Chapter 7 — Farm Distribution Systems

Contents **NJ652.07**

Tables

NJ652.07 Farm Distribution Systems

(a) Pipeline Delivery System

Pipeline systems are most common in New Jersey. They can be pumped or gravity flow. Generally pumped pressure pipeline is used. Buried pipeline extends from a water source to the farm and to individual fields with surface pipe used for distribution within the field. Buried pipe can also extend into fields as a field main or submain with risers and valves appropriately spaced to deliver water to sprinkler and micro irrigation systems.

A pump is used to provide adequate pressure head to overcome elevation, pipe friction losses and fitting losses and design pressures at the emission points.

Typical use includes:

- Pipe within a pumping plant system that lifts water from source to open ditch or field.
- Conveyance and Distribution System
- Pipelines to contain pressurized flows for use in sprinkler and micro irrigation systems.

Materials are generally welded steel, galvanized steel, aluminum, or plastic.

(b) Open Ditches

Field and farm ditches convey and distribute water from the source of supply (reservoir, canal, or well) to a field(s) within a farm. In New Jersey open ditches and water control structures are used on many cranberry and blueberry operations to maintain high water tables for subsurface irrigation, to flood cranberry bogs during harvest and winter months, and to provide drainage when necessary. Open ditches should be designed on a nearly level grade. Good workable grades are 0.05 - 0.2 foot per 100 feet.

Open ditches can provide good habitat for a variety of wildlife. Well vegetated ditch banks can help prevent soil erosion and at the same time be good habitat for several varieties of upland game birds.

(c) Water Control Structures

Where open ditches are used to deliver water, structures are typically needed to screen and remove trash and debris, settle and remove sediment, measure flow, divide water, control grade for erosion protection, for spill and overflow, head control, ditch checks, pipeline inlets and outlets, and to carry water under farm roads or field access points (culverts).

(d) Water Measurement

Water measurement is essential for equitable distribution of the water supply and for efficient use on the farm. Knowing *how much* water is applied is essential for proper irrigation water management. Flow measurement has other uses; for example, it can indicate when a pump impeller is becoming worn and inefficient, or when well discharge becomes reduced. Flow changes can also indicate clogged screens and filters, or partly closed or plugged valves. Water supply issues in the state of New Jersey may lead to strong recommendations that measuring devices be installed.

To accurately measure water, water measurement devices must be installed according to requirements specific to that device; operated under the conditions for which they are designed; and maintained.

There are various methods and devices each having their own flow equation or calibration process. In New Jersey, generally irrigation pipe flow is measured using flow meters (propeller, impeller). Flow meters are volumetrically calibrated at the factory for various pipe diameters. Accuracy can be within 5 percent of actual if the meter is well maintained and calibrated periodically. It is recommended they be installed downstream of a screen filter to prevent debris or sand particles from damaging the impeller, or causing malfunction. Flow meters require straight run distances (no fittings or bends in pipeline) upstream and downstream, to reduce turbulence and maintain accurate readings.

(e) Irrigation Tailwater Recovery and Reuse

Tailwater recovery and reuse (pumpback) facilities collect irrigation runoff and return it to the same or adjacent fields for irrigation use. Runoff is temporarily stored until sufficient volume has accumulated to optimize application efficiency on each succeeding irrigation.

In New Jersey tailwater recovery is becoming a common practice on container nursery operations using solid set sprinkler systems in hoophouses. Runoff has been calculated to be 70 – 80 percent of the irrigation application. This is due to the amount of open areas (not occupied by containers) that are wetted, the canopy area in the pot that deflects water from getting into the containers, and the large areas of impervious and compacted ground.

Components of tailwater recovery systems on container nursery operations consist of: water conveyance practices such as grassed or stoned lined waterways (which also control erosion), ditches, diversions, and pipelines to convey water to a central collection area (reservoir); a reservoir for water storage; a pump and power unit for recycling back to the hoophouses; a treatment system such as chlorination and filtration or ionization to kill disease spores, bacteria etc.; and pipeline to convey water for redistribution and reuse. Tailwater reuse facilities collect enough water to use as an independent supply or as a supplement to the original supply. Thus they have the most flexibility. The reservoir size depends on whether collected water is handled as an independent supply and, if not, on the rate water is pumped for reuse.

Tailwater reservoirs for hoophouse container operations should be at least 8 – 10 feet deep with side slopes 2:1 or flatter for weed control and soil stability. The reservoir should be sealed with bentonite or a plastic liner to prevent nitrate and chemical leachate into the groundwater. The reservoir should remain nearly full when not in use to help assure a positive hydraulic gradient for reservoir sealing. A sediment trap may be designed at the tailwater inflow.

Sizing for Runoff: As a rule of thumb, the minimum capacity can be designed to handle runoff from at least 1 - 2 irrigation sets (2 – 4 days of irrigation multiplied by the number of hours per day the pump is running). Expected recovery may be 65 – 80% due to seepage, evaporation, overflow, and miscellaneous losses.

As an example: A 10 acre container nursery operation’s primary irrigation water supply is a well with a pumping capacity of 500 gpm. About 80% of the irrigation application runs off the hoophouse acreage, and 70% can be recovered. The irrigation run time is 8 hours, every 2 days (this only completes 5 acres). The pump must run 8 hours every day to meet crop water requirements. It is recommended that 4 irrigation days, (32 hours) are used to calculate runoff and storage capacity needed (Q).

Therefore size reservoir as follows:

Q = 500 gpm x .8 x 60 min/hr x 32 hours x .7

= 537,600 gallons storage capacity

Water quality concerns are associated with tailwater runoff and reuse. Fertilizer, chemicals, and disease pathogens are often present in the tailwater, and therefore the collected water must be treated prior to reuse. Common methods of treatment include gas chlorination (continuous) and ionization processes.

(f) Pumping Plant

The pumping plant selected must be capable of delivering the required capacity at the design operating pressure. Economy of operation is also a primary consideration and must include evaluation of the operation with the power source available. More discussions of pumping plants are contained in Chapter 8 of the NRCS National Engineering Handbook, Section 15 Irrigation. Manufacturer's representatives must also be contacted to assure that the pumping plant selected can perform in accordance with the system requirements.

The function of an irrigation system pumping plant is to perform work to move water in the amount needed and at the pressure required to meet demands of the irrigation system. Every commercially manufactured pump has a known and published relationship between head (pressure) and volume (capacity) produced. This relationship is generally plotted as a curve called the pump characteristic curve or pump performance curve. Multiple curves are used to show characteristics of different impeller diameters and impeller rotation speeds used in the same size and model pump. Pump curves are available from pump dealers, and manufacturers free of charge to designers and pump owners.

A pump operates most satisfactorily under a head and at a speed approximately that for which it was designed. The operating conditions should, therefore, be determined as accurately as possible. If there is a variation in operating head, both the maximum and the minimum should be determined and furnished to the manufacturer to permit selection of the most satisfactory pump.

An understanding of certain terms common to pump irrigation will be of value to both the irrigator and the planner. Knowledge of the terminology as it applies to selection and application of pumping equipment is equally important to the designer and the user. With the use of accurate data, the system planner can make proper selection of pumping equipment and assure the user satisfactory performance of the system.

Head and Pressure

When water is at rest, the pressure at any point in the water is due to the weight of water above the point. The height of water above the point is referred to as "head" and is expressed in feet. "Head" can be converted directly to "pressure', by multiplying "head" by an appropriate constant. To convert "head" in feet to "pressure" in pounds per square inch (psi), multiply "head" by 0.433 (Water weighs 62.4 pounds per cubic feet (pcf), so "head" (in feet) x 62.4 pcf/144 square inches per square foot = 0.433 psi). Conversely, "pressure" in psi can be converted to "head" in feet by multiplying "pressure" by 2.31. Pressures are usually measured directly with a gage.

Dynamic Head

An operating sprinkler system has water flowing through the pipes, thus the head under which the system is operating is dynamic.

Dynamic head is made up of several components, as follows:

1. Static Head - Static head is a vertical distance. It is the distance through which the pump must raise the water. Where the water source is below the pump centerline, the distance from the water surface to the pump centerline is called the static suction lift. If the pump centerline is below the water surface elevation, the distance described is termed the static suction head. Net Positive Suction Head (NPSH) is the elevation water can be raised at sea level by the suction side of the specific pump impeller. Unless the pump is self priming, the pump impeller must first be filled with water. If the allowable NPSH for a specific pump is exceeded, it will lose prime. The height of water which pushes back on the pump is called the static discharge head. It is the vertical distance from the pump centerline to the outlet pipe centerline. The outlet pipe is the pipe from which the water is discharged into the atmosphere and the outlet may be either free-flowing or constricted, such as with a sprinkler head.

   Total Static Head is the sum of the static suction lift and the static discharge head when the pump centerline is located above the water source. If the pump centerline is below the water surface elevation, the static suction head is helping the pump and is subtracted from the static discharge head.

2. Pressure Head - Sprinkler operating pressure converted to head is termed pressure head. The sprinkler converts pressure head to velocity head which carries the water out into its trajectory.

3. Friction Head - The friction caused by water flowing through a pipe decreases pressure in the pipe. The pump must overcome this loss, termed friction head, which is a function of pipe size, type, condition and length, and water velocity. Use Table NJ 6.11 to determine friction head (loss). Similar losses are incurred by water flowing through pipe fittings.

4. Velocity Head - Flowing water represents energy, and work must be done by the pump to impart motion to the water. The work required to impart movement to the water is similar in effect to friction. Velocity head is computed by squaring the velocity and dividing by two times acceleration due to gravity, or

$$Hv = \frac{V^2}{2g}$$

Velocity is measured in feet per second and can be computed from

$$V = \frac{0.408 \times gpm}{D^2}$$

Where:
gpm = discharge in gallons per minute
D = inside diameter of the pipe in inches.
Hv values are small and usually negligible unless large volumes are pumped through small diameter pipes.

5. Total Dynamic Head (T.D.H.)

This is a very important factor in selecting the pumping unit. An accurate estimate is necessary to assure satisfactory pump performance. First calculate the components discussed in the preceding paragraphs and add them together:

Total dynamic head =

total static head + pressure head + friction head + velocity head

<u>Losses in Fittings and Valves</u>

Allowance must be made for friction losses in all elbows, tees, crossings, reducers, increasers, adapters, and valves placed in lateral lines, main lines or submains, and in the suction line. Where deep-well turbine pumps are used, losses in the column must be considered. Pump manufacturers include allowances for losses within the pumps in pump performance data. No additional allowance for pump friction loss is needed.

Losses in fittings and valves are computed by the formula:

$$h_f = K \frac{V^2}{2g}$$

Where:

h_f = friction head loss in feet
K = resistance coefficient for the fitting or valve
$V^2/2g$ = velocity head in feet for a fitting or valve

Values of the resistance coefficient K may be taken from Table NJ 7.1 and values of $V^2/2g$ from Table NJ 7.2.

Variables contributing to the head-capacity relationship include:

- Pump make, model number, and discharge size
- Impeller type, diameter, and speed of rotation
- Number of impellers or pumps operating in series
- Net input energy required (usually expressed in brake horsepower
- Net positive suction head
- Impeller efficiency

Every pump installation has an optimum operating efficiency. The designer should strive to select pump operation at or near that efficiency. It is very unlikely that a used or even new pump at a bargain price can be obtained that fully meets the system needs without first checking the specific Head-Capacity Curve for that specific make, model, and size of pump. **Horsepower alone is an inadequate specification for selecting a pump.** Flow capacity (Q) and Total Dynamic Head (TDH) are required for pump selection.

Detailed examples of pump design are in NEH, Part 623 (Section 15), Chapter 8, Irrigation Pumping Plants, and NEH, Part 624 (Section 16), Chapter 7, Drainage Pumping. In addition pump manufacturers’ catalogs and computer programs have information and design assistance on pump design and pump-head capacity characteristics. The National Irrigation Guide, Chapter 15 gives information on interpreting pump curves, and Chapter 11 has information about cost analysis for irrigation systems.

Example: The following example shows how head is determined for centrifugal pumps. Refer to Figure NJ 7.1 for layout sketch.

Problem: Check total dynamic suction lift and total dynamic head.

A. Compute total dynamic suction lift: FEET

1.	Static suction lift	13.00
2.	Friction head in pipelines:	
	From Table NJ 6.11, 5" aluminum pipe at 500 gpm, loss = 5.04 ft/100 ft.	
	Suction pipe = (25' + 10') = 35' 35' of 5" pipe at 500 gpm = 35' x 0.0504 ft./ft	1.76
3.	Velocity head $V^2/2g$ (Table NJ 7.2)(5" @ 500 gpm)	1.13
4.	Friction head in fittings (use Tables NJ 7.1 and NJ 7.2):	
	5-inch 45° long radius bend ($h_f = K \times V^2/2g$ = 0. 18 x 1.127)	0.21
	Foot valve ($h_f = K \times V^2/2g$ = 0.8 x 1. 127)	0.90
	Strainer ($h = K \times V^2/2g$ = 0.95 x 1.127)	1.07
	Total Suction Lift	18.07

New Jersey is near sea level so this is an acceptable value for suction lift.

B. Compute total dynamic discharge head: FEET

1.	Static discharge head	30.00
2.	Friction head in pipelines (use Table NJ 6.11):	
	400' of 6" pipe at 500 gpm = 400 x .02047	8.19
	300' of 5" pipe at 500 gpm = 300 x .05039	15.12
3.	Friction head in fittings (use Tables NJ 7.1 and NJ 7.2):	

One 5" to 6" increase $K = (1-5^2/6^2)^2 = 0.093$

($h_f = K \times V^2/2g = 0.093 \times 1.127$) 0.11

One 6" standard flanged 900 elbow

($h_f = K \times V^2/2g = 0.28 \times 0.54$) 0.15
One 6” gate valve, open

($h_f = K \times V^2/2g = 0.11 \times 0.54$) 0.06

Five 611 takeoff valves
(same as gate valve open: 0.11 x 0.54 x 5) 0.30

Four 5” takeoff valves
(same as gate valve open: 0.13 x 1.127 x 4) 0.73

One tee, branch flow
($h_f = K \times V^2/2g = 0.65 \times 1.127$) 0.14

One 6” to 5” reducer $K = 0.7(l - 5^2/6^2)^2 = 0.065$
($h_f = K \times V^2/2g = 0.065 \times 1.127$) 0.07

4. Velocity head at end of discharge pipe

(5” pipe at 500 gpm) 1.13

5. Pressure required to operate lateral (50 psi x 2.31’) 115.50

Total Discharge Head 171. 50

T.D.H. = Total dynamic suction lift + total dynamic discharge head - suction velocity head
= 18.07 + 17 1.50 - 1.13 = <u>190.7 feet</u>

The pump selected should be capable of discharging 500 gpm at 191 feet of head.

<u>Pumps</u>

The output work required of the pump is expressed in water horsepower. Water horsepower can be determined by the following equation:

$$\text{Water Horsepower} = \frac{\text{gpm} \times \text{T.D.H}}{3960}$$

Water horsepower is a measure of the output of a pump. However, pumps are not 100% efficient. Pump efficiency depends on the type of pump, bearings, materials, water temperature, and discharge. The pump is connected to the motor through a drive system. Direct drive systems are nearly 100% efficient, but other drive systems are less efficient. Manufacturers of pumps and drive systems provide performance data, including efficiency, for their products.

Power Source
The power source must supply the required water horsepower, plus the losses due to inefficiencies in the pump and drive system. The required output of the power source is called brake horsepower (BHP) and can be computed by the following equation:

$$BHP = \frac{\text{gpm} \times \text{T.D.H.}}{3960 \times \frac{\text{Drive efficiency}}{100} \times \frac{\text{Pump efficiency}}{100}}$$

Example: The system requires 500 gpm at 191 feet total dynamic head. If a direct drive system is used with a centrifugal pump which operates at 73% efficiency, the minimum required brake horsepower would be:

$$BHP = \frac{500 \text{ gpm} \times 191 \text{ ft. T.D.H.}}{3960 \times \frac{100}{100} \times \frac{73}{100}}$$

$$BHP = 33.0$$

The power source must be able to supply the required BHP under field conditions, which may be severe, and under continuous operation. Electric motors are usually rated for continuous operation, but may need to be derated for high temperature (hotter than 95^0F) or high altitude conditions.

Internal combustion engines are often not rated for continuous use. Automotive and lightweight industrial engines are usually rated for "peak" power output, and must be derated substantially (typically 40%) for continuous use. Heavy duty industrial, agricultural and farm tractor engines are usually rated for "intermittent" use, and must also be derated (15 - 20%) for continuous use. Internal combustion engines are more sensitive to altitude and temperature than electric motors, so careful attention must be given to actual field conditions and the manufacturers engine performance recommendations. Power allowance must also be made for engine accessories, such as the water pump, fan, alternator, etc.

Example: For the above example, suppose that a diesel engine will supply the power. The engine is rated for intermittent use at sea level and 60 degree F. Field conditions will be 90 degree F and near sea level (New Jersey). The following power corrections must be made: for continuous operation, 20%; accessories, 5%; temperature (use 1% for each 10 degree F change), 3%. Total correction is 28%:

$$Bhp = \frac{33.0 \text{ bhp}}{1.00 - 28/100} = 45.8 \text{ bhp.}$$

The engine must be rated for at least 46 bhp.

The pump and power source must not be under-sized, because poor performance and unreliability will result. Also, normal wear of the pump and power source will reduce efficiencies. However, over-sizing should also be avoided, because over-sizing increases initial costs, reduces operating efficiencies, and thereby increases costs overall.

Figure NJ 7.1 Typical Centrifugal Pump System

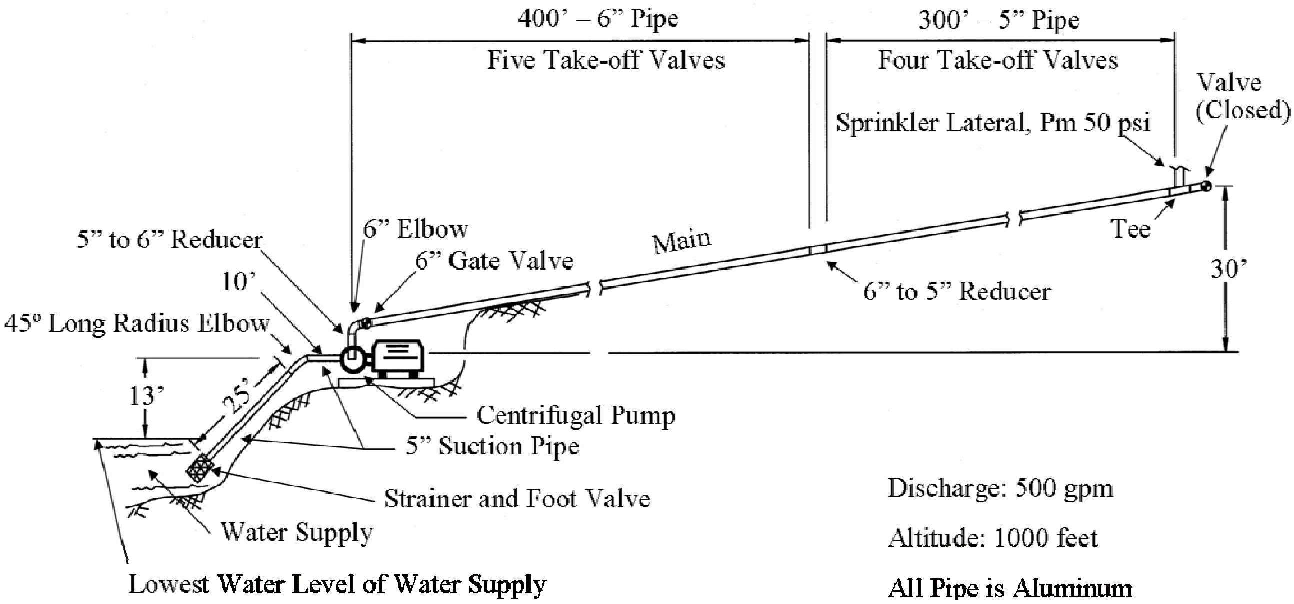

TABLE NJ 7.1 VALUES OF RESISTANCE COEFFICIENT K FOR FITTINGS AND VALVES

Fitting or Valve	Nominal Diameter 3-in	4in	5-in	6-in	7-in	8in	10-in	Source of Authority
				STANDARD PIPE				
Elbows:								
Regular flanged 90^0	0.34	0.31	0.30	0.28	0.27	0.26	0.25	Pipe Friction Manual
Long radius flanged 90^0	0.25	0.22	0.20	0.28	0.17	0.15	0.14	Hydraulic Institute
Long radius flanged 45^0	0.19	0.18	0.18	0.17	0.17	0.17	0.16	Same as above
Regular screwed 90^0	0.80	0.70						Same as above
Long radius screwed 90^0	0.30	0.23						Same as above
Regular screwed 45^0	0.30	0.28						Same as above
Bends:								
Return flanged	0.33	0.30	0.29	0.28	0.27	0.25	0.24	Pipe Friction Manual
Return screwed	0.80	0.70						Hydraulic Institute
Tees:								
Flanged line flow	0.16	0.14	0.13	0.12	0.11	0.10	0.09	Same as above
Flanged branch flow	0.73	0.68	0.65	0.60	0.58	0.56	0.52	Same as above
Screwed line flow	0.90	0.90						Same as above
Screwed branch flow	1.20	1.10						Same as above
Valves:								
Globe flanged	7.0	6.3	6.0	5.8	5.7	5.6	5.5	Same as above
Globe screwed	6.0	5.7						Same as above
Gate flanged	0.21	0.16	0.13	0.11	0.09	0.075	0.06	Same as above
Gate screwed	0.14	0.12						Same as above
Swing check flanged	2.0	2.0	2.0	2.0	2.0	2.0	2.0	Same as above
Swing check screwed	2.1	2.0						Same as above
Angle flanged	2.2	2.1	2.0	2.0	2.0	2.0	2.0	Same as above
Angle screwed	1.3	1.0						Same as above
Foot	0.80	0.80	0.80	0.80	0.80	0.80	0.80	Same as above
Strainers-basket type	1.25	1.05	0.95	0.85	0.80	0.75	0.67	Same as above
				OTHER				
Inlets or entrances:								
Inward projecting	0.78	All diameters						King's Handbook
Sharp cornered	0.50	All diameters						King's Handbook
Slightly rounded	0.23	All diameters						King's Handbook
Bell-mouth	0.04	All diameters						King's Handbook
Sudden enlargements	$K = (1 - d_1^2/d_2^2)^2$ where d_l = diameter of smaller pipe							S.I.A. Handbook
Sudden enlargements	$K = 0.7(1 - d_1^2/d_2^2)^2$ where d_l = diameter of smaller pipe							S.I.A. Handbook

I/ For use in formula $h_f = K V^2/2g$

TABLE NJ 7.2-VALUES OF VELOCITY HEAD $\frac{V^2}{2g}$ FOR ALUMINUM PIPE, IN FEET

Flow (gallons per minute)	3 in (2.914)	4-in (3.906)	5-:in (4.896)	6-in (5.884)	7-in (6.872)	8-in (7.856)	10-inch (9.818)
50	0.090	0.028					
100	0.359	0.111	0.045	0.021			
150	0.809	0.250	0.101	0.049			
200	1.438	0.445	0.180	0.086	0.046		
250	2.246	0.696	0.282	0.135	0.085		
300	3.235	1.002	0.406	0.195	0.105	0.061	
350	4.402	1.364	0.552	0.265	0.142	0.083	
400	5.750	1.781	0.722	0.346	0.186	0.109	0.044
450		2.255	0.913	0.438	0.235	0.138	0.056
500		2.783	1.127	0.540	0.290	0.170	0.070
550		3.368	1.364	0.654	0.351	0.206	0.084
600		4.008	1.623	0.778	0.418	0.245	0.100
650		4.704	1.906	0.913	0.491	0.287	0.118
700		5.455	2.210	1.059	0.569	0.333	0.137
750		6.262	2.537	1.216	0.654	0.383	0.157
800			2.886	1.384	0.744	0.435	0.178
850			3.258	1.562	0.840	0.492	0.201
900			3.653	1.751	0.941	0.551	0.226
950			4.070	1.951	1.049	0.614	0.252
1000			4.510	2.162	1.162	0.680	0.279
1100			5.457	2.616	1.406	0.823	0.337
1200			6.494	3.113	1.673	0.980	0.402
1300				3.654	1.964	1.150	0.471
1400				4.238	2.278	1.333	0.347
1500				4.865	2.615	1.531	0.627
1600				5.535	2.975	1.742	0.714
1700				6.248	3.358	1.966	0.806
1800					3.765	2.204	0.904
1900					4.195	2.456	1.007
2000					4.648	2.722	1.116