PNW 290
Reprinted October 1997

MAKING THE MOST OF IRRIGATION

Sizing Irrigation Mainlines and Fittings

W. Trimmer and H. Hansen

When designing or retrofitting an irrigation system, one of the key decisions is picking the proper size pipes and fittings for the system. The best pipe size or fitting is not always the one with the lowest initial cost. The important consideration is the lowest cost of ownership. The objective is to minimize the sum of capital, pumping, maintenance, and energy costs during the life of the system.

Cost categories

In general, costs can be classified under two categories. The first is capital or fixed cost of the pipe and fittings. This cost is determined by the initial installed purchase price of the pipe or fitting and the number of years of service that it is projected to last (usually 20 years). The annual cost of different-sized pipe or fittings is found by amortizing the purchase price, using the interest rate and service life. This amortization is similar to the repayments that are made on a loan. In fact, if all the money to purchase the pipe or fittings is borrowed, the annual cost will be the loan repayment.

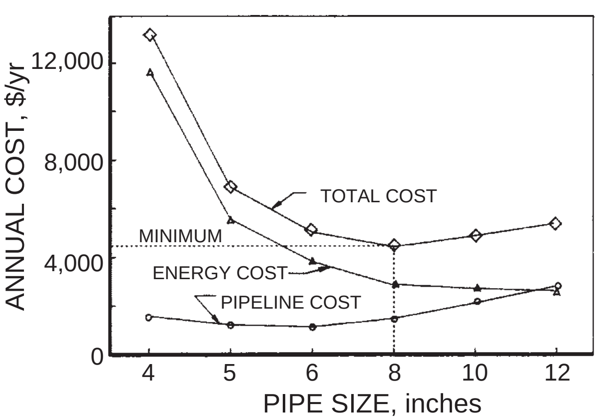

Figure 1.—*Annual irrigation cost as varied by mainline pipe size.*

The second cost category is the operating or variable cost. These costs depend on the number of hours the irrigation system is operated and the expected friction loss in the pipeline and fittings. Smaller pipelines and fittings will have a greater friction loss and, hence, a higher operating cost than larger-diameter pipes and fittings. The total operating cost will depend on the number of hours the system is operated, the total friction loss, and the present and future cost per unit (kWh) of electrical energy. The friction loss depends on pipe size, pipe material, pipe length, and flow rate in gallons per minute.

An economic analysis of a typical system is illustrated in Figure 1. This example assumes the following conditions:

Flow rate (in gallons per minute) = 600
Operating hours per year = 2,500
Pumping plant wire-to-water efficiency = 60%
Cost per kWh for electricity = 4¢[a]
Length of pipeline = 3,000 feet[b]
Minimum sprinkler pressure = 52 psi
Projected life of system = 20 years
Interest = 12%

[a]The cost per kWh for electricity is the average over the entire irrigation season and includes applicable demand charges prorated proportionately over all the kWh used.

[b]Include “equivalent length of pipe” for fittings from Table 3.

Prepared originally for the Bonneville Power Administration by Walter L. Trimmer, former Extension irrigation specialist, and Hugh J. Hansen, Extension agricultural engineer emeritus; Oregon State University.

The 8-inch pipe offers the lowest total annual operating cost. It is obvious that an undersized pipe has very high energy costs. If the pipeline is too small, the fixed costs may be higher than for the next larger pipe size due to the requirement and cost of a larger pump.

Friction losses in pipes

As a general rule of thumb, a water velocity in the pipe of 5 feet per second is the maximum allowable in most circumstances except suction pipes on centrifugal pumps, which should be between 2 and 3 feet per second. Table 1 shows the flow rate for various size pipelines when the velocity is 5 feet per second.

There also are differences between types of pipes. Smooth pipe has less friction loss and, hence, a lower operating cost than rough pipes. Plastic pipe, such as PVC, is the smoothest, followed by aluminum, steel, and concrete, in that order. Therefore, pipeline cost comparisons should be based on total operating costs rather than on only initial installed purchase price.

Table 2 shows some typical friction losses in commonly used pipe; it can be used for estimating operating costs for pipelines and fittings. More precise figures from manufacturers' specifications should be used for design purposes.

Friction losses in valves and fittings

The least cost of operating a system also extends to selecting the proper size valves and fittings. The economic analysis is similar to that of the pipeline.

The friction loss in a fitting can be estimated by a technique called "equivalent length of steel pipe." To do so, the friction loss through the fitting is equated to the friction loss in an equivalent length of straight steel pipe of the same diameter as the fitting. Table 3 provides factors needed to calculate equivalent lengths of several types of fittings and valves. It generally is best to select fittings and valves of the same size as the main pipeline.

Table 1.—*Maximum flow rate in different pipe sizes.*

Pipe size (in.)	2	3	4	5	6	8	10	12	16
Flow rate (gpm)	50	110	200	310	440	780	1,225	1,760	3,140

Table 2.—*Friction losses in feet of head per 100 feet of pipe.*

Pipe size	4-inch			6-inch			8-inch			10-inch			12-inch		
	Steel	Alum.	PVC	Steel	Alum.	PVC	Steel	Alum.	PVC	Steel	Alum.	PVC	Steel	Alum.	PVC
Flow rate (gpm)															
100	1.2	0.9	0.6	—	—	—	—	—	—	—	—				
150	2.5	1.8	1.2	0.3	0.2	0.2	—	—	—	—	—	—			
200	4.3	3.0	2.1	0.6	0.4	0.3	0.1	0.1	0.1	—	—	—	—		
250	6.7	4.8	3.2	0.9	0.6	0.4	0.2	0.1	0.1	0.1	0 1	—	—	—	
300	9.5	6.2	4.3	1.3	0.8	0.6	0.3	0.2	0.1	0.1	0.1	—	—	—	—
400	16.0	10.6	7.2	2.2	1.5	1.0	0.5	0.3	0.2	0.2	0.1	0.1	0.1	—	—
500	24.1	17.1	11.4	3.4	2.4	1.6	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1
750	51.1	36.3	24.1	7.1	5.0	3.4	1.8	1.3	0.8	0.6	0.4	0.3	0.2	0.1	0.1
1,000	87.0	61.8	41.1	12.1	8.6	5.7	3.0	2.1	1.4	1.0	0.7	0.5	0.4	0.3	0.2
1,250	131.4	93.3	62.1	18.3	13.0	8.6	4.5	3.2	2.1	1.5	1.1	0.7	0.6	0.4	0.3
1,500	184.1	130.7	87.0	25.6	18.2	12.1	6.3	4.5	3.0	2.1	1.5	1.0	0.9	0.6	0.4
1,750	244.9	173.9	115.7	34.1	24.2	16.1	8.4	6.0	4.0	2.8	2.0	1.3	1.2	0.9	0.6
2,000	313.4	222.5	148.1	43.6	31.0	20.6	10.8	7.7	5.1	3.6	2.6	1.7	1.5	1.1	0.7

Note: Flow rates below horizontal line for each pipe size exceed the recommended 5-feet-per-second velocity.

Table 3.—*Friction loss in valves and fittings.*	
Fitting	Equivalent length in feet per inch diameter
Angle valve (fully open)	12.0
Butterfly valve	3.3
Gate valve (fully open)	1.1
Globe valve (fully open)	28.0
Foot valve with strainer	6.3
Swing check valve	11.0
Water check valve	12.5
90° elbow	2.5

Example: A 6-inch butterfly valve is to be installed in an 8-inch pipeline. The "equivalent length of steel pipe" for the 6-inch butterfly valve is 3.3 (from table) times 6 (diameter) or 3.3 x 6 = 20 ft of steel pipe.

Estimating fixed costs

A simple method of comparing the fixed costs of two different pipe sizes or two different fittings or valves is to compare the relative total costs of each. The fixed costs can be estimated by multiplying the purchase price of the pipe or fitting by the appropriate factor from Table 4. This gives the annual ownership cost.

Estimating operating costs

The annual operating cost of a fitting or pipeline can be estimated with the following equation:

$$\$ = \frac{gpm \times H \times T \times C}{E \times 5{,}300}$$

where

$\$$ = annual operating cost
gpm = flow rate in gallons per minute
H = head loss in feet
T = number of operating hours per year
C = cost per kWh ($/kWh), including prorated demand charges
E = pumping plant efficiency (decimal)

For example, on the discharge of a centrifugal pump a butterfly valve is to be installed. The flow rate is 1,000 gpm, the pump discharge size is 6-inch, and the steel pipeline size is 10-inch. What size valve is most economical? Calculate the operating costs for each size valve. Assume 12 percent interest, 2,000 hours of operation, 70 percent pumping plant efficiency, and $0.04/kWh energy costs.

Using the equation above, Table 5 can be generated. The lowest operating cost is for the 10-inch valve. A similar analysis can be made for pipe using the cost per 100 feet of pipe.

Table 4.—*Amortization factors for 20-year life equipment.*

Interest rate (%)	8	10	12	14	16
Factor	.1019	.1175	.1339	.1510	.1687

Table 5.—*Total valve operating costs.*

Valve size (inches)	Price	Fixed cost[a]	Eq. l. ft[b]	Friction loss (ft)[c]	Operating cost[d]	Total cost
6	$135	$18	20	2.4	$52	$70
8	180	24	26	0.8	17	41
10	240	32	33	0.3	6	38
12	305	41	40	0.2	4	45

[a]From Table 4. [b]From Table 3. [c]From Table 2. [d]From equation.

Summary

Selecting pipeline sizes and fittings by this method provides the minimum cost for an irrigation system. It should be noted that if a system is not operated a large number of hours per year, smaller-size pipelines and fittings and higher energy costs are somewhat more attractive. Smaller-size pipelines and fittings also are more attractive with higher interest rates. One factor not easily accounted for, however, is that with increasing energy costs, larger-size pipes and fittings will become more economical with time. However, the 5-feet-per-second pipeline velocity rule is applicable over a very wide range of pipeline prices, interest rates, and annual operating hours. This lends a certain amount of assurance that a properly sized pipeline under today's economic conditions will tend to be properly sized even under future economic conditions that may change a great deal.

For more information

To order copies of the following Pacific Northwest Extension publications, send the publication's complete title and series number, along with a check or money order for the amount listed, to:

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration
Corvallis, OR 97331-2119
Fax: 541-737-0817

We offer discounts on orders of 100 or more copies of a single title. Please call 541-737-2513 for price quotes.

You may order up to six no-charge publications without charge. If you request seven or more no-charge publications, include 25 cents for each publication beyond six.

You can access our Educational Materials catalog and many of our publications through our Web page at http://wwwagcomm.ads.orst.edu/

Pumping Plant Efficiencies, PNW 285 (1986). No charge.

Offsets for Stationary Sprinkler Systems, PNW 286 (1986). No charge.

Irrigation Runoff Control Strategies, PNW 287 (1986). No charge.

Irrigation Scheduling, PNW 288 (Reprinted 1994). 50¢

Converting Sprinkler Systems to Lower Pressure, PNW 289 (1986). No charge.

Sizing Irrigation Mainlines and Fittings, PNW 290 (Reprinted 1997). $1.00

Electrical Demand Charges: How to Keep Them Low, PNW 291 (1986). No charge.

Extending Electric Motor Life, PNW 292 (1986). No charge.

Walk-Through Irrigation Systems Analysis, PNW 293 (Reprinted 1997). $1.00

Pacific Northwest Extension publications are jointly produced by the three Pacific Northwest states—Oregon, Washington, and Idaho. Similar crops, climate, and topography create a natural geographic unit that crosses state lines. Since 1949 the PNW program has published more than 450 titles. Joint writing, editing, and production have prevented duplication of effort, broadened the availability of faculty specialists, and substantially reduced the costs for participating states.

Published and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914, by the Oregon State University Extension Service, Washington State University Cooperative Extension, the University of Idaho Cooperative Extension System, and the U.S. Department of Agriculture cooperating

$1.00/$1.00/$1.00