IRRIGATION IN KENTUCKY

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Irrigation is not a new practice in Kentucky. Farmers here, as in all states east of the Mississippi River, have long sought for a method of overcoming the ill effects of drouth periods—even those of comparatively short duration, which occur almost every year. For many years, they have felt the need of supplementing natural rainfall by irrigation. Truck farmers have installed permanent overhead sprinkler systems on level land of high productivity with very satisfactory results even though the cost per acre of the installation was much higher than the cost of the portable pipe sprinkler system now becoming popular. Where water is available, or can be made available, sprinkler irrigation may become a very popular and profitable practice.

The practice of irrigation by flooding common in western states is not practical in Kentucky because of the state's rolling topography and the limited supply of water. The development of centrifugal irrigation pumps, lightweight portable pipe with automatic couplers, and rotary sprinklers has made it possible to irrigate rolling land economically.

FREQUENCY OF DROUTH PERIODS

Even though the average annual total rainfall is about 44 inches in the eastern part of the state and 48 inches in the western, its uneven distribution results in dry periods practically every year, retarding plant growth and depressing both the yield and quality of farm crops. During the period 1938-48 there were no great variations from the normal annual precipitation. However, the average number of drouth periods of 14 days or more during which there was no more than 1/4 inch of rainfall in any 24-hour period were as follows:

	Number of drouth periods	
Length of drouth	*Eastern Kentucky*	*Western Kentucky*
14 days or longer	3.8	4.5
21 days or longer	3.0	2.7
28 days or longer	1.0	1.0

Statewide, longer drouth periods of several months' duration, such as those of 1930, 1936, 1943, and 1951-54 are not unusual. Successive drouth years also are not unusual.

Normally the average rainfall per month for the early months of the growing season is considerably greater than for the months at the end of the growing seasons. The average rainfall in western Kentucky for March, April, May and June is 4.40 inches per month. For July, August, September and October it is about 25 percent less, or 3.23 inches. For the eastern part of the state the average rainfall during March, April, May and June is 4.06 inches per month and for July, August, September and October 3.28 inches or about 20 percent less. As a rule, more rainfall is required during the latter part of the growing season because (1) there is a greater percentage of evaporation from the soil during hot weather, (2) a greater amount of moisture is required by spring-seeded plants as they near maturity and are producing seed and (3) a greater amount of forage is required by young animals as they increase in age. Supplemental irrigation is of value in meeting those requirements.

WHAT CROPS TO IRRIGATE

As a general rule, crops of a high cash value per acre, such as vegetables, berries, and tobacco, when grown on productive soil, will give the greatest return from irrigation. The irrigation of pasture harvested by dairy cattle returns greater dividends than that pastured by beef cattle because of the greater per acre value of the marketable product. Up to 1954, farmers have reported supplemental irrigation in Kentucky to be profitable on truck crops including Irish potatoes; also on tobacco, pasture, alfalfa, corn and berries. The irrigation of fall seedings of grain, grasses and legumes guarantees quick germination, and rapid growth, thus reducing the hazard of loss of seed, labor and crop resulting from lack of moisture and guaranteeing an early vegetative cover to protect the soil from leaching and erosion.

Corn

Irrigation of corn has been quite profitable when the crop was planted in fertile soil and, especially, when planted for the production of hybrid seed. The corn plant up to the tasseling stage does not require much moisture, and seldom is it necessary to irrigate until a week before the tassels begin to form. However, the plants should not be permitted to discontinue growth because of the lack of soil moisture. The soil should contain an ample supply of moisture from the beginning of tasseling to the end of silking. Irrigation after that time may result in a slight increase in yield but probably not enough to pay for the cost of irrigation. The labor requirements for moving laterals in tall corn is about twice that for the same operation on low-growing crops, or about 2 man-hours per acre. Where corn is of average height at tasseling time lateral pipe may be moved by two men carrying one or two lengths of pipe held above their heads. In very high corn forked sticks may be required to raise pipe above the top of corn plants.

Alfalfa

Probably little increase in yield will be obtained by irrigating the first cutting of alfalfa in Kentucky. The irrigation of other cuttings may be profitable unless rainfall is normal, provided the soil is not deficient in plant food. In the dry fall seasons of 1952 and 1953 irrigation of alfalfa after the second and third cuttings resulted in good third and fourth cuttings. The results from the irrigation of fall seedings which might otherwise have failed or resulted in poor stands because of the lack of moisture, have been quite pleasing to farmers not only because of increased yields the following year, but because the chances of loss of labor and seed are greatly reduced.

Tobacco

Tobacco is a crop of a high cash value per acre and is usually grown in fertile soil. Therefore, it is one of those crops which has been most profitably irrigated in Kentucky. Authorities on the production of burley tobacco state that "rapid growth, especially in the early part of the growing season, is necessary to produce the thin, smooth, colory grades of burley tobacco now in greatest demand. Some of the finest crops are made in 75 days or less. To secure such rapid growth, the soil must be capable of supplying large amounts of available plant food in a relatively short time."

An adequate supply of soil moisture, as well as that of plant food, is essential to the continuous rapid growth of tobacco or any other crop. Supplemental irrigation therefore eliminates the lack of soil moisture as a factor limiting either the quantity or quality of tobacco produced.

To aid in determining if the irrigation of tobacco is a profitable practice in Kentucky, farmers were asked to report on the

Fig. 1—A typical field of tobacco that has been irrigated. Note the sprinkler in the right center of the picture. Tobacco fields are generally irrigated two or three times with 1 to 1½ inches of water each time. During the three years, 1951-53, irrigation increased the income of tobacco for 69 crops in 25 counties an average of $408.17 an acre.

yields and selling prices of irrigated tobacco grown on their farms in 1951, 1952 and 1953 where fertilization, housing and selling conditions were similar for irrigated and non-irrigated tobacco. The results of these farm tests are given in Table 1.

Much interest has been expressed in records which would indicate the benefits of irrigation during years when monthly rainfall averages more normal.

Table 1.—Results of Farm Tobacco Irrigation Tests*

			IRRIGATED			NON-IRRIGATED		
Year	No. crops	Counties	Av. lb./A.	Av. price	Av. $/A.	Av. lb./A.	Av. price	Av. $/A.
1951	12	8	2081	$61.20	$1273.47	1493	$55.00	$820.35
1952	15	10	1970	54.00	1063.69	1296	49.38	640.00
1953	42	19	1959	55.92	1095.09	1398	51.82	747.31
1951) 1952) 1953)	69	25	2003	57.04	1144.06	1396	52.07	735.89

* Rainfall, during the growing seasons of 1951-52 and 1953 was below normal, and the departure from even distribution in the state as a whole was greater than in a normal year.

In 1953 records were kept in Shelby County on 10 farms, growing an average of 8 acres of tobacco, where the amount of rainfall was considered ideal for the production of tobacco. Rainfall for April, May and June was slightly above normal and only 0.10 inch less than normal for July. Rainfall following July was below normal. Non-irrigated check areas were establishd in each field, and records of yields, selling prices, and cost were calculated by a representative of the Department of Agricultural Economics.

A summary of the results on the 10 farms for 1953 show the average investment in irrigation equipment to have been $2500, with an additional investment of $2000 per farm for the construction of an irrigation reservoir. The amount of water applied by tobacco growers varied from a total of 1.5 to 4.25 inches in one or two applications at periods when it appeared the soil was becoming dry. Yields per acre on the irrigated land were 2,204 pounds and on the non-irrigated land 2,032 pounds. The average selling price was $62.29 per 100 pounds on irrigated land and $58.80 on the non-irrigated.

The total increase in value per acre of the irrigated over the non-irrigated tobacco was $178.03. The average total cost of irrigation based on an investment of $4500 including interest, depreciation, labor, taxes and operating expense was $22.94 per acre, leaving a net increased income per acre of $155.09. The total net increase for the 8 acres was $1240.72 on the investment of $4500. Seemingly this is an adequate return for supplemental irrigation in a season when rainfall was considered ideal for the production of tobacco.

Many farmers did not buy irrigation systems in 1952 until the 1952 drouth was well advanced and, therefore, did not irrigate tobacco until after August 1. The effect of the time of the first irrigation on the average selling price of tobacco is indicated in Table 2.

Table 2.— Effect of Time of First Irrigation on Average Selling Price—1952

No. Crops	*Time of First Irrigation*	*Average Selling Price*
18	Before August 1	$58.20/100 lb.
22	After August 1	$53.44/100 lb.

Pasture

The irrigation of pasture on well fertilized soils has been profitable, especially when the pasture was grazed by dairy cattle because the forage converted into milk has a greater value per acre than the same forage used to produce meat. Contributing factors are the maintenance of legumes in the pasture mixture, an extension of the grazing season in the late fall months, and a more nearly complete ground cover.

A definite schedule for irrigation of pasture should be established and maintained during the season, and the number and frequency of applications will depend on rainfall. If irrigation is limited by lack of water or labor it will be more profitable to apply late applications to fall seedings of grain and legumes than to established pastures. The occasional irrigation of established pastures after they have suffered from a lack of moisture will help prevent further damage, but will probably not increase their carrying capacity to any great extent. Farm experience indicates it is more profitable to irrigate and fertilize a limited area properly than to cover a greater area with an insufficient amount of water and fertilizer.

TRUCK CROPS AND BERRIES

Truck farmers in commercial areas, such as Jefferson County, have been practicing irrigation by sprinkling for many years. Irrigation not only increases yields but the quality of the produce. Present methods of marketing and preserving vegetables by freezing require that truck crops be of high quality, otherwise there is little demand for them.

On July 19, 1954, during the extremely hot and dry period of early summer, radio station WHAS reported that the only tomatoes reaching the Louisville market from local growers were from irrigated plants.

FREQUENCY OF IRRIGATION

In Kentucky, irrigation must be considered a supplement to rainfall. It is a guarantee that crop yield and quality need not be materially reduced by drouth periods. The total precipitation (irrigation plus rainfall) which will be most profitable has not been determined for many farm crops in states east of the Mississippi River. As a rule, crops such as alfalfa require a heavy total application at comparatively long intervals, while shallow-rooted crops require a lighter application at shorter intervals.

All crops should be irrigated before they have suffered from a lack of moisture. Otherwise, they never fully recover in yield or quality. If irrigation is not started in a field requiring several days to irrigate until the lack of moisture is apparent the crop on some portion of the field is likely to be damaged severely before soil moisture is replenished.

It is usually unwise to delay irrigation during hot dry weather in anticipation of rainfall. Even though rain may fall it may be inadequate to supply the soil with moisture to the desired depth, or a high percentage of it may be evaporated into the air. The rain may be intense for a short period of time, resulting in a very shallow penetration, because of a high percentage of runoff.

Some type of soil moisture meter should be available for indicating the amount of moisture in the soil at various depths. A rain gage should be installed on every farm having an irrigation system as a check on the amount of rainfall received as compared with that reported at the nearest weather station. Frequently there is a wide variation between the amount of rainfall on one farm and that of neighboring farms and recording stations.

RATE OF APPLICATION

Most of the soils in Kentucky are classified as having "medium" texture, and when not covered by vegetation they will absorb water applied by a sprinkler system at a rate of from 0.4 to 0.5 inch per hour and will hold about 1.5 inches of water per foot of depth. In lighter soils having more organic matter, such as those found in some river bottoms, the rate of absorption of bare soil may be increased to 0.75 inch per hour and the water-holding capacity decreased slightly. Where heavier-than-average soils exist, such as the Eden clays, the rate of absorption may be as low as 0.25 inch per hour and the water-holding capacity reduced to 1 inch per foot of depth. Soils having an absorption rate of as little as 0.25 inch per hour and poor internal and surface drainage may become water-logged by a combination of rainfall following irrigation. There is little danger that rainfall following irrigation of well drained soils will be injurious to crops during the growing season except possibly in the case of tobacco fertilized with too much nitrogen. Then the tobacco may continue to grow when it should be ripening.

Several different types of soil may be found on the same farm and even in the same field. It is not practical to design or operate an irrigation system for all of these varying conditions. An application rate of 0.3 or 0.4 inch per hour will be satisfactory for most bare soils in Kentucky. The rate of application may be increased for a given pumping condition by increasing the size of nozzles in sprinklers and sprinkler operating pressures, provided some reserve capacity is provided for in the pumping unit.

AMOUNT OF WATER TO APPLY

The amount of water to apply at any one time will vary with the crop to be irrigated, the depth of root system and the amount of moisture in the soil at root depth. The following application at one irrigation is suggested as a general guide for different types of crops:

Mixed grass-legume pasture	1½″-2″
Alfalfa	2″-3″
Vegetables	1″-1½″
Tobacco (First irrigation soon after setting)	¾″-1″
Tobacco	1″-1½″
Root Crops	1″-2″
New seeding of grains, grasses, and legumes	1″

A common practice is to make a heavy application to a deep-rooted crop, such as alfalfa. From 2 to 3 inches will supply the needs for one cutting. Truck farmers apply about one inch to shallow-rooted crops following a week or 10 days during which natural rainfall has not equaled ½ inch.

The feel of the soil taken from the root zone is often used to determine the need of moisture and show when a sufficient amount has been applied. When a sample of soil is crumbly but will not hold together, the amount of moisture is "low." If the soil is crumbly but will hold together, the moisture condition is considered "fair." When the soil forms a ball which will stick together, the moisture condition is considered "good." If the soil forms a ball and is pliable, sticks readily, and clear water comes to the surface when the ball is squeezed, the moisture condition is considered "excellent." Irrigation should begin when the moisture content lowers to "fair" and be discontinued when it reaches "excellent."

EVAPORATION LOSS

Evaporation losses may be as high as 20 percent of the water delivered by sprinklers in very hot, dry weather. Irrigation in the late afternoon or at night reduces these losses. If an exact amount of water is to be applied, the loss from evaporation may be offset by extending the period of operation.

SOURCES OF WATER

Wells, rivers, creeks, artificial lakes, and farm reservoirs are potential sources of water for irrigation. Even though some of the sources may not supply enough water for irrigation during an extended drouth period, they will supply a sufficient amount to supplement rainfall during the average year of unevenly distributed rainfall.

A farmer should make an estimate of the number of acre-inches required for his crop or crops (an acre-inch is the amount of water required to cover an acre to a depth of one inch, or 27,154 gallons) as the preliminary step in planning for a system of irrigation. If reservoirs are to be constructed exclusively for storing irrigation water the cost of the reservoir should be included in the investment for irrigation. On an average, 6 acre-inches will be required for each acre to be irrigated excepting pasture. From 8 to 16 inches may be required for pasture during a very dry year. If the water is stored in reservoirs, at least 2 acre-inches should be stored for each acre-inch used. This allows for evaporation and loss by seepage. If the reservoir is to supply water for livestock, an additional allowance may be made for it. The percentage of the water contained in a large irrigation reservoir that will be consumed by the stock will be very low.

Example: To provide water for irrigating 9 acres of tobacco with four applications of 1 inch each, a total of 36 acre-inches would be required. Twice 36 acre-inches or 72 acre-inches should be stored. A reservoir one acre in area with an average depth of 6 feet (72 inches) would contain 72 acre-inches and supply water for irrigating 9 acres of tobacco with a 50 percent allowance for seepage, evaporation and livestock.

Even though it is possible that rainfall would replenish the supply of water in the reservoir during the growing season, no dependence should be placed in this occurring. In some instances, a reservoir may be refilled from a stream with irrigation pumping equipment. In hilly land, reservoirs built at high elevations may be used to operate sprinklers at lower elevations, by gravity flow. Low pressure-low volume per minute sprinklers may be used. Since no motor power is required to operate sprinklers they can be operated 24 hours per day to maintain a high rate of coverage in acres per day.

In most of the limestone counties of Kentucky, deep or shallow wells do not supply water at a rate sufficient for irrigation purposes. However, along the Ohio river beds and in the counties west of the Tennessee River, wells with a pumping capacity of 50 to 200 gallons per minute or more may be obtained at a depth of from 100 to 200 feet.

A deep-well turbine pump is used to deliver water under pressure from deep wells. In some sections of the Ohio river counties, shallow driven wells have a capacity of about 25 gallons per minute. Where the vertical lift does not exceed 15 feet, several of these wells may be connected at ground level and water delivered by one centrifugal irrigation pump to the distribution lines. Savings in the cost of equipment and of operating expense may be made if sources of irrigation water and areas to be irrigated are not far distant. Farm reservoirs to be constructed can frequently be located near tobacco fields.

COST OF IRRIGATION SYSTEMS

Equipment

The cost of irrigation equipment cannot be accurately stated on the per acre basis except for an individual system and then only after the maximum number of acres of all crops to be irrigated and the cost of the irrigation system with its capacity to cover the required acreage with a given amount of water in a given period of time has been calculated.

The investment in complete irrigation systems has ranged from about $1,000 to as high as $15,000. Several irrigation companies are available for designing irrigation systems and submitting estimates of cost.

In checking costs submitted by various companies, one should compare carefully the following things: the capacity of pump and engine or motor, the number and size of sprinklers, the amount and size of pipe, the proposed spacing of sprinklers and lateral lines, and the rate of application in inches per hour.

Operation

Irrigation is recommended for crops of a high cash value per acre that are grown on fertile soils. Such crops as tobacco, truck crops, hybrid seed corn and berries can doubtless be irrigated profitably even though the amounts of water pumped annually by an irrigation system is not sufficient to keep costs to a minimum.

The Agricultural Economics Department of the College of Agriculture and Home Economics has summarized cost data from farmers who irrigated tobacco and other crops in 1951. Total costs ranged from as low as $1.67 per acre-inch for one farmer who had an investment of $1,863 and pumped 254 acre-inches of water to as high as $34.79 per acre-inch for another who had an investment of $875 but who pumped only 3.6 acre-inches.

A group of 12 farmers had a total cost of from $13.71 down to $1.67 per acre-inch. Probably the majority of farmers will have total costs which fall within the range of this group.

The amount of tobacco required to pay for irrigation is indicated by a group of 12 farmers whose total cost varied from $1.67 per acre-inch to $13.71 per acre-inch. Irrigated tobacco on all test farms sold for $61.20 per 100 pounds in 1951; using this selling price, 2.75 pounds of tobacco was required to offset the cost of an acre-inch of water on the farm having a cost of $1.67 per acre-inch and 22.5 pounds on the farm having the high total cost of $13.71 per acre-inch.

In 1951, no farmer used more than 4.5 acre-inches of water per acre. If it is assumed that the farmers having the highest and lowest costs used 4.5 inches on each acre, the cost range in terms of tobacco sold at the average price of irrigating tobacco in 1951 was from 12.5 pounds to 101 pounds per acre.

The average increase in yield of tobacco resulting from irrigation on test farms in 1951 was 588 pounds per acre.

SELECTING AN IRRIGATION SYSTEM

An irrigation system, to be of maximum service at a minimum of cost and operating expense, should be designed for the conditions under which it is to operate. It should be designed by a person familiar with cropping and soil fertilization practices as well as the engineering principles involved in pumping water in varying quantities to different elevations. The information required for planning an irrigation system may be indicated on a map of the farm drawn to scale. It should show the fields to be irrigated, the crops to be grown, the location and sources of water, with the amount of water available in terms of acre-inches, cubic feet, or gallons in the case of lakes or reservoirs, and in gallons per minute in case of wells, streams, and springs. The elevation in feet of the high and low points of each field above sources of water is needed. Distances may be scaled from the map for preliminary estimates.

If no map is available, the data above should be obtained and shown on a sketch of the farm.

MAJOR ITEMS OF IRRIGATION SYSTEM

The major parts of an irrigation system are the pump, main pipe lines with couplers leading to fields to be irrigated, sprinkler lines, and sprinklers. Parts including Y's, T's, reducers, valves, end plugs and suction hose or pipe are also required. Gages to indicate pressure in pounds per square inch at the pump and at lateral lines are essential where a system is used under different pumping conditions of volume and pressure.

Centrifugal Pump

An irrigation pump is usually a centrifugal pump capable of delivering a large volume of water against high pressure. The capacity in gallons per minute (GPM) varies with the pressure in pounds per square inch (PSI) against which water is to be delivered. That is, the higher the pressure needed the lower

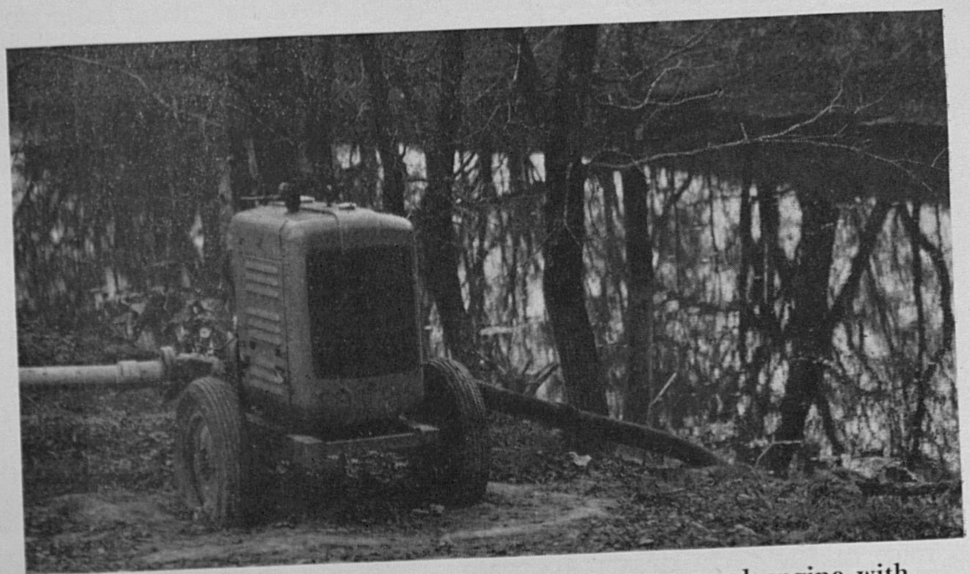

Fig. 2.—An irrigation pump having a direct-connected engine with automatic safety controls.

will be the capacity in GPM. For example, a pump may be rated at 225 GPM at 85 PSI, or at 400 GPM at 40 PSI. A smaller capacity pump may furnish 80 GPM at 75 PSI, or 150 GPM at 40 PSI. The capacity varies with the speed of the pump, which in turn is controlled by the speed of the engine or motor which drives it where the power is connected directly to the pump and also by the size of pulleys in other cases.

The installation of automatic safety controls and priming devices is made simple where gas engines are directly connected to a centrifugal pump. These safety devices stop the engine in case a shortage of oil or water causes overheating and prevents excessive speeds if for any reason water is not available to the pump.

The maximum recommended vertical lift of a centrifugal pump is 15 feet.

Turbine Pumps

Turbine pumps are used in deep wells where the lift from low water level to ground level exceeds 15 or 20 feet. They are usually driven by electric motors. Turbine pumps may be used to advantage where there is a deep well of sufficient capacity in gallons per minute, adequate electric power is available, and the anticipated total net income from irrigation is great enough to justify the investment.

Power

A large majority of irrigation pumps are driven by gasoline engines which are connected directly to the pump. All internal combustion engines as supplied by manufacturers are of such horsepower as to hold up under specified operating conditions at a given speed. If they are operated at a higher speed satisfactory performance over a long period of time should not be expected. The continuous performance load placed on a gasoline engine should not exceed 70 to 80 percent of its maximum rated horsepower.

A deisel engine may be operated more economically than a gasoline engine, but the investment is considerably greater. Where 40 horsepower or more are required to operate a pump and the irrigation system will be operated 350 hours a year or more, a deisel engine may prove a more economical source of power than a gasoline engine.

Tractor power may be available on the farm to drive a pump by belt or power take-off. Unless an extra tractor is available it is best to use a pump with direct connected engine or motor. The farm tractor is frequently needed for farm work at the time irrigation equipment should be in operation. Automobile engines usually have inadequate cooling systems for continuous heavy loads and often do not prove to be a satisfactory source of power.

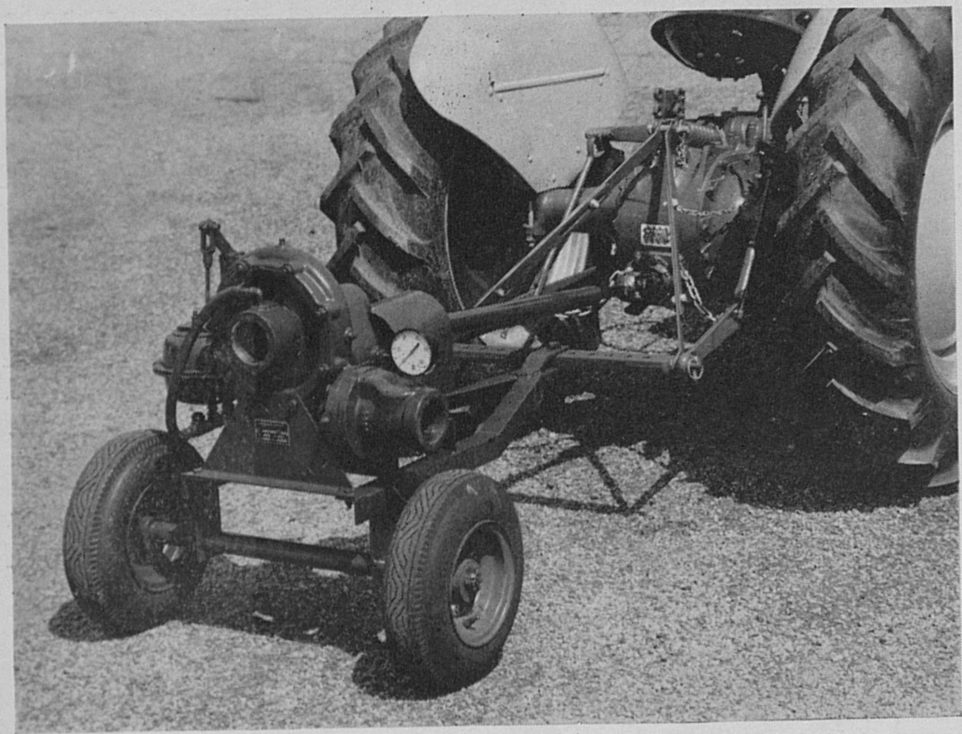

Fig. 3.—Centrifugal pump driven by the power take-off of a tractor.

Electric motors can be used as a source of power to the best advantage where the irrigation system is required to deliver water from only one source and when the load on a pump is nearly constant at all times. If it is necessary to locate the pump at more than one source of supply, the cost of extending electric lines to these sources usually becomes prohibitive. The cost of an electric line must be charged to the investment in equipment. A 5- or 7½-horsepower motor is the largest that is permitted on a single-phase line. Larger motors can be operated from a 3-phase line. Before planning to use electric power one should check carefully on electric rates, power available and the cost of line extensions. Where conditions are satisfactory for the use of electric power, it may be cheaper and more dependable than gas engine power.

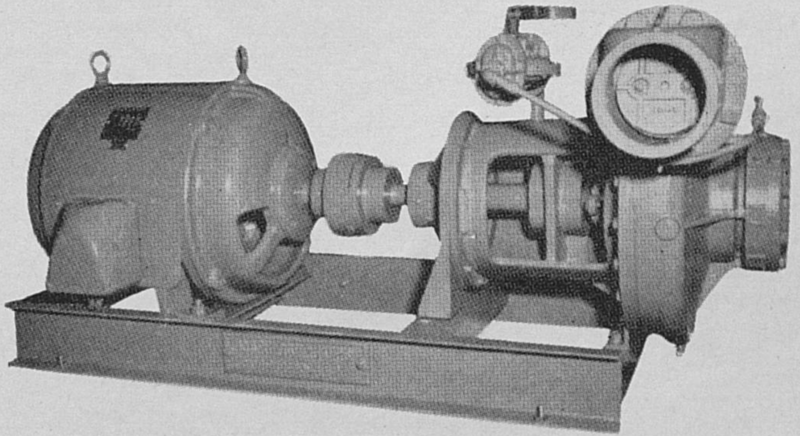

Fig. 4.—A permanently located electric-motor-driven pump may operate most economically if you have low-cost electricity available.

Pipe Sizes

A pipe size must be selected which does not add an excessive amount to the pumping load as a result of friction caused by water passing through the pipe. In small installations, 3-inch or even 2-inch pipe may not add an excessive friction load in short lines, while in others, 6-inch pipe or larger may be required to keep the total friction in long lines from increasing the pumping load excessively. Pipe friction is given in table form, showing friction loss in PSI per 100 feet of pipe for different pipe sizes when the flow in GPM is given. (See page 21.)

In sprinkler or distribution lines attached to a main or delivery line, the amount of water carried in the line is reduced at each sprinkler on the line. Therefore, in many sprinkler lines the size of pipe can be reduced as the distance from the main increases. The total friction loss in a sprinkler line should not exceed 20 percent, or 1/5 of the pressure at which sprinklers are to operate. For the average size sprinklers used in Kentucky with a capacity of from 10 GPM at 30 PSI to those of 20 GPM at 40 PSI the maximum friction loss in a single line would vary from 6 PSI to 8 PSI. An excessive friction loss resulting from the use of too small or too long a line results in poor break up of water or a low output of sprinklers at the end of the line.

Irrigation pipe is usually made of aluminum and is sold either in 20- or 30-foot lengths, with an automatic coupler attached

Fig. 5.— Portable pipe lines with quick couplers are laid on top of the ground.

to each joint. Dealers stock 1½″ and 2″ pipe in 20-foot lengths, while 3″ pipe or larger may be purchased in either 20- or 30-foot lengths. The longer lengths are sold at a lower cost because not so many couplers are required for pipe covering a given distance. The longer lengths are more difficult to move either by hand or truck.

Sprinklers

Rotary sprinklers are designed and sold to meet a variety of conditions. They vary in capacity from a small type which delivers about 3 gallons per minute (GPM) at 20 pounds pressure to a very large type which delivers about 400 GPM at 100 pounds pressure. The type most often selected for all-purpose farm irrigation supplies about 12 GPM at 30 pounds pressure. These sprinklers if placed 40 feet apart on the line and the line is moved 60 feet, would irrigate at the rate of ½ inch per hour. If the spacing were changed to 60 feet with an 80-foot horizontal movement of the line, the rate of application would be ¼ inch per hour.

The capacity of sprinklers can also be changed by changing the size of the nozzles and the pressure at the nozzle.

By changing sprinkler spacing, lateral line movements, size of nozzles, and pumping pressure, an irrigation system can be

Fig. 6.—Sprinklers are usually placed 40 or 60 feet apart and the lines are moved 60 or 80 feet.

designed which will be effective under many different conditions.

The number, size and spacing of sprinklers must be selected that will distribute the water evenly over the field at a rate that will not cause the water to run over the surface of the ground, but which will enable it to be absorbed by the soil as fast as it falls. The water must be broken up into a fine spray so that small seedlings will not be damaged and the surface soil not packed. Too fine a spray resulting from too high a nozzle pressure will result in excessive evaporation. The number of sprinklers is usually determined by the length or width of the field and the spacing between sprinklers, such as 40 feet or 60 feet. The selection and spacing of sprinklers also determines the rate of application. The capacity in gallons per minute of the sprinklers multiplied by the maximum number to be used in the system fixes the required capacity of the pump in GPM.

Vertical Lift

Pressure, measured in pounds per square inch, is required at a pump to deliver water from one level to a higher level. One PSI is required to lift water 2.31 feet. Therefore, the total pressure required to lift water from one level to another is equal to the total lift in feet divided by 2.31. The vertical distance through which water is lifted in Kentucky varies from 15 or 20 feet where bottom land adjacent to a stream is being irrigated to as much as 100 feet or more where fields are located on ridge land. Many irrigation pumps are required to meet these different pumping conditions on the same farm. The system must be designed with sufficient pump capacity and power to fulfill the maximum requirements. Minimum requirements are usually met by decreasing the speed of the pump.

WHAT A FARMER SHOULD KNOW ABOUT DESIGNING HIS IRRIGATION SYSTEM

As previously indicated, a reliable, competent person should be engaged to design an irrigation system, prepare an itemized estimate of the cost and provide a map showing the layout of the system on each field, the rate of application and pressure to be maintained at the pump and on lateral lines and pipe sizes. However, the engineer must depend on information supplied by the farmer as to the kind, location and acreage of crops to be irrigated and the location and sources of present and possible future sources of water. The possible future expansion of the irrigation system should also be considered.

The following suggestions are made in order to help a farmer determine his needs to better advantage and for him to participate to a greater extent in the design of a system to fill his needs.

Water Needed

1. Determine the total amount of water in acre-inches required for supplementing rainfall for all crops that can be profitably irrigated during a dry year on your farm. Experience has indicated that the amount of water per acre required to supplement rainfall for various crops will be about as follows:

Crop	*No. of Irrigations*	*Total Applications, Inches*
Tobacco	3	4-5
Corn	2	3
Alfalfa	2 or 3	4-6
Truck Crops—Shallow-rooted	3	3
Deep-rooted	3	4½
Fall Seedings, Cover Crops, Grain	2	3
Grass Legume Seedings	2	3
Strawberries	3	3
Established Pasture	6-9	10-12

2. Compare the available supply with the amount of water needed. This is especially important where water is to be pumped from reservoirs or from a pool in a stream.

3. If water must be pumped for some distance from the source of supply to a field or fields consider moving the crop to land nearer the source of water or establishing a new source of water (well or irrigation reservoir) nearer the present field.

4. Estimate the number of acres per day that must be covered in a given number of hours of operation including the moving of pipe. This is done so that the entire crop can be irrigated between the time water is first needed and before any damage to the plants has occurred. In most cases not more than 5 or 6 days should be allowed for covering a given field. The time of setting or planting different portions of such crops as corn and tobacco influences the total time that can be allotted for the irrigation of the total acreage.

5. Determine the number of gallons of water per minute that must be delivered to sprinklers in order that the required acreage be covered in a given length of time at the maximum rate of application that will not cause run-off. This step requires a knowledge of the ability of the soil to absorb water, the sprinkler operation and the layout of an irrigation system which will be economical in cost and operation. This information can best be supplied by an irrigation engineer. Performance charts distributed by sprinkler manufacturers supply needed information.

6. Determine the pumping pressure in pounds per square inch required to deliver the required amount of water in gallons per minute to the field most difficult to irrigate. This must be determined by some person having had experience in designing irrigation systems. However, the farmer should know that the total pumping head is determined by the following items: *Figures in parenthesis indicate assumed data for purpose of illustration.

Vertical lift: Feet divided by 2.31 (69 ft. divided by 2.31)	30.0 PSI
Sprinkler pressure: (Sprinklers operated at 40 PSI and supplying 12.5 GPM, spaced 40 ft. apart on the line with line moved 60 ft., rate of application 0.50 inch per hour, 7/32″ nozzle. Two lines of 8 sprinklers each, operating at the same time, require 200 GPM.)	40.0 PSI

* Commercial sprinkler catalogues contain graphs and tables to aid in determining friction loss, rate of application, etc.

Lateral friction: (3″ lateral line; 8 sprinklers; 12.5 GPM; 40 ft. spacing.)	2.0 PSI
Main friction: (200 GPM through 1000 ft. of 4″ pipe) (Friction equal to 1.30 PSI per 100 ft. of pipe)	13.0 PSI
	85.0 PSI
+ 10% friction in valves and fittings	8.5
	93.5

A pump is required which will deliver 200 GPM at 93.5 PSI at continuous service rating.

7. The engineer should supply the farmer with a map showing the location of sources of water, the location of pipe including the main and laterals for each field to be irrigated and the pressures that should be maintained at the pump and on lateral lines. The operating costs can be increased by carrying higher pressures than necessary while insufficient pressures result in inefficient operation and a lower rate of application than contemplated. A farmer may well obtain bids from more than one company. A bill of material with cost figures is not sufficient information on which to determine the best bid. The specifications of the irrigation system together with a bill of material and a map make such comparison possible.

WATER RIGHTS LEGISLATION

Drouths in 1952 and 1953 caused many Kentucky streams to provide insufficient water for irrigation. The 1954 Kentucky General Assembly passed legislation known as H. B. 497 which clears up many legal questions relating to the use of water from public streams. However, a study to be made by the Legislative Research Commission may indicate that revisions or extensions of this act should be made.

The following is a copy of the 1954 legislation as passed by the General Assembly and signed by the Governor:

H. B. 497

AN ACT relating to the conservation, development and use of water resources. Be it enacted by the General Assembly of the Commonwealth of Kentucky:

SECTION 1. The conservation, development and proper use of the water resources of the Commonwealth of Kentucky has become increasingly important as a result of technological advances, agricultural production problems and varied industrial, municipal and recreational uses. Excessive rainfall at certain seasons causes damages from overflowing streams. Prolonged drouths at other seasons curtail industrial, municipal, agricultural and recreational uses of water and threaten the economic well being of the Commonwealth. The advancement of the safety, happiness and the protection of property of the people require that the power inherent in the people be utilized to promote and to regulate the conservation, development and proper use of the water resources. It is hereby declared that the general welfare requires that the water resources of the Commonwealth be put to beneficial use to the fullest extent of which they are capable, and that the waste or non-beneficial use of water be prevented, and that the conservation and beneficial use of water be exercised in the interest of the people. The proper investment of public and private funds to promote the conservation and beneficial use of water resources is recognized as being in the public interest and such investments shall be encouraged.

SECTION 2. Water occurring in any natural stream, natural lake or other natural water body in the Commonwealth which may be applied to any useful and beneficial purpose is hereby declared to be a natural resource and public water of the Commonwealth and subject to control and regulation for the public welfare. Diffused surface water which flows vagrantly over the surface of the ground shall not be regarded as public water, and the owner of the land on which such water falls or flows shall have the right to its use. Water left standing in natural pools in a natural stream when the natural flow of the stream has ceased shall not be regarded as public water and the owners of the land contiguous to that water shall have the right to its use for their purposes.

SECTION 3.

(1) The owner of land contiguous to public water shall at all times have the right to the use of water therefrom in the quantity necessary to satisfy his needs for domestic purposes, which shall include water for household purposes, drinking water for livestock, poultry and domestic animals. The use of water for such domestic purposes shall have priority and be superior to any and all other uses.

(2) The owner of land contiguous to public water shall have the right to such reasonable use of this water for other than domestic purposes as will not deny the use of such water to other owners for domestic purposes, or impair existing uses of other owners heretofore established, or unreasonably interfere with a beneficial use by other owners.

(3) An owner or group of owners of land contiguous to public water shall have the right to impound and conserve such water for their use by impounding such water behind a dam in the natural stream bed or on their land or by pumping such water from the stream or lake to a reservoir when the flow in the stream or the level of the lake is in excess of existing reasonable uses. An obstruction placed across a natural stream shall provide an outlet for the release of water which the owner is not entitled to use under this act, and the owner shall operate the outlet in accordance with this provision.

SECTION 4. The General Assembly recognizes that many specific problems relating to water resources exist. To secure additional information on this subject the Legislative Research Commission is hereby directed to conduct a study of water resources, usage and rights and report its finding to the General Assembly at the 1956 session. All other agencies of the Commonwealth shall cooperate with the Legislative Research Commission in making this study when requested by the Commission to do so.

Lexington, Ky. February, 1955

Cooperative Extension Work in Agriculture and Home Economics: College of Agriculture and Home Economics, University of Kentucky, and the United States Department of Agriculture, cooperating. Frank J. Welch, Director. Issued in furtherance of the Acts of May 8 and June 30, 1914.

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