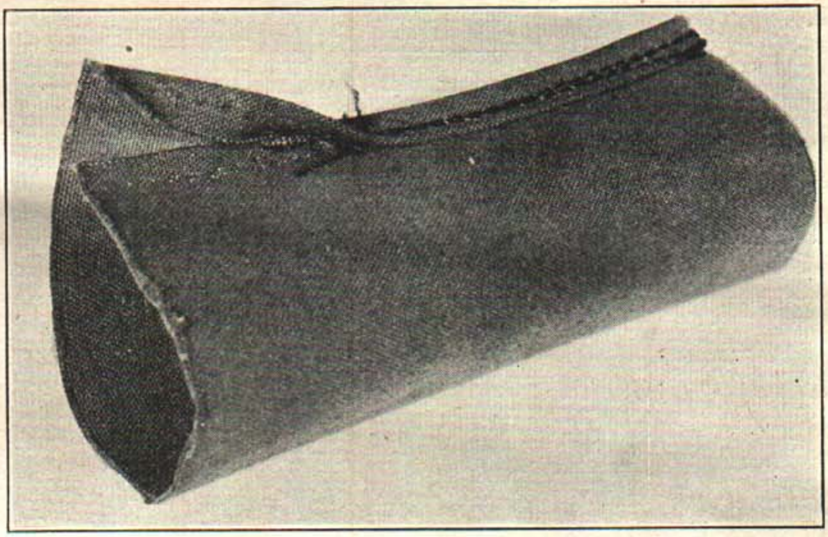

Fig. 7.—A section of the hose used in our experimental work.

it may be necessary to reverse the order and put the heavy canvas at the lower end of the line.

The hose used in our experimental work were made from 12, 10, and 8 ounce duck and in some cases material as heavy as No. 6 and No. 8 roll duck was used where extra pressure was necessary. For short lines, 8 or 10 ounce duck will be found satisfactory, but for the longer lines a combination of weights is usually necessary. A 600 foot line may be made up of 100 feet of No. 8 roll duck, 200 feet of 12 ounce duck, 200 feet of 10 ounce, and 100 feet of 8 ounce. For most purposes hose, two and one-half inches in diameter is satisfactory, Figure 7.

The durability of canvas hose has not been fully determined. Some of our experimental hose have been in use for three years. The life of the hose may be prolonged by treating with a mixture made of asphalt paint, 1 gallon; kerosene, ½ pint; and gasoline, ½ pint. The mixture should be stirred thoroughly.

This treatment may be applied with a brush or the hose may be run through a tank of this solution, then passed through a clothes wringer to squeeze out the excess, Figure 8. The hose should be allowed to dry for 24 hours before being used or rolled.

In the case of row crops, a line of hose is laid down each row and allowed to remain long enough to apply the proper amount of water, then the hose line is moved to the next row, Figure 9. In the case of potatoes, strawberries, and crops of similar spacing, it is not usually possible to cover more than one row at a time. However, in the case of garden truck in narrow

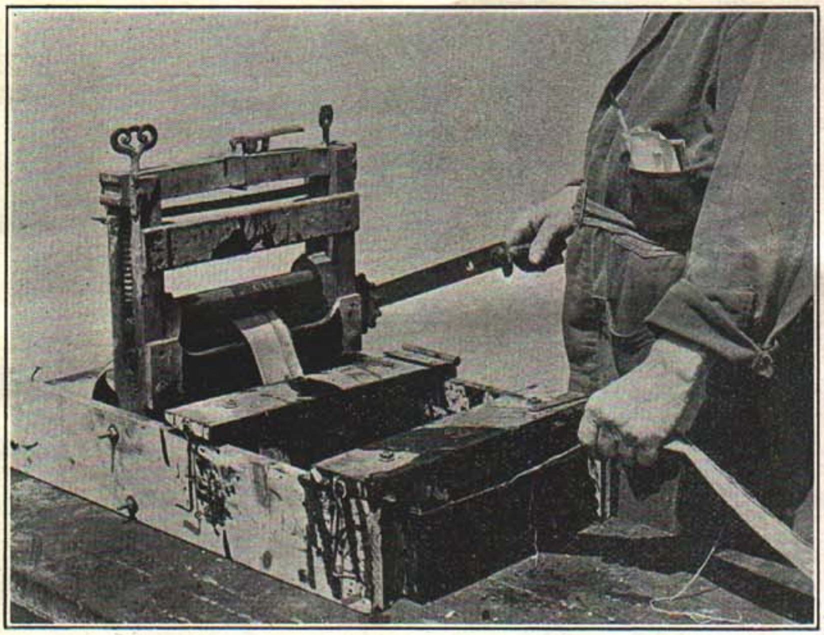

Fig. 8.—The apparatus used in treating the hose.

rows and with flat cultivation, two or more rows may be irrigated with one placing of the hose. Soil conditions and methods of cultivation will determine the width of distribution.

Since the water is applied directly to the ground and not on the foliage, the irrigation may be carried on at any time during the day or night. Also, the water may be pumped direct from the source of supply; it need not be stored and warmed by the sun before applying.

Water Supply

Before attempting to irrigate, a suitable water supply should be available. Large quantities of water are required to irrigate even small areas. For instance, it takes 27,154 gallons to cover an acre one inch deep with water. Seldom is it desirable to apply less than this amount and often heavier ap-

Fig. 9.—Moving the hose from one row to the next.

Fig. 10.—The roller used in moving the hose.

plications are necessary. The usual practice is to apply about one inch of water each week.

Lakes, rivers, and small streams are possible sources of water supply for irrigating; in some locations, wells can be used. Where the water table is close enough to the surface to be within the reach of a shallow well pump, not more than 20 feet, a number of wells may be connected together and worked with one pump, Figure 12. Deep well pumping may be resorted to in some cases. There are places where it will be cheaper to install a deep well and pumping equipment rather than a long pipe line.

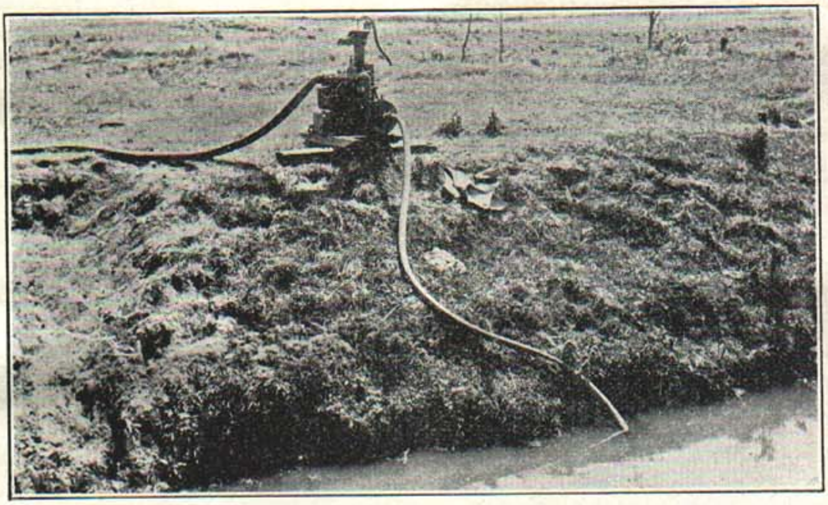

Fig. 11.—Pumping water from a small stream with a centrifugal pump.

Soil Suitable for Irrigation

The ideal soil for irrigation purposes is a sand or sandy loam with a rather heavy subsoil about 16 inches below the surface. Muck also responds very well to irrigation. Irrigation should not be attempted on heavy clay.

Cost of Irrigating

The cost of irrigating is dependent upon the following factors:

1. Cost of equipment and upkeep;
2. Cost of pumping;
3. Cost of labor.

Since each one of these factors are different with each installation, it is almost impossible to give information that will be applicable to every installation. Tables and figures given in the following pages will help out in determining the probable cost of installing and operating irrigation equipment.

It might be stated, however, that in a 10-acre experiment on potatoes in 1932, the depreciation and interest on equipment, labor and electricity for pumping an acre inch of water were as follows:

Depreciation and interest on equipment	$0.55
Labor	.35
Electricity @ $0.02 per k. w. h.	.53
Cost per acre inch	$1.43

Selecting the Proper Irrigation Equipment

The selection of equipment is dependent upon the use to which it will be put and the investment which it is desirable to make. One of the advantages of the porous hose system of irrigation is its flexibility and portability. It can very easily be moved from one field to another and the area to be irrigated can be reduced or increased with very little change in equipment. For a permanent irrigation system, it may be desirable to install different pumping and power equipment than for a portable one.

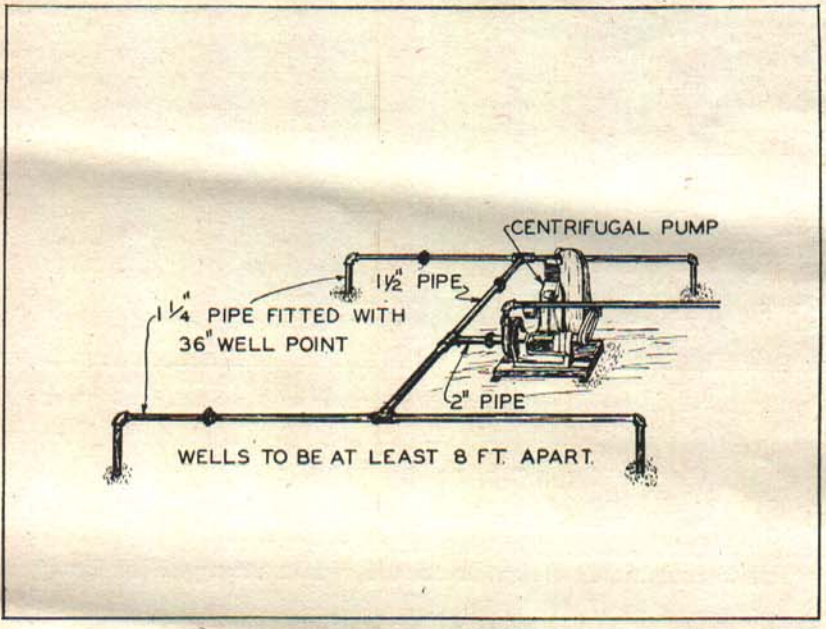

Fig. 12.—A number of shallow wells 15 to 20 ft. deep may be connected together and operated with one pump.

Size of Equipment Needed

Before selecting equipment, the first thing to consider is the area to be irrigated and the rate the water is to be applied. For instance, if five acres is to be irrigated and the whole area is to be covered in one day it will require a larger pump and larger piping than if two, three, or even five days are taken to cover the same area.

Where a large area is to be covered, the system is often planned to irrigate about one-fifth or one-sixth of the total area per day allowing the application to be repeated once a week. The system is usually designed to handle the equivalent of one inch of rainfall per application. In some cases, however, it is desirable to have capacity enough to cover the entire area in two or three days leaving the balance of the week for other work.

When the area to be irrigated and the time in which to do the work has been decided upon, turn to Table No. 2 and the size of pump necessary can be quickly determined. Find in the column on the left, the area to be irrigated per day. Move across the page to the right under the proper column headed with the number of hours the system is to be operated per day, the capacity of the pump will be given in gallons per minute.

Table 2.—Size of pump required for applying one inch of irrigation water on various areas.

Size of Area in Acres	Rate of Application—Hours									
	1	2	3	4	5	6	7	8	9	10
	Gallons per Minute									
0.1	50	25	16.6	12.5	10	8.3	7.1	6.2	5.5	5
0.2	100	50	33.3	25.	20	16.6	14.2	12.5	11.	10
0.3	150	75	50.	37.5	30	25.	21.4	18.7	16.6	15
0.4	200	100	66.6	50.	40	33.3	28.5	25.	22.	20
0.5	250	125	83.3	62.5	50	41.6	35.7	31.	27.7	25
0.6	300	150	100.	75.	60	50.	42.8	37.5	33.3	30
0.7	350	175	116.6	87.5	70	58.3	50.	43.7	38.8	35
0.8	400	200	133.3	100.0	80	66.6	57.	50.	44.4	40
0.9	450	225	150.	112.5	90	75.	64.	56.	50.	45
1	500	250	166.	125.	100	83.	71.	62.	55.	50
2	1000	500	333.	250.	200	166.	142.	125.	110.	100
3	1500	750	500.	375.	300	250.	214.	187.	166.	150
4	2000	1000	666.	500.	400	333.	285.	250.	220.	200
5	2500	1250	833.	625.	500	416.	357.	310.	277.	250
6	3000	1500	1000.	750.	600	500.	428.	375.	333.	300
7	3500	1750	1166.	875.	700	583.	500.	437.	388.	350
8	4000	2000	1333.	1000.	800	666.	570.	500.	444.	400
9	4500	2250	1500.	1125.	900	750.	640.	560.	500.	450
10	5000	2500	1660.	1250.	1000	830.	710.	620.	550.	500

Piping

Usually, it is necessary to convey the water to the field through a pipe line. If the field to be irrigated is located alongside of the source of water, little piping will be required, but, if the water must be pumped from a stream or lake at some distance, the type and size of pump, the amount of power necessary, and the distance the water is to be pumped will affect the size of pipe line necessary.

When water flows through a pipe line, there is more or less resistance and friction loss. This increases with the length of the pipe line and number of gallons flowing per minute, but decreases as the size of the pipe is increased. This resistance is usually expressed in loss of "head" expressed in feet of height or pounds pressure. For example, to force 30 gallons per minute through 300 feet of one and one-half inch pipe laid on the level, requires as much power as is needed to lift the same quantity of water 26 feet. The friction loss in this case is equivalent to a 26-foot "head". The smaller sizes of pipe are less costly to install, but it costs more to pump water through them. In Table 3, data are presented showing the loss in feet of "head" for various lengths of pipe of different sizes and with different rates of flow.

The pump must not only lift the water from its level in the well, stream or lake to the highest point from whence it flows out on the land, but it must overcome the friction incident to flowing through the pipe line. It must also maintain the necessary additional pressure to operate the hose line.

The total head which the pump must operate against then is made up of the following: (1) vertical distance from the water level to the pump; (2) vertical distance from the pump to the highest point in the field; (3) friction loss in the pipe line, as indicated in Table 3; (4) and head required to operate the hose, which usually is about 30 feet.

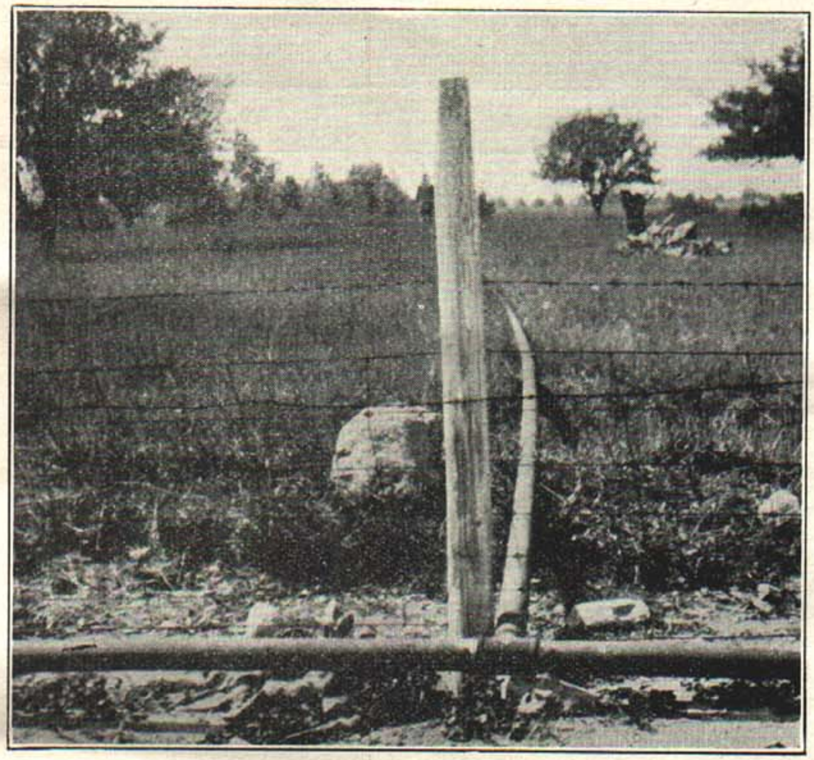

Fig. 13.—The size of the pipe line is determined by a number of factors such as length, quantity of water to be pumped and power available.

The Hose Line

The amount of hose line necessary will depend on the length of rows and the capacity of the pump. For each 100 feet of hose line, a pump capacity of 10 gallons per minute is needed. Thus for a line 500 feet long the pump should have a capacity of 50 gallons per minute.

The amount of hose which one man can handle will depend somewhat upon local conditions and the rate of application. From 1,000 to 1,500 feet of hose can probably be handled by one man.

The hose should be left in each row long enough to apply the proper amount

Table 3.—Recommended pipe sizes for ordinary installations.

Gallons per Minute		Length of Pipe in Feet											
		100	200	300	400	500	600	700	800	900	1000	1200	1400
10......	Size of Pipe... Loss in Feet..	¾" 30	1" 21	1" 31	1" 41	1¼" 12½	1¼" 15	1¼" 17	1¼" 19	1¼" 21½	1¼" 24	1¼" 29	1¼" 33½
15......	Size of Pipe... Loss in Feet..	1" 16	1" 32	1" 48	1¼" 22	1¼" 27	1¼" 33	1¼" 38	1¼" 44	1½" 20	1½" 22	1½" 27	1½" 31
20......	Size of Pipe... Loss in Feet..	1" 28	1¼" 9	1¼" 19	1¼" 28	1¼" 38	1½" 23	1½" 27	1½" 30½	1½" 34	1½" 38	1½" 42	2" 14
25......	Size of Pipe... Loss in Feet..	1¼" 15	1¼" 30	1½" 15	1½" 20	1½" 25	1½" 30	1½" 35	1½" 40	2" 13	2" 14	2" 17	2" 20
30......	Size of Pipe... Loss in Feet..	1¼" 21	1¼" 42	1½" 26	1½" 35	1½" 43	2" 13	2" 15	2" 17	2" 19	2" 21	2" 25	2" 29
35......	Size of Pipe... Loss in Feet..	1¼" 29	1½" 23	1½" 35	1½" 46	2" 14	2" 17	2" 19	2" 22	2" 25	2" 28	2" 33	2" 39
40......	Size of Pipe... Loss in Feet..	1¼" 37	1½" 30	1½" 45	2" 15	2" 18	2" 22	2" 26	2" 30	2" 33	2" 37	2" 44	2" 51
45......	Size of Pipe... Loss in Feet..	1½" 19	1½" 38	2" 14	2" 18	2" 23	2" 28	2" 32	2" 37	2" 41	2" 46	2½" 18	2½" 21
50......	Size of Pipe... Loss in Feet..	1½" 23	1½" 46	2" 17	2" 22	2" 28	2" 34	2" 39	2" 45	2" 51	2½" 19	2½" 22	2½" 26
60......	Size of Pipe... Loss in Feet..	1½" 33	2" 19	2" 27	2" 36	2" 44	2" 53	2½" 19	2½" 22	2½" 24	2½" 27	2½" 32	2½" 38
70......	Size of Pipe... Loss in Feet..	2" 11	2" 22	2" 33	2" 44	2" 55	2½" 21	2½" 24	2½" 28	2½" 31	2½" 35	2½" 42	2½" 48
80......	Size of Pipe... Loss in Feet..	2" 15	2" 29	2" 44	2½" 19	2½" 23	2½" 28	2½" 32	2½" 37	2½" 42	2½" 46	3" 25	3" 29
90......	Size of Pipe... Loss in Feet..	2" 18	2" 36	2½" 18	2½" 24	2½" 30	2½" 36	2½" 42	2½" 48	3" 23	3" 25	3" 31	3" 36
100......	Size of Pipe... Loss in Feet..	2" 22	2" 44	2½" 21	2½" 28	2½" 35	2½" 42	2½" 49	3" 24	3" 27	3" 30	3" 36	3" 42
125......	Size of Pipe... Loss in Feet..	2" 34	2½" 23	2½" 34	2½" 45	3" 23	3" 27	3" 32	3" 37	3" 41	3" 46	3½" 27	3½" 31
150......	Size of Pipe... Loss in Feet..	2½" 16	2½" 32	2½" 48	3" 26	3" 33	3" 39	3" 46	3" 53	3½" 28	3½" 31	3½" 37	3½" 44
175......	Size of Pipe... Loss in Feet..	2½" 22	2½" 44	3" 27	3" 36	3" 44	3" 53	3½" 30	3½" 34	3½" 38	3½" 43	3½" 47	4" 30
200......	Size of Pipe... Loss in Feet..	2½" 29	3" 23	3" 35	3" 46	4" 14	4" 17	4" 20	4" 23	4" 25	4" 28	4" 31	4" 34
225......	Size of Pipe... Loss in Feet..	3" 16	3" 31	3" 48	4" 15	4" 19	4" 33	4" 27	4" 31	4" 35	4" 39	4" 47	4" 54
250......	Size of Pipe... Loss in Feet..	3" 18	3" 36	3½" 26	3½" 34	3½" 43	3½" 51	4" 31	4" 35	4" 39	4" 44	4" 52	4" 61

of water. Table 4 will be found useful in determining the length of time necessary to leave the hose in a three foot row in order to apply one inch of water.

Pumps

Water for irrigation purposes may be pumped from lakes, streams, or wells. In the case of shallow wells of rather limited capacity, two or more may be connected and operated with one pump.

Several types of pumps are commonly used, turbine, rotary, centrifugal,

Table 4.—Showing number of minutes hose should remain in different length rows to apply 1-in. of water.*

Gallons Pumped per Minute	Length of Row in Feet									
	20	50	75	100	200	250	300	400	500	600
5	8	19								
10	4	10	14	19						
15	3	6	9	13						
20	2	5	7	10	20					
25	......	4	6	8	16	20				
40	......	2	3	5	8	10	15	20		
50	......	......	3	4	8	9	11	15		
60	......	......	......	3	6	8	9	13	16	19
75	......	......	......	2	5	6	7	10	12	15
100	......	......	......	2	4	5	6	8	9	11
125	......	......	......	......	3	4	5	6	8	9
150	......	......	......	......	......	3	4	5	6	7

*Table based on a 3 ft. row. Fractional parts of a minute have been omitted.

and piston. Piston or plunger pumps (the ordinary hand pump belongs in this class) are built for either deep or shallow wells, and the pump which is best adapted to conditions should be obtained. If the water level stands at more than 25 feet below the surface, a deep well pump is necessary. The plunger pump is capable of pumping against high pressures and, since its action is positive, the pipe line cannot be closed while the pump is running without damaging either the pump or the piping, unless fitted with some sort of relief valve. This type of pump is suitable only for water that is free from sand and dirt.

The centrifugal pump consists of a revolving impeller in a metal housing. The water is thrown off this impeller by centrifugal force which produces

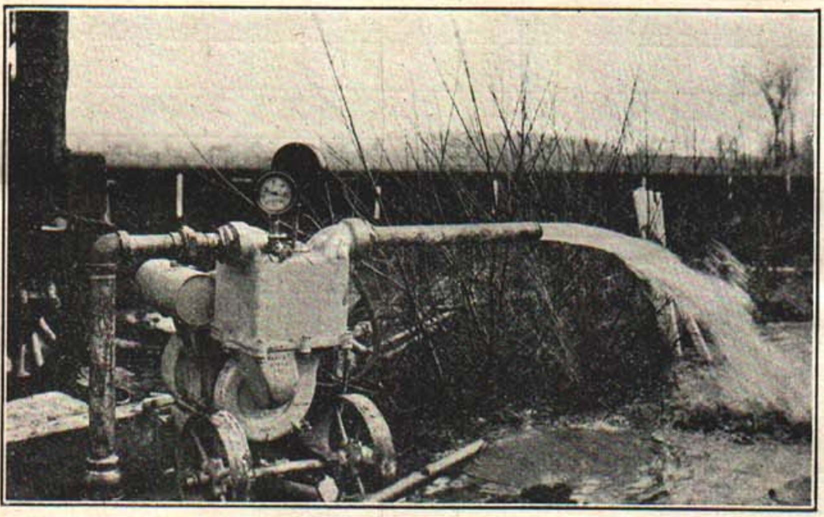

Fig. 14.—A centrifugal pump delivering 120 gallons per minute from a 4-in. well.

suction below the impeller and sufficient pressure above to drive the water through the pipes. It is best to set a centrifugal pump as close to the water as possible—never more than 10 feet above the surface, unless provided with some special priming device. The centrifugal pump is especially adapted for pumping gritty or dirty water from lakes or streams. Manufacturers design these pumps for given capacities when operated at certain speeds and they do not operate satisfactorily except under those conditions. Therefore, the manufacturer should be informed as to the capacity and pressure required and the conditions under which the pump must operate if good results are to be obtained. Centrifugal pumps can be designed for high as well as low pressures; but low pressure pumps, suitable for canvas hose irrigation, are much less expensive and on the whole are satisfactory. The fact that the pipe line can be closed with this type of pump while the pump is running without injury to the equipment is sometimes an advantage.

Fig. 15.—A piston pump operated with an electric motor pumping from 4 shallow wells.

Rotary pumps are not often used to pump irrigation water. Turbine pumps are sometimes used for deep well installations. Pumps vary in their efficiency, depending on their type, size, construction and working conditions, from 25 per cent in some of the smaller and cheaper models to 80 per cent in some of the larger and better ones.

Power

The most common sources of power for pumping are the gasoline engine and the electric motor. Where electricity is available and can be employed without too much additional wiring, the electric motor is very convenient and reliable. A gas engine may be used when the pump must be placed at such a distance from the house that use of electric motor would require considerable line construction and where a drop in voltage would occur.

To determine the horsepower required for a given assemblage of equipment, assuming a pump efficiency of 50 per cent, reference may be made to Table 5. Thus for a 50-gallon per minute delivery and with a 50-foot head (determined as indicated under "pump lift") 1¼ horsepower would be required; for a 100-gallon per minute delivery and with a 100-foot head five horsepower would be required.

Table 5.—Horsepower required for pumping water at 50% pump efficiency.

Gallons per Minute	Total Head in Feet									
	10	20	30	40	50	60	75	100	125	150
10	.05	.10	.15	.20	.25	.30	.37	.50	.62	.75
15	.08	.15	.22	.30	.37	.44	.56	.75	.94	1.12
20	.10	.20	.30	.40	.50	.60	.75	1.00	1.25	1.50
25	.13	.25	.37	.50	.62	.74	.94	1.25	1.56	1.87
30	.15	.30	.45	.60	.75	.90	1.12	1.50	1.87	2.25
35	.18	.35	.52	.70	.87	1.04	1.31	1.75	2.19	2.62
40	.20	.40	.60	.80	1.00	1.20	1.50	2.00	2.50	3.00
45	.23	.45	.67	.90	1.12	1.34	1.69	2.25	2.81	3.37
50	.25	.50	.75	1.00	1.25	1.50	1.87	2.50	3.12	3.75
60	.30	.60	.90	1.20	1.50	1.80	2.25	3.00	3.75	4.50
75	.38	.75	1.12	1.50	1.87	2.24	2.81	3.75	4.69	5.62
90	.45	.90	1.35	1.80	2.25	2.70	3.37	4.50	5.62	6.75
100	.50	1.00	1.50	2.00	2.50	3.00	3.75	5.00	6.25	7.50
125	.63	1.25	1.87	2.50	3.12	3.74	4.69	6.25	7.81	9.37
150	.75	1.50	2.25	3.00	3.75	4.50	5.62	7.50	9.37	11.25
175	.88	1.75	2.62	3.50	4.37	5.24	6.56	8.75	10.94	13.12
200	1.00	2.00	3.00	4.00	5.00	6.00	7.50	10.00	12.50	15.00
250	1.25	2.50	3.75	5.00	6.25	7.50	9.37	12.50	15.72	18.75

Costs

Data that will help determine pumping costs with various heads are given in Table No. 6. For instance, when pumping against a head of 100 feet, an acre inch of water will cost $0.54 for gasoline and oil with gasoline at

Table 6.—Cost of pumping an acre inch of water against various heads with a gasoline engine or electric motor.

Head in Feet	Gas Engine				Electric Motor		
	Gasoline Price per Gallon Cents				Electricity Price per K. W. H. Cents		
	10	12	14	16	2	3	5
20	$0.09	$0.10	$0.12	$0.14	$0.09	$0.14	$0.23
30	.13	.15	.19	.21	.12	.17	.29
40	.19	.22	.25	.30	.18	.27	.45
50	.23	.26	.30	.34	.23	.34	.57
60	.27	.32	.36	.42	.27	.40	.63
70	.31	.38	.43	.50	.32	.48	.79
80	.35	.42	.48	.56	.36	.54	.91
90	.39	.48	.54	.63	.41	.61	1.02
100	.45	.54	.63	.71	.45	.68	1.13
125	.54	.65	.76	.88	.57	.85	1.42
150	.66	.79	.93	1.08	.68	1.02	1.69
175	.77	.92	1.09	1.24	.80	1.20	2.00
200	.88	1.08	1.22	1.42	.90	1.35	2.26

This table is based on normal operating conditions. The cost of pumping may be materially increased by having a power unit too large for the pump, by having equipment out of adjustment or by not having a pump suitable for the job.

$0.12 per gallon. With electricity at $0.03 per k. w. h., it will cost $0.68 if a motor is used. This does not include depreciation or repairs on equipment.

A Practical Problem

In order to familiarize the reader with the method of determining the size of equipment, the following example is given: There are five acres to irrigate. The pump is to be operated 10 hours per day for five days each week. The source of water is a stream 600 feet from the field. The pump can be located on the bank 10 feet above the water. The highest point in the field is 50 feet above the pump. Electricity is not available.

Solution—To cover five acres in five days, one acre must be covered per day. Referring to Table 2, to cover one acre in 10 hours requires a pump capacity of 50 gallons per minute.

The size of piping required, according to Table 3, for 50 gallons per minute and 600 feet in length is two inches. The friction loss in the pipe line is 34 feet. The total head for the pump to operate against is: Suction 10 feet, vertical lift 50 feet, friction loss 34 feet, for operating pressure in hose 30 feet. Total head is 10 plus 50 plus 34 plus 30 equals 124 feet.

Power required according to Table 4 for 50 gallons per minute with 125 foot head is 3.12 h. p. or a four horsepower gas engine would be ample. The probable cost for pumping an acre inch would be according to Table No. 6, $0.65, with gasoline at $0.12 per gallon.

PLANNING YOUR OWN SYSTEM

By filling in the blank below and referring to the tables suggested you will be able to determine the size of pump, piping, etc., necessary for your irrigation needs.

How many acres have you to irrigate? .....

How much do you wish to cover per day of ..... hrs? ..... acres.
(Read page 14.)

What depth of water per application ..... inches?

A pump with a capacity of ..... gals. per min. will be necessary.
(Refer to Table 2, page 15.)

What is the source of water, well, river, lake? .....

Has it sufficient capacity for a pump of the above size? .....

How long a pipe line will be required to deliver the water from the source to the most distant point in the field where the hose line will be attached? ..... ft.

What size of pipe line will be necessary? ..... inch.
(Refer to Table 3, page 17.)

What is the friction head on the ..... ft. of pipe at..... gals. per min. ..... ft.? .....ft.
(Refer to Table 3, page 17.)

What is the vertical distance from the water level to the highest point in the field? .....ft.

What head should be allowed for pressure in hose line? 30 ft.

What will be the total head on the pump? .....ft.
(Add the above three items.)

What h. p. engine or motor will be required for a total lift of .....ft. and ..... gals. per min.?
(Refer to Table 5, page 20.)

With gasoline at ..... gal. or electricity at ..... per k. w. h., what will be the cost of pumping an acre inch?
(Refer to Table 6, page 20.)

How many feet of hose will be necessary?
(Allow approximately 10 ft. of hose per gal. of pump capacity.)

How much 8 oz. hose .....; 10 oz. .....; 12 oz. .....?

How long will it be necessary to leave the hose in each row in order to apply one inch of water? ..... min.
(Refer to Table 4, page 18)

In case you have difficulty in solving your own problem, fill out this sheet with as much information as possible and return to the Agricultural Engineering Department.