SPRINKLER IRRIGATION
Costs and Practices
(Willamette Valley, Oregon, 1950)

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Foreword

Irrigated acreage in the Willamette Valley has nearly trebled during the last decade. This large increase has been accompanied by a demand for economic information relating to sprinkler irrigation.

This bulletin contains costs of applying water on 111 farms, lists some of the variations in costs, and suggests ways of lowering costs or increasing the effectiveness of the water applied.

One of the major faults of the existing systems was that they were larger than necessary for the acreage irrigated, with the result that annual overhead costs of interest and depreciation were abnormally high. If the irrigated acreage on these high cost farms is expanded to the capacity of the respective irrigating systems, the overhead costs will be lowered, otherwise the higher costs will continue.

Irrigation in the Willamette Valley has reached the development stage which calls for more attention to good irrigation practices as well as management and design for lowest unit costs.

F. E. Price

Dean and Director

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Introduction

IRRIGATION in the Willamette Valley, Oregon, is relatively new. The acreages under irrigation were first reported in the 1930 Census. At that time the Willamette Valley counties (excluding Clackamas and Multnomah counties) reported 3,385 acres under irrigation. Prior to 1930, most of this land was flood irrigated. During the next decade sprinkler irrigation became more popular and the acreage irrigated increased tremendously throughout the Valley. The 1940 Census shows 24,104 acres under irrigation in this same area. Some of this growth came about through increased acreage under flood irrigation but the majority probably was a result of increased use of sprinklers. Immediately following World War II, with the introduction of lightweight aluminum pipe and other contributing factors, the acreage under sprinkler irrigation continued to rise. The 1950 Census for Oregon listed 70,781 acres under irrigation for this same area. Of this total, 53,987 acres were irrigated by sprinklers. Judging from the number of new sprinkler installations seen throughout the Valley and the amount of pipe and irrigation equipment sold in the area, it is quite probable that these figures are even now considerably out of date.

The question foremost in the minds of many farmers is, "Will sprinkler irrigation pay?" Each farmer must make his own decision on his own farm by weighing the costs against the expected increase in returns. This publication provides average costs which farmers may use as a guide in making their decisions.

Objectives

The objectives of this study were: to determine the cost of applying supplemental water by means of sprinkler irrigation; to determine variations in costs of applying supplemental water; and to appraise or evaluate the present systems that are being used.

Source of data

Information regarding irrigation costs and practices for the year 1950 were obtained from farmers in the Willamette Valley by means of the survey method. Each farm was visited twice by a trained enumerator. During the first visit pressure readings were taken on the sprinkler system and sketches were made of the sprinkler layout. During the second visit, detailed information was obtained regarding crops irrigated, number and frequency of applications, costs of the equipment, and costs of operation.

Selection of sample

The major areas of sprinkler concentration were delineated on a map of the Willamette Valley. Certain points within each area were selected at random. From each of these selected points the enumerator started down the road and stopped at every farm where sprinklers were being used. After four or five records were obtained, the enumerator would move to another of the selected points and start the procedure over again. In this manner a sample of small concentrations of sprinkler systems was obtained within each of the major areas. Information was obtained on each system regardless of size or the crops being irrigated. In some cases the enumerators were unable to interview a selected farmer after two or three visits. When this was the case another record in the immediate vicinity was obtained. Records were obtained only from irrigators who had been using their systems for the entire irrigating season of 1950.

Description of the area

Irrigation may seem out of place in an area that averages about 40 inches of precipitation annually, but the growing season from May through October has an average of only about 9 inches of rainfall. Normally less than 2½ inches of rainfall occur during the three summer months, making the Willamette Valley then as dry or drier than the arid regions where irrigation is considered a necessity. The growing season is long and includes the spring months when rainfall usually is adequate for most crops.

Farm land in the Willamette Valley is composed of more than 30 separate soil series, each containing several soil types. The long growing season and different soil types afford an opportunity to grow a wide variety of crops. Water for irrigation can be developed economically in most areas—either from nearby streams or ponds or from shallow wells. The majority of the land that is irrigated is located in the first and second bottoms along rivers and streams.

The 111 farms included in this study are located in all parts of the Valley with the exception of Multnomah and Clackamas counties in the northeast portion of the Valley.

Description of Farms Included in Study

Several different types of agriculture are represented in the 111 farms in the sample. Farms were classified according to the major source of income (Table 1). Vegetable farms were smallest in acreage, but largest in terms of total productive man work units. (A productive man work unit is the average amount of work accomplished by one man in a day at usual farm tasks and under average conditions.) The average size of farm was 117 acres. The acreage irrigated on the different types of farms was quite comparable, aver-

Table 1. TYPE AND SIZE OF FARMS STUDIED
(Willamette Valley, Oregon, 1950)

Kind of farm[1]	Number of farms	Size of farm	Area sprinkled per farm	Animal units per farm	Productive man work units per farm
		Acres	*Acres*		
Dairy	33	147	31	38	598
Beef and sheep	8	158	40	31	174
Vegetables and specialty crops	53	90	34	3	807
General crop and livestock	17	121	36	14	530
All farms	111	117	34	17	657

[1]Classified by major source of income.

Table 2. LAND USE ON 111 FARMS
(Willamette Valley, Oregon, 1950)

Item	Average per farm	Farms reporting	Average of those reporting
	Acres		*Acres*
Irrigated land			
Pasture	10	61	18
Sweet corn	5	35	16
Mint	5	15	37
Pole beans	3	35	10
Clover	3	18	22
Miscellaneous vegetables	4	40	11
Seed and grain	4	35	13
Total irrigated land	34	111	34
Nonirrigated land			
Total crops	40	87	51
Fallow	3	20	17
Pasture	8	37	24
Total nonirrigated land	51	87	65
Total cropland	85	111	85
Noncrop land			
Woods and wasteland	29	78	41
Farmstead and roads	3	111	3
Total noncrop land	32	111	32
TOTAL LAND IN FARM	117	111	117

aging 34 acres for all farms. Land use is shown in Table 2. More than 40 different irrigated crops were grown on the farms studied and approximately 30 other crops were not irrigated. The classification of the irrigated land is shown in Table 3.

Table 3. SOIL TYPE OF IRRIGATED LAND ON 111 FARMS
(Willamette Valley, Oregon, 1950)

Soil type	Number of farms
Newberg	
Loam	1
Silt loam	14
Silty clay loam	2
Fine sandy loam	6
Chehalis	
Loam	2
Silt loam	21
Clay loam	3
Silty clay loam	13
Fine sandy loam	2
Wapato	
Silt loam	2
Silty clay loam	2
Willamette	
Loam	11
Silt loam	15
Silty clay loam	3
Amity	
Silt loam	5
Silty clay loam	2
Gravelly loams	6
Hill soil	1
TOTAL, ALL SOIL TYPES	111

Description of Irrigation Systems

General

The irrigation systems used in the Willamette Valley varied considerably in size and make-up among the different farms. In the main, the systems are composed of 20- or 40-foot sections of aluminum or lightweight pipe fitted with commercial couplers. Rotating sprinklers are placed on the pipe at intervals depending upon the size and type of sprinkler and the pressure at which the water is delivered. Many of the systems were purchased as complete units from commercial firms while others were assembled piecemeal, i.e., parts of the systems were purchased from different sources and assembled by the farmer. Of the systems studied, 49 were designed by the farmers themselves; 43 by representatives of commercial firms selling sprinkler irrigation equipment; 7 by power company representatives; 4 by some independent agency; and the remaining

8 systems were purchased with the farm and the designer was unknown.

Size of systems

The size of an irrigation system may be expressed in several different ways. Size may be expressed in terms of total acreage irrigated, acreage that is irrigated with one setting of the equipment, or total output of the system in gallons of water per minute. The total acreage irrigated on each farm ranged from 5 acres to 120 acres. The area covered at one setting ranged from less than ½ acre to more than 3 acres with the majority of the systems covering from ½ acre to 2 acres at one setting. Output of water ranged from 24 to 1,100 gallons per minute.

Age of equipment

Six of the systems in this study had been in use for more than 12 years. On the other hand, 16 of the systems were in operation for the first time during 1950. Seventy-three of the systems had been purchased within the past 5 years.

Power

Electricity was the major source of power for pumping. Electricity exclusively was used for pumping on 88 farms; 15 farms used gasoline motors; 3 farms were pumping with tractors as power; and the remaining 5 farms used a combination of electricity and a gasoline motor for their power.

Source of water

Nearly half (53) of the farms were supplied with water from wells; 39 were supplied from flowing streams; 4 from irrigation ditches; 9 from lakes or ponds; and 6 farms were supplied with water from both wells and surface water. Only 13 of the systems had lifts in excess of 20 feet. Pumps, therefore, are mainly of the centrifugal type.

Main line pipe

The kind and size of main line pipe varied considerably according to the type of layout and the acreage being irrigated. Three main types of layout design were used. Thirty-eight of the farmers distributed the main line pipe once during the season and left it there until the irrigating season was over, at which time it was removed from the field and stored for the winter. Twenty-nine of the farms had permanent main line pipe. This type of layout was usually found on pastures, or fields that were being irrigated every year. At the time the sprinkler system was installed the permanent main lines were placed on the ground and have remained in place since that time. Thirty-seven of the farms had portable main lines which were moved from field to field during the year. Some of these were taken up in the fall and stored for the winter. On seven of the farms part of the pipe was permanent and part of it was moved during the season.

Fifty-five of the farms used steel main lines. Thirty-two of the farms had all aluminum main line, and twenty-two had a combination of both steel and aluminum main line pipe. Concrete main line was found on two of the farms. These farms had low-pressure perforated pipe irrigation systems.

Laterals

Nearly all of the systems were composed of portable lateral pipes. Seventy-one of the systems were made up of aluminum pipe which was moved during the season, and nineteen were using steel pipe. The remainder of the systems were made up of different types of pipe of which some were portable and some permanent. On a few farms lateral pipes were permanent. In these instances only the sprinklers were moved. This was not a common practice, however, and was found on only a few of the older systems.

Sprinklers

All but two of the systems in this study used rotating sprinkler heads. The two exceptions were low-pressure perforated pipe systems. Sprinkler sizes range from 2 gallons up to 25 gallons per minute output. The majority of the sprinklers, however, ranged in output from 6 to 12 gallons per minute. Sprinklers usually were placed 40 feet apart on the lateral lines and the lateral lines were spaced at 60-foot intervals on the main line pipe. With this spacing the majority of the systems delivered between 2.5 and 5 inches of water during a 10-hour setting.

Investment in Equipment

The average original purchase price of the irrigation equipment on the farms studied was $116 per acre. The estimated present value of this equipment averaged $81 per acre. The original investment in irrigation equipment ranged from $30 to $504 per acre. The distribution of this investment in the component parts for those systems pumping from both surface and underground water is shown in Table 4.

The cost of the well averaged $335 per farm (about $9 per acre) on those farms pumping from wells. The systems that were

Table 4. DISTRIBUTION OF INVESTMENT IN IRRIGATION EQUIPMENT
(Willamette Valley, Oregon, 1950)

Item	Source of water	
	Underground	Surface
	Per cent	*Per cent*
Well	11	......
Pump and motor	18	18
Power line construction	5	10
Main line pipe	29	37
Lateral pipe	28	26
Sprinklers and risers	6	5
Miscellaneous (fittings, etc.)	3	4
Total investment	100	100

pumping from surface water had a higher average investment in main line pipe than did those systems pumping from wells, making the average investment in equipment approximately the same per acre.

Twenty-nine of the systems studied had some investment for power line construction. With the increase in the area now served by power companies this initial investment can usually be ignored by the prospective irrigator. Most power companies now build the line themselves. The cost of the additional line to service a farm is recovered in the rate charged for the power. Thus the irrigator often pays for the line in the form of higher annual costs for power.

The amount of equipment necessary to irrigate a given piece of land varies considerably with the conditions that exist on the individual farm. Generally speaking, those farms that are irrigated with water from streams or ponds have higher investments for main line pipe. This is true because the source of water is usually located at or near one edge of the field. When the water is supplied by wells, the pump is often located near the center of the area sprinkled. This may result in a considerable saving in main line pipe investment. Less pipe is needed and the smaller size results in a lower investment.

In some instances low investment costs were offset by higher operating costs. For example, if the source of water were located in the center of the field, one could have enough permanent main line to reach both ends of the field or he could have only enough main line pipe to reach one end of the field at a time. Farmers who used permanent main line pipes had a higher average investment than those who used portable main line pipe. In many cases this was offset by lower labor costs during the operating season. Whether or not a farmer chooses to have permanent main lines will depend upon the number of times he has to move the main line pipe during the year, and whether or not labor is available to move it at that time of the year.

Investment costs per acre were usually lower on the larger systems (Table 5). For those systems irrigating less than 15 acres the average original investment was $187 per acre. For those systems that were irrigating more than 45 acres the investment averaged only $68 per acre. For the small systems the average gallons per minute per acre was 14.7, which is more capacity than is usually needed in the Willamette Valley. The middle two groups of systems had adequate capacity in terms of gallons per minute per acre.

Table 5. ORIGINAL INVESTMENT PER ACRE BY ACREAGE IRRIGATED
(Willamette Valley, Oregon, 1950)

Item	Acreage irrigated per farm				All farms
	0 to 14.9 acres	15 to 29.9 acres	30 to 44.9 acres	45 acres or more	
Number of records	29	32	22	28	111
Average acres irrigated	9.3	22.8	33.5	70.5	34.0
Original investment per acre	$187	$108	$96	$68	$116
Capacity of system in gallons per minute per acre	14.7	10.0	9.5	6.1	10.2

The large group (systems covering more than 45 acres) had an average of 6 gallons per minute per acre capacity. A few of these systems were too small for the acreage that was being irrigated. With the large acreage, however, there is some flexibility and if the water requirements of the crops do not all come at exactly the same time, it is possible that the systems could deliver an adequate amount of water.

The original investment in irrigation equipment for comparable acreages was about the same during the past 15 years, even though the general price level has risen considerably. This is probably due to differences in design of the systems and changes in the type of equipment used.

Average Annual Operating Costs

The annual costs of operation shown here and in Table 6 are averages based on the composite use of all the systems on all the crops that were irrigated. Each acre received an average of 18 inches of water during the season at the average rate of slightly less than 3 inches per application. The average length of time that the water ran during each setting was about 7½ hours. The water ran an average of 17 hours each day that irrigation was being carried on. Farmers used their sprinkler systems an average of 53 per cent of the time during the critical month of irrigation on their farms. A total of 277 fields were irrigated on the 111 farms—an average of about 2½ fields per farm.

The average total cost of applying water in 1950 was $1.99 per acre inch (Table 6). Interest and depreciation on the system itself

Table 6. SPRINKLER IRRIGATION COSTS
(Willamette Valley, Oregon, 1950)

Item	Cost per acre inch	Proportion of total
		Per cent
Equipment costs, cash		
Power	$0.47	24
Repairs	0.02	1
Water charge[1]	0.02	1
Equipment costs, noncash		
Depreciation	0.60	30
Interest	0.24	12
Total equipment costs	$1.35	68
Labor costs @ $1 per hour		
Set up system	$0.04	2
Take down system	0.03	2
Move laterals	0.47	24
Move main line and pump	0.05	2
Total labor costs	$0.59	30
Machinery costs	$0.05	2
TOTAL ALL COSTS	$1.99	100

OTHER FACTORS

Number of records	111
Acres irrigated per farm	34
Average acre inches per acre	18.1
Times irrigated	6.5

[1]Only four irrigators purchased water.

amounted to 42 per cent of the total cost. Labor charges were 30 per cent of the total; power charges for pumping, 24 per cent; and charges for repairs, water, and machinery used to move pipes, 4 per cent.

Depreciation and interest

Depreciation costs are based on farmer estimates of how long the system will be in operation. Depreciation was computed by the straight line method. The average expected life for these systems was found to be 16.2 years. The systems averaged a little over 5 years in age. Depreciation costs amounted to 30 per cent of the total—or 60 cents per acre inch. Interest on the investment was computed at 5 per cent of the average investment over the length of life of the irrigation system. This was 12 per cent of the total cost or 24 cents per acre inch.

Labor

All labor was charged at the rate of $1.00 per hour. The labor cost to move pipe during the irrigation season was 59 cents per acre inch. Forty-seven cents of this total labor charge was for moving the lateral lines during the irrigating season. The remaining 12 cents were for setting up the system in the spring, taking it down in the fall, and for moving main lines, pump, and motor where more than one pumping station was used.

Power

Charges for power to pump the water averaged 47 cents per acre inch or about 24 per cent of the total cost.

The cost of power for pumping averaged 1.88 cents per kilowatthour. This ranged from .9 of 1 cent to 5.08 cents per kwhr. This extremely high charge included a minimum annual charge that the irrigator had to pay. The power that was used actually only cost 3.5 cents per kwhr and the remainder of the charge consisted of a minimum payment. On those farms using electricity exclusively an average of 23.05 kwhr of electricity was used for pumping and delivering an acre inch of water and approximately 2.3 acres were irrigated by each horsepower of motor.

Electric power was obtained from five different power companies in the area. Each company operated under a somewhat different schedule of rates. Also each farmer had his own individual rate schedule, depending upon the conditions under which the power was delivered. The amount of line that was built and the demand on the line are factors which determine the cost of power to each individual irrigator.

Miscellaneous charges

Miscellaneous charge for repairs, water, and machinery averaged less than 10 cents per acre inch. Repairs on irrigation systems are usually quite low, and consist primarily of replacing gaskets, sprinkler parts, or pipe couplers. Only four irrigators obtained water from irrigation ditches. For this reason the average water charge as shown in Table 6 is very low. On those farms where water was obtained from irrigation ditches the cost of the water averaged about $6 per acre. Charges for use of machinery for moving pipe are very low. Most of the pipe is moved by hand. Where machinery such as a tractor and trailer or a truck is used to move pipe, it is generally for setting up the system in the spring or taking it down in the fall. In a few cases where the entire system is moved from one field to another, machine equipment is often used.

Variation in Irrigation Costs

The range in annual operating costs was extremely wide—from less than $.50 to more than $7.50 per acre inch. This wide variation is due to a number of factors. Some of these are layout of the system, kind of crops grown, amount of water used, length and frequency of application, and number of crops irrigated. Some of these factors may cause certain elements of cost to be higher while others will be lower. All are interrelated. For this reason variations in each of the major portion of operating costs will be discussed.

Depreciation and interest

Since over 40 per cent of the total irrigation cost was composed of charges for interest and depreciation, irrigation costs were lowest when extensive use was made of the system. By using the system near capacity, the overhead charges of interest and depreciation were spread over a large number of units of water delivered.

On 31 farms where systems were used an average of 23 per cent of the time during one month the operating costs were $3.11 per acre inch. Another group of farms that were using their systems at 50 per cent of the monthly capacity had costs averaging $1.84 per acre inch. The remaining group of farms, all of which used their systems over 70 per cent of the time during the one month period, had operating costs of $1.03 per acre inch (Table 7).

Table 7. Monthly Use of Irrigation Equipment and Costs on 111 Farms
(Willamette Valley, Oregon, 1950)

Item	Per cent of monthly capacity			All systems
	0-34	35-69	Over 70	
Average per cent of monthly use	23	50	91	53
Total cost per acre inch	$3.11	$1.84	$1.03	$1.99
Power cost per acre inch	$0.65	$0.47	$0.28	$0.47
Acres irrigated	23	34	44	34
Total acre inches applied	187	520	901	523
Number of records	31	52	28	111

The power cost per acre inch was also lower on these farms. The averages for the three groups of farms ranged from 28 cents per acre inch to 65 cents per acre inch for power for pumping. This is due to the fact that the rate at which power is charged decreases as additional power is used.

Power

The cost of power for pumping water for irrigating depends upon the total dynamic head, the type of power, the efficiency of the pumping unit and the rate at which the power is charged.

The average total dynamic head for the systems included in this study was 147 feet. This figure is quite typical of the total head for most of the systems in the study. The total head will determine the kind of pump necessary to do the work on each farm. This can be computed for any given circumstance.

The average cost for power was 40 cents per acre inch for the 88 systems that were pumping with electricity exclusively. Power costs averaged 76 cents per acre inch for the 15 systems that were using gasoline motors exclusively. In this study where tractors were used to do the pumping, a flat rate per hour was charged for the use of the tractor. For this reason tractor costs are not comparable to other sources of power since interest and depreciation on the tractor are included in the hourly charge instead of in the equipment charge. Only three farmers in this study were pumping with tractors exclusively.

The difference in cost of electricity delivered to individual irrigators causes some of the variation in pumping charges. Figure

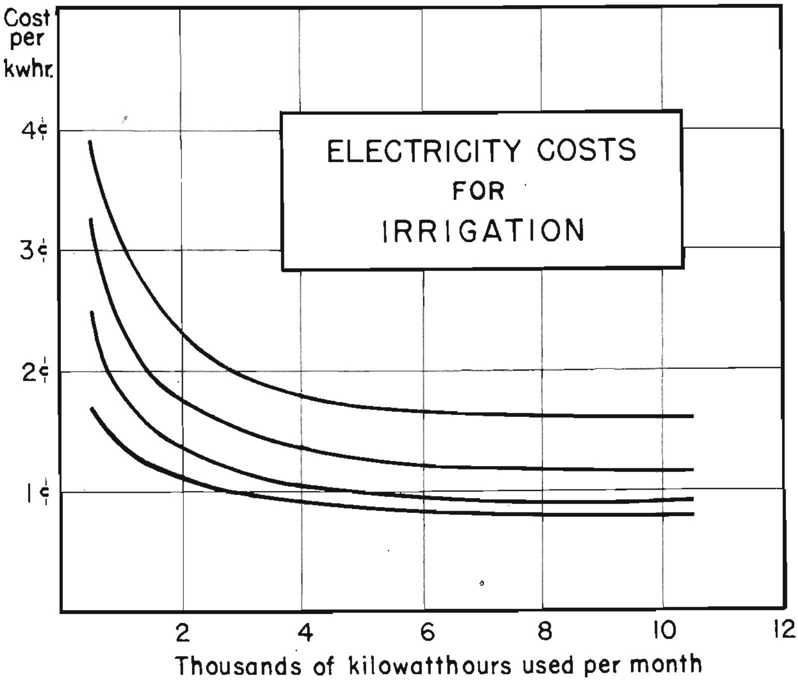

Figure 1. Average costs per kilowatthour of electricity for irrigation from four power companies, monthly rates, for a 15-horsepower motor.

1 shows cost schedules for various quantities of power on 4 different farms. Each farm uses a 15 horsepower motor and purchases power from a different power company. Charges based on cost of electricity as represented on the bottom line would be considerably lower than those based on the top line for any given quantity of power used.

Power costs may vary between irrigators operating under similar power cost schedules. The number of months that the irrigation season lasts also affects the total power cost. For example, (using the rate shown in the bottom line of Figure 1) if 10,000 kwhr of power were used during 1 month the cost would be $105. If this same quantity were used during a 2-month period, the cost would be $120. If this same quantity of power were used over 4 months or at the rate of 2,500 kwhr per month, the total cost for power would be $150. The illustrations are used merely to point out some of the variation in power cost between irrigators. Actually the individual farmer has little control over this. The pattern of use of power will depend upon the crops that are grown. When it is necessary for him to irrigate, he must do so regardless of the fact that he might be able to get his power slightly cheaper if he bunched it up within a given month. Attempting to save money for pumping costs in this manner would be false economy.

Labor

The wide range in labor costs is due to the extent and layout of the irrigation system, the type of soil, and the crop being irrigated. The majority of the labor costs are variable costs in that as the amount of irrigation increases the amount of labor used also increases. Moving the system into the field initially in the spring and taking it down in the fall can be considered a fixed cost. Moving the laterals during the irrigation season would be considered the variable cost.

Those systems that are portable (both the main line and the laterals movable) will have higher labor costs for irrigating than will those of a more permanent nature. This higher labor cost is offset somewhat by the lower investment cost necessary to provide enough equipment to irrigate the whole farm.

Labor costs will be higher on those fields where the crop or the soil make frequent, light applications necessary. Labor costs will be double for those farms that put on 2 inches per application rather than 4 inches. Labor costs for moving lateral pipe averaged about $1 per acre for each move. In other words, for a field that was irrigated five times during the season the labor costs would be $5. For a crop such as pole beans, where the pipes are placed on top of the posts, the labor cost per move is considerably higher than for a crop such as pasture, where the pipes are laid on the ground. Not only is the cost per move greater, but the labor cost per acre inch is usually greater, since fewer inches are applied at each setting. Thus the labor cost per acre inch is affected by the number of irrigations, length of set, type of crop, and type of soil.

Water Use and Application Costs on Selected Crops

Forty-six different field crops in addition to pasture were irrigated on the farms included in this study. Many of these crops were grown on only one or two farms. For this reason the water used on farms covered in this study is shown only for some of the major crops that were irrigated (Table 8). Water application costs

Table 8. SPRINKLER IRRIGATION PRACTICES AND AVERAGE COSTS ON SELECTED CROPS
(Willamette Valley, Oregon, 1950)

Crop	Number of cases	Number of irrigations	Water applied	Cost per acre inch	Investment per acre of crop irrigated
			Inches		
Pasture	58	7.5	26.5	$1.41	$139
Sweet corn	32	2.6	6.3	2.30	57
Pole beans	31	9.6	14.0	3.01	168
Clover	18	1.9	6.5	1.77	35
Grain	15	1.1	3.1	2.06	22
Mint	15	7.2	23.8	1.34	107

were highest for pole beans and lowest for mint. The high cost of irrigating pole beans is due to the higher investment per acre in equipment and to increased labor in moving the pipe. Labor costs were higher because of frequent light applications and more difficulty in moving pipe since the laterals were usually placed on top of poles. The figures shown in Table 8 are averages for the 111 farms in this study.

Irrigation period for selected crops

The normal season for irrigation in the Willamette Valley is from May through September. The actual starting and ending dates vary somewhat with the season, but most of the irrigation is done during this period. In 1950, the year of this study, the annual rainfall reported at Albany, Oregon, exceeded the normal rainfall by more than 16 inches. This excess fell during the winter months. In fact, from May through September the total rainfall was approximately 2 inches less than normal. Rainfall was also less than normal during the month of April, so it is possible that during 1950 some irrigators started slightly earlier than usual.

The irrigation season for pasture, one of the main crops irrigated in the Willamette Valley, usually begins in May or June and extends through September. Irrigations are spaced about an equal number of days apart throughout this entire season. The irrigating season for mint usually includes May, June, July, and part of August, with the heaviest applications in July and early August. Irrigation for pole beans is concentrated in the months of July and August with a smaller amount of irrigating in June and very little in May and September. The irrigations during the first month (May) and last month (September) usually are found only on those fields that were planted extremely early or that grew quite late. July and August are the months during which most of the irrigating is done on sweet corn and carrots. June and July are the months requiring most irrigation for table beets. The clover that is irrigated in the Willamette Valley usually is irrigated only once or twice after the hay crop has been removed. Grain, on the other hand, is usually irrigated once or twice early in the season, that is, in May or June.

The seasonal distribution of irrigation will differ on individual farms depending on the cropping program. The planting time will determine to a certain extent the time of irrigation. Fluctuations in monthly rainfall and temperature may also shift the use of the equipment. If rainfall is extremely light during April and May more irrigating may be done early to help pastures start producing, start early plantings of vegetables, and help along the spring grain.

An Appraisal of Existing Irrigation Systems[1]

The goal of every irrigator is, or should be, to deliver an adequate amount of water equally distributed over the field at the lowest total cost. With this in mind, the 111 systems in this study were judged by the following four criteria: capacity, lateral size, operating pressure, and main line size. Some tolerance from the standards was allowed under certain circumstances.

The total output of the system in terms of gallons per minute should be enough to give a coverage of 6 gallons per minute for each acre being irrigated. Since there is some difference in water requirements for various crops and cropping programs, a range in output of from 4 to 10 gallons per minute per acre was chosen as being the desirable amount. For example: to irrigate 40 acres, the capacity of the system should be at least 240 gallons per minute. $240 \div 40 = 6$ gallons per minute per acre.

[1]This section prepared in collaboration with John W. Wolfe, irrigation engineer, Oregon State College.

The pressure loss between the first and last sprinkler should be less than 20 per cent in order to give even coverage throughout the field.

Pressure was considered as adequate if the sprinklers were operated at or above the following pressures, but not to exceed 50 to 60 pounds per square inch.

6 to 7 gallons per minute—30 pounds per square inch
8 to 10 gallons per minute—35 pounds per square inch
12 to 15 gallons per minute—35 to 40 pounds per square inch

The standard used for judging the size of main line pipe was as follows:

2-inch pipe— 0 to 40 gallons per minute
3-inch pipe— 20 to 100 gallons per minute
4-inch pipe— 70 to 180 gallons per minute
5-inch pipe—130 to 320 gallons per minute
6-inch pipe—250 to 500 gallons per minute
7-inch pipe—400 to 700 gallons per minute

Selection of the proper size of pipe also will be affected by power costs.

By the four standards mentioned (capacity, lateral size, operating pressure, and main line size), 14 of the systems studied were properly designed in all respects. The capacity of these systems was geared to the water requirements of the farm and all the component parts of the system were in the proper combination to give good coverage at minimum costs. Five of the systems were considered to be overdesigned. In other words, they had too much capacity for the amount of land that was being irrigated if the system were used properly. These systems were properly designed in respect to the combination of size of equipment and would be satisfactory for a much larger acreage. Annual operating costs for these systems were too high because of their excess capacity.

Forty-four of the systems studied had excess capacity and the combination of equipment being used was improper. These systems were capable of delivering more water than was needed for the acreage being irrigated. This was not the only fault of this group of systems. Merely expanding the acreage under irrigation would not make them properly designed. In some cases the pipe was the wrong size, operating pressure was not proper, and even distribution of water throughout the field was not being obtained. In some cases changing some part of the system would make the system more efficient. If this were done, the system itself would be more efficient, but it still would not be the proper size for the acreage that was being irrigated.

Thirty-one of the systems had the proper capacity for the acreage being irrigated, but the size and combination of equipment being used was incorrect. While these systems were about the right size for the acreage being irrigated, water was not being evenly distributed at the lowest total cost because of improper selection of the component parts of the system. In some cases pipe sizes were too small—with the result that friction losses were excessive and power costs were higher than normal. In other cases, the coverage was not equal due to improper lateral size and too low operating pressures.

Only 17 of the systems studied were considered to be underdesigned. These systems did not have enough capacity to properly irrigate the present acreage.

Average water application costs were lowest on the 14 farms having properly designed irrigation systems ($1.50 per acre inch). The 44 farms that had irrigation systems which were classified as being too large and of improper design had the highest costs ($2.28 per acre inch). Costs were high on these farms because of the large overhead charge for interest and depreciation on the system. On 31 farms that had systems of the proper capacity, but were poorly designed from the standpoint of the combination of equipment used and poor distribution of water, the average cost was $1.79 per acre inch. The average cost for the 17 systems classified as underdesigned was also $1.79 per acre inch. The average application costs on the last two groups were not excessively high, but the output of these systems was not as effective as it would have been if the systems had been properly designed.

A classification of the systems according to various standards of adequacy follows:

1. *Total output of water.* Forty-five systems had the recommended capacity, 49 had excess capacity, and 17 were too small.

2. *Proper size of main line.* Fifty-one had the recommended size of main line pipe, 43 had main line pipe which was too small, and 17 had main line pipe larger than was necessary.

3. *Operating pressure on the lateral.* Eighty-one systems were found where the operating pressure loss on the laterals was within 20 per cent of the starting pressure. On 30 of the systems the variation was too great for even coverage.

4. *Operating pressure of the system.* Fifty-one of the systems were operating at the recommended pressure. On these systems coverage was equal throughout the entire field. Forty-six of the systems were operating at pressures lower than that prescribed by the manufacturer of the sprinkler. Sixteen of the systems were operated at pressures higher than necessary for even coverage. In these cases, power costs were higher than they need be and in some cases distribution was not equal throughout the field.

Considerable improvement could be made on many of these sprinkler systems without major changes. In some cases total irrigation costs would be lowered if an exchange of equipment could be made readily. In other cases, particularly where there is not enough capacity to cover the acreage, irrigation costs as measured by costs per acre inch of water may increase. In the long run, this change would probably be desirable since a better job of irrigating would be done. Low application costs are not the prime consideration. Rather it is to deliver water at the lowest cost but still do a good job of irrigating.

The relatively high investment and operating costs for sprinkler irrigation justify a considerable amount of planning before the purchase of an irrigation system. After the prospective irrigator has decided to purchase a system, he should determine that a water supply adequate to meet his needs is available. He should then make every effort possible to secure a system that is fitted to the job. The system should be large enough to give adequate coverage to the acreage he intends to irrigate, but should be no larger than necessary since unused capacity is very costly. The component parts of the system should be such that they will provide the most efficient distribution of the water at the lowest possible cost. Technical assistance in designing the system is available from several sources.

The system should then be used on the acreage for which it is designed. If further expansion is desired at a later date, additions should not be made in a haphazard manner. The additional acreage presents a new set of conditions and the whole system should be fitted to them. This should be done if the irrigator is to get the most return from the expenditure of his irrigation dollar.

Summary

The farms studied averaged 117 acres in size, of which 34 acres were irrigated. The majority of the farms (53) received most of their income from vegetables and specialty crops. Other types of farming represented are dairying (33), beef and sheep (8) and general crop and livestock (17). More than forty different crops were irrigated.

Systems in use were mainly of portable design with rotating sprinkler heads. The acreage irrigated ranged from 5 to 120 acres per farm. Seventy-three of the systems had been purchased within the past 5 years. Electricity was the main source of power for pumping. Water was obtained from shallow wells on nearly half of the farms.

The original investment in irrigation equipment on the farms studied averaged $116 per acre and ranged from $30 to $504 per acre. Investment per acre was less for large systems.

The average total cost of applying water by sprinkler irrigation was $1.99 per acre inch. An average of 18 inches of water was applied to the 34 acres in 6.5 applications. The average length of application was 7.5 hours.

The total cost of applying water was made up of the following charges: interest and depreciation, 42 per cent; labor, 30 per cent; power, 24 per cent; miscellaneous charges, 4 per cent.

Operating costs ranged from less than $.50 to over $7.50 per acre inch. This wide variation was due to differences in the following: layout of the system, kind of and number of crops grown, amount of water used, and length and frequency of applications.

On groups of farms where irrigation systems were used at less than 35 per cent, 35 to 70 per cent, and over 70 per cent of monthly capacity, the average costs per acre inch were $3.11, $1.84, and $1.03, respectively. Low costs were found where systems were used at or near capacity. The lower cost was due to less charge per unit of water for interest, depreciation, and power.

Power costs for pumping were lowest on those farms using electricity. An average of 23 kilowatthours of electricity was used to deliver 1 acre inch of water. The average total head for the systems was 147 feet. Power cost ranged from 0.9 of 1 cent to more than 5 cents per kwhr.

Labor costs averaged approximately $1 per acre for each setting of lateral pipe.

The average number of inches applied to the principal crops irrigated was as follows: pasture, 26.5; sweet corn, 6.3; pole beans, 14.0; clover, 6.5; grain, 3.1; and mint, 23.8.

The adequacy of the design of the sprinkler systems was judged by the following four criteria: (1) capacity, (2) operating pressure, (3) lateral size, (4) main line size. By these standards 14 systems were properly designed in all respects. Five were considered overdesigned, i.e., the system itself was well designed, but did not fit the acreage. Forty-four of the systems had excess capacity but failed to meet the other standards. Thirty-one systems had the proper capacity, but the size and combination of equipment used was not correct. Seventeen of the systems were underdesigned.

It is unlikely that irrigation costs on all farms will be identical because of the varying conditions that exist. The costs of applying water, however, could be lowered on many farms without sacrificing the effectiveness of the water applied.

APPENDIX

Farmers' Experience with Sprinkler Irrigation

During the interview farmers were asked questions regarding their experience with sprinkler irrigation. The following is a listing of the answers obtained.

What were your reasons for installing sprinkler irrigation equipment instead of using flood irrigation?

Ninety-seven of the farmers answered that the land was unsuitable for leveling or that leveling costs would be excessive. Eleven farmers installed sprinklers because they felt that with the limited water available they could do a better job. Three farmers felt that there would be some saving of labor during the irrigation season.

Do you feel that wind interferes with the distribution pattern of your water?

Seventy-nine of the farmers felt that wind was not serious enough to interfere with the distribution. Twenty felt that it did distort the pattern slightly, but no remedy was taken to correct the situation. Twelve farmers felt that wind interfered quite seriously with the distribution pattern. When wind was a problem some of the farmers changed the spacing of their lateral pipe slightly to correct for interference from the wind.

Do you experience any run-off on the fields that are being irrigated?

All of the farmers interviewed in this study indicated that they did not consider run-off to be a serious problem.

Do you apply some type of commercial fertilizer through your irrigation system?

Sixty-four of the farmers indicated that at some time during the year they were applying commercial fertilizer through their irrigation system. Two farmers indicated that they were applying insecticides through the system as well.

What are your plans for the near future in regard to your sprinkler irrigation program?

Seventy-five farmers answered that they would continue to operate the systems which they now have on the same acreage. Thirty-two farmers indicated that they were planning to expand their present system and include more acreage for irrigation. Two farmers indicated that they were planning to discontinue irrigating.

One farmer stated he planned to decrease the acreage that was being sprinkled and one farmer planned to cover more acreage with his present system.

Explanation of Terms and Procedure

One acre inch is the amount of water necessary to cover an area equal to 1 acre 1 inch deep.

The following procedure was used in computing costs in Table 5. Detailed information was obtained from each of the irrigators concerning his irrigation program. Each farm was visited while the sprinklers were in operation, and pressure readings on the sprinkler lines were taken. Using these pressure readings, and the other information obtained from the irrigator, the total amount of water delivered during the season was computed. This was done in the following manner:

1. The amount of gallons supplied per minute from each sprinkler was determined from the pressure at which the sprinkler operated and the size of the nozzle openings.

2. This amount of water was then converted to output of water in inches per hour. This was taken from tables based on the spacing of the sprinklers and the output in gallons per minute.

3. The total acre inches per irrigation was computed using the number of hours the sprinklers operated during each irrigation.

4. The number of acre inches applied per acre during the season was then determined from the number of inches per irrigation and the number of irrigations.

5. This was computed for each of the fields irrigated. The acre inches of water used on all fields were then added together and the total output for the system for the season was determined.

Power

Where electricity was used as a source of power for pumping, power consumption was obtained for each farm directly from the power company. The total cost for power was divided by the number of acre inches applied to get the cost of power per acre inch. In some cases, this figure includes a minimum annual charge. Where stationary engines were used as a source of power, cost of fuel and oil for lubrication was included in the cost of power. Where tractors were used as a source of power for pumping, an hourly charge for the use of the tractor was made.

Repairs on the system were charged in the amount that was expended during the year. This item includes such things as new gaskets, couplers, sprinkler nozzles, etc.

Water charge

In those few instances that irrigators were pumping from an irrigation ditch, the annual water charge was included in the total cost. This was usually in the form of a flat fee per acre of land being irrigated.

Depreciation

Depreciation was figured on the straight line basis. Farmer's estimates as to the length of life of the system were used. The original cost was divided by the number of years of expected life. This was done for each component part of the system, since all parts of the system do not have the same expected life.

Interest

Interest was charged at 5 per cent on average investment. For example, a piece of equipment which cost $1,000 and was expected to last 10 years was charged $25 interest annually ($500 × 5 per cent).

Labor

Labor was charged at the rate of $1 per hour. Labor was divided into four operations: (1) setting up the system in the spring, (2) taking down the system in the fall, (3) moving laterals, and (4) moving the main line and the pump.

Machine charges

Charges for the use of machinery were made on a rental basis. These charges were broken down into overhead charges and changing charges. Overhead charges for machinery include the use of machinery for setting up the system initially in the spring and for taking it down in the fall. Machine charges used for changing equipment include charges for machinery used in moving laterals or other parts of the system during the irrigating season.

Per cent of monthly capacity

This term is an expression of the portion of the time that the system was operated during the 1-month period of greatest use during the season. Using a 30-day month, it would be possible to irrigate for 720 hours. If the system were operated or being moved for 360 hours, the system was operating at 50 per cent capacity. If the system were being operated or being moved during all that time, it would be said to operate at 100 per cent capacity. The period of 1 month was chosen rather than the whole season since monthly water requirements vary between crops that are being irrigated in the Willamette Valley.