PHILIPPINE NATIONAL STANDARD

PNS/BAFS/PAES 224:2017
ICS 65.060.35

Design of a Pressurized Irrigation System – Part B: Drip Irrigation

DEPARTMENT OF AGRICULTURE
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DEPARTMENT OF
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PHILIPPINES

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Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancement of Nutrient and Water Use Efficiency Through Standardization of Engineering Support Systems for Precision Farming" funded by the Philippine Council for Agriculture, Aquaculture and Forestry and Natural Resources Research and Development - Department of Science and Technology (PCAARRD - DOST).

As provided by the Republic Act 10601 also known as the Agricultural and Fisheries Mechanization Law (AFMech Law of 2013), the Bureau of Agriculture and Fisheries Standards (BAFS) is mandated to develop standard specifications and test procedures for agricultural and fisheries machinery and equipment. Consistent with its standards development process, BAFS has endorsed this standard for the approval of the DA Secretary through the Bureau of Agricultural and Fisheries Engineering (BAFE) and to the Bureau of Philippine Standards (BPS) for appropriate numbering and inclusion to the Philippine National Standard (PNS) repository.

This standard has been technically prepared in accordance with BPS Directives Part 3:2003 – Rules for the Structure and Drafting of International Standards.

The word "shall" is used to indicate mandatory requirements to conform to the standard.

The word "should" is used to indicate that among several possibilities one is recommended as particularly suitable without mentioning or excluding others.

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ANNEXES

1 Scope

This standard provides minimum requirements, criteria and procedure for the design of a drip irrigation system.

2 References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this National Standard:

PNS/BAFS/PAES 217:2017 Determination of Irrigation Water Requirements

3 Symbols and Nomenclature

Parameter	Symbol	Unit
Area wetted by one emitter	A_w	m^2
Diameter of wetted area	D	m
Application efficiency	E_a	
Electrical conductivity of irrigation water	EC_w	dS/m or mmhos/cm
Lctual evapotranspiration	ET_a	mm/day
Localized evapotranspiration	$ET_{crop-loc}$	mm/day
Gross irrgifation requirement	IR_g	mm/day
Net irrigation requirement	IR_n	mm/day
Ground cover reduction factor	k_r	
Leaching requirement	LR	mm/day
Leaching requirement ratio under drip irrigation	LR_t	
Electrical conductivity of saturated soil extract that will reduce the crop yield to zero	$maxEC_e$	dS/m or mmhos/cm
Number of emitters per plant	N_p	
Percentage ground cover	P_d	
Percentage wetted area	P_w	%
Emitter discharge	q	L/h
Rainfall	R	mm/day
Emitter Spacing	S_e	m

Distance between the plants within a row	S_p	m
Row Spacing	S_r	m
Duration of irrigation per day	T_a	h
Wetted width	W	m

4 Definitions

For the purpose of this standard, the following terms shall apply:

4.1
drip irrigation
trickle irrigation
involves dripping water onto the soil at very low rates (2-20 L/h) from the emitters where water is applied close to plants so that only part of the soil in which the roots grow is wetted

4.2
emitters
applicator used in drip, subsurface, or bubbler irrigation designed to dissipate pressure and to discharge a small uniform flow or trickle of water at a constant rate that does not vary significantly because of minor differences in pressure

4.3
emitter spacing
spacing between emitters or emission points along a lateral line

4.4
lateral spacing
spacing between irrigation laterals

4.5
leaching
deep percolation of water beyond the root zone of plants, resulting in loss of salts or nutrients

4.6
manifold
portion of the pipe network between the mainline and the laterals

4.7
manufacturer's coefficient of variation
Cv
measure of the variability of discharge of a random sample of a given make, model and size of emitter, as provided by the manufacturer and before any field operations or aging has taken place determined through a discharge test of a sample of 50 emitters under a set pressure at 20^0C

4.8
optimal emitter spacing
drip emitter spacing which is 80% of the wetted diameter estimated from field tests

4.9
wetted widths
width of the strip that would be wetted by a row of emitters spaced at their optimal spacing along a single lateral line

5 Components of Drip Irrigation System

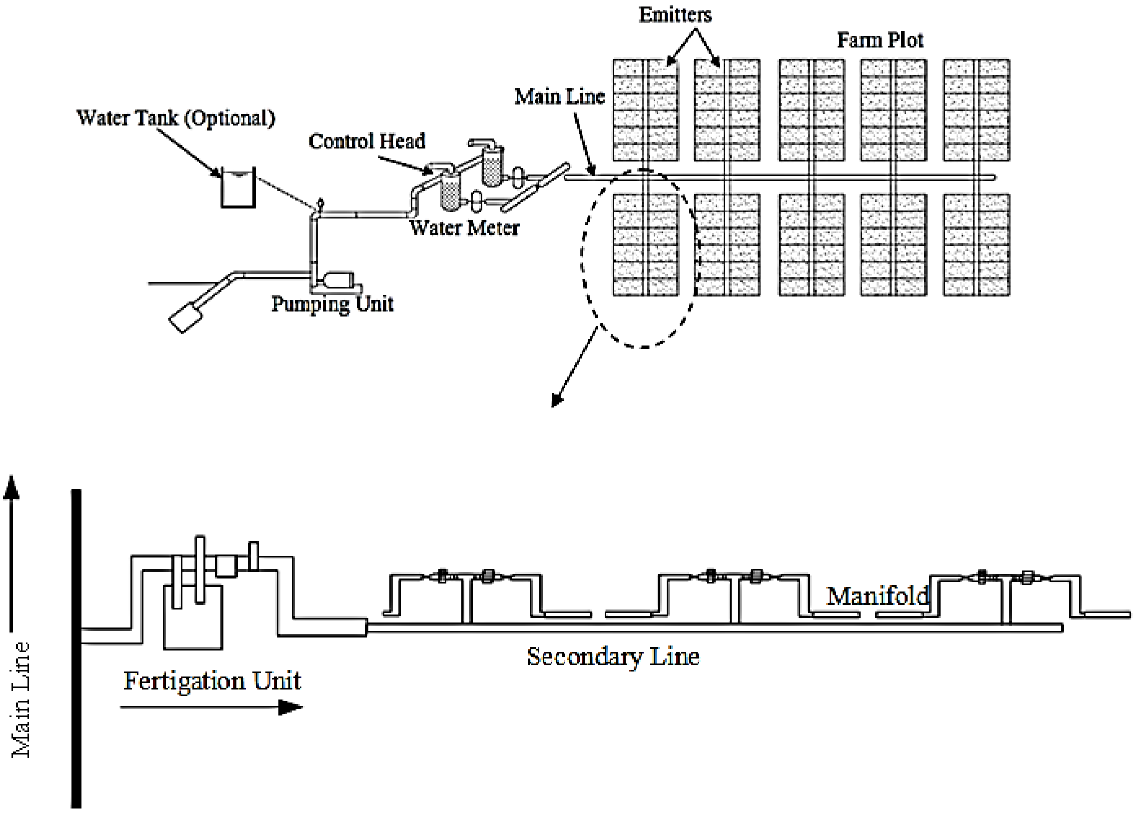

Figure 1. A typical drip irrigation system and its components
SOURCE: Savva and Frenken. FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance. 2002.
* drip irrigation illustration with emitter

5.1 Control head - consists of valves to control the discharge and pressure in the entire system which may have filters and a a fertilizer or nutrient tank.

5.2 Pump unit - takes water from the source and provides the right pressure for delivery into the pipe system

5.3 Main, submain lines and laterals - supply water from the control head into the fields which are usually made from PVC or polyethylene hose and should be buried below ground because they easily degrade when exposed to direct solar radiation

5.4 Manifold – contains filters, pressure regulators, air and/or vacuum relief valves

5.5 Filter – removes particle to prevent emitter clogging where its net diameter is smaller than one-tenth to one-fouth of the emitter opening diameter.

5.6 Emitters – see section 4.2

6 General Design Criteria

6.1 Type of Crop –drip irrigation can be used in high value crops such as row crops (vegetables, soft fruit), tree and vine crops where one or more emitters can be provided for each plant.

6.2 Slope – drip irrigation can be used in any farmable slope where the crop would be planted along contour lines and the water supply pipes (laterals) would be laid along the contour as well.

6.3 Soil Type –drip irrigation may be used for most soils.On clay soils, water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.

6.4 Irrigation Water –irrigation water shall be free of sediments including algae, fertilizer deposits and dissolved chemicals which precipitate such as calcium and iron. Otherwise, filtration of the irrigation water will be needed.

6.5 System Layout and Pipe Network

6.5.1 The pipe network shall be designed to deliver water to the emitters at the appropriate pressure.

6.5.2 The components of the pipe network shall be noncorrosive and non-scaling such as polybutylene, polyethylene, or PVC.

7 Data Requirements

7.1 Topographic map – the topographic map shall include the following details:

- the proposed irrigated area, with contour lines
- farm and field boundaries and water source or sources
- power points, such as electricity lines, in relation to water source and area to be irrigated
- roads andother relevant general features such as obstacles

7.2 Water resources data

- quantity and quality of water resources over time

- water rights
- cost of water if applicable

7.3 Climate of the area and its influence on the water requirements of the selected crop

7.4 Soil characteristics and their compatibility with the crops

8 Design Procedure

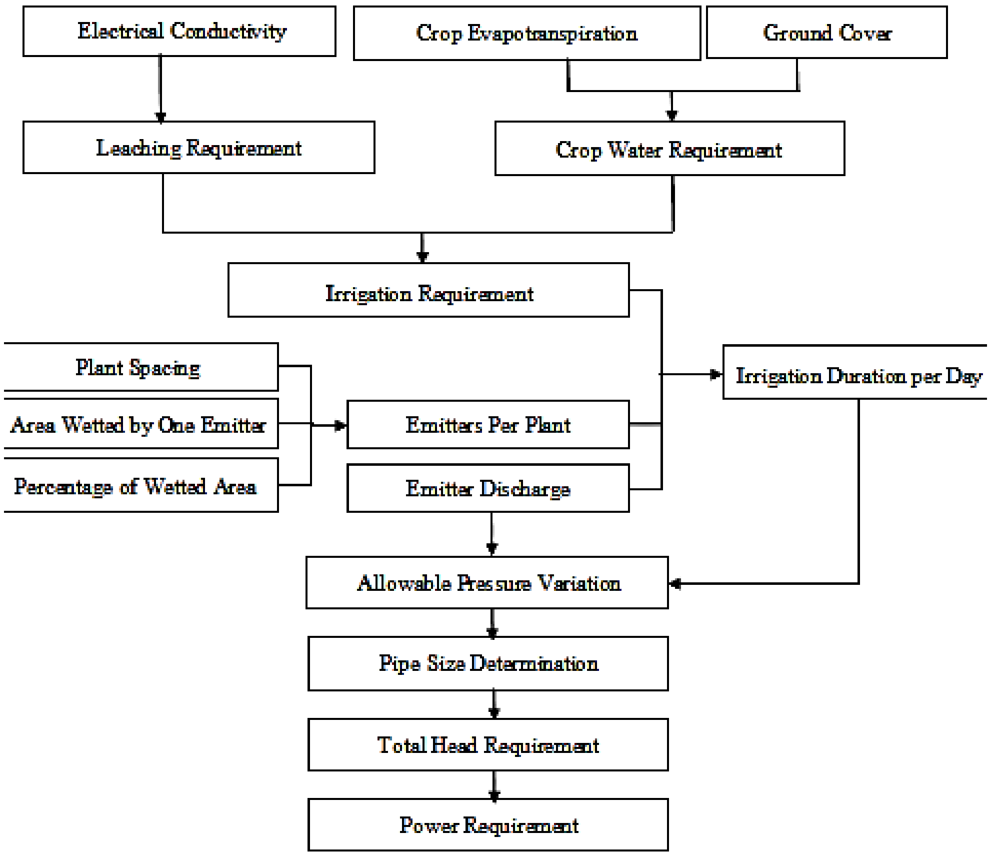

Figure 2. Design Procedure for a Drip Irrigation System

8.1 Crop Water Requirement – The water requirement to be considered shall be the localized evapotranspiration based on the formulae below. This shall be computed on a monthly or decadal basis.

$$ET_{crop-loc} = ET_a \times k_r$$

where:

$ET_{crop-loc}$	is the localized evapotranspiration, mm/day
ET_a	is the actual evapotranspiration, mm/day (estimated as shown in PNS/BAFS/PAES 217:2017 – Determination of Irrigation Water Requirements)
k_r	is the ground cover reduction factor (Table 1)

Table 1. Values of k_r suggested by different authors

Ground Cover (%)	K_r according to		
	Keller and Karmeli	Freeman and Garzoli	Decroix CTG REF
10	0.12	0.10	0.20
20	0.24	0.20	0.30
30	0.35	0.30	0.40
40	0.47	0.40	0.50
50	0.59	0.75	0.60
60	0.70	0.80	0.70
70	0.82	0.85	0.80
80	0.94	0.90	0.90
90	1.00	0.95	1.00
100	1.00	1.00	1.00

SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

Formula by Keller and Bliesner may also be used,

$$ET_{crop-loc} = ET_a \times [0.1(P_d)^{0.5}]$$

where:

$ET_{crop-loc}$	is the localized evapotranspiration, mm/day
ET_a	is the actual evapotranspiration, mm/day (estimated as shown in PNS/BAFS/PAES 217:2017 – Determination of Irrigation Water Requirements)
P_d	is the percentage ground cover

8.2 Leaching Requirements

$$LR_t = \frac{EC_w}{2 \times [maxEC_e]}$$

where:

LR_t	is the leaching requirement ratio under drip irrigation
EC_w	is the electrical conductivity of irrigation water (ds/m or mmhos/cm)
$maxEC_e$	is the electrical conductivity of saturated soil extract that will reduce the crop yield to zero (dS/m or mmhos/cm)

$$IR_n = ET_{crop-loc} - R + LR$$

$$LR = LR_t \times \left[\frac{IR_n}{E_a}\right]$$

where:

LR	is the leaching requirement (mm/day)
LR_t	is the leaching requirement ratio under drip irrigation
IR_n	is the net irrigation requirement (mm/day)
E_a	is the application efficiency (%)

Table 2. Minimum and maximum values of EC_e for various crops

Crop	EC_e (dS/m)		Crop	EC_e (dS/m)	
	Min	Max		Min	Max
Field Crops					
Cotton	7.7	27	Corn	1.7	10
Sugar beet	7.0	24	Flax	1.7	10
Sorghum	6.8	13	Broad bean	1.6	12
Soya bean	5.0	10	Cow pea	1.3	8.5
Sugarcane	1.7	19	Bean	1.0	6.5
Fruit and Nut Crops					
Date palm	4.0	32	Apricot	1.6	6
Fig olive	2.7	14	Grape	1.5	12
Pomegrenate	1.8	14	Almond	1.5	7
Grapefruit	1.7	8	Plum	1.5	7
Orange	1.7	8	Blackberry	1.5	6
Lemon	1.7	8	Boysenberry	1.5	6
Apple, pear	1.7	8	Avocado	1.3	6
Walnut	1.7	8	Raspberry	1.0	5.5
Peach	1.7	6.5	Strawberry	1.0	4
Vegetable Crops					
Zucchini squash	4.7	15	Sweet corn	1.7	10
Beets	4.0	15	Sweet potato	1.5	10.5
Brocolli	2.8	13.5	Pepper	1.5	8.5
Tomato	2.5	12.5	Lettuce	1.3	9
Cucumber	2.5	10	Radish	1.2	9
Cantaloupe	2.2	16	Onion	1.2	7.5
Spinach	2.0	15	Carrot	1.0	8
Cabbage	1.8	12	Turnip	0.9	12
Potato	1.7	10			

SOURCE: Keller and Bliesner, Sprinkle and Trickle Irrigation, 1990

8.3 Irrigation Requirement

$$IR_g = \frac{ET_{crop-loc}}{E_a} - R + LR$$

where:

IR_g	is the gross irrigation requirement (mm/day)
$ET_{crop-loc}$	is the localized evapotranspiration (mm/day)
E_a	is the application efficiency (%)
R	is the rainfall (mm/day)
LR	is the leaching requirement (mm/day)

8.4 Percentage Wetted Area

$$P_w = \frac{100 \times N_p \times S_e \times W}{S_p \times S_r}$$

where:

P_w	is the percentage wetted area (%)
W	is the wetted width or width of wetted strip along lateral with emitters (m)
S_r	is the distance between plant rows or row spacing (m)

8.5 Number of Emitters Per Plant and Emitter Spacing

$$N_p = \frac{Area\ per\ plant\ \times P_w}{A_w}$$

where:

N_p	is the Number of emitters per plant
P_w	is the Percentage wetted area/100 (%/100)
A_w	is the Area wetted by one emitter (m^2)

$$S_e = \frac{S_p}{N_p}$$

where:

S_e	is the emitter spacing (m)
S_p	is the distance between the plants within a row (m)
N_p	is the number of emitters per plant

$$A_w = \frac{\pi \times D^2}{4}$$

where:

A_w	is the area wetted by one emitter (m^2)
D	is the diameter of wetted area (m) (see Table 3)

8.6 Irrigation Frequency and Duration

$$T_a = \frac{IR_g}{N_p \times q}$$

where:

T_a is the duration of irrigation per day (h)
IR_g is the gross irrigation requirement (mm/day)
N_p is the number of emitters per plant
q is the emitter discharge (L/h)

Table 3. Estimated Areas Wetted by a 4 L/h Drip Emitter Operating Under Various Field Conditions

Soil or Root Depth and Soil Texture[1]	Degree of Soil Stratification[2] and Equivalent Wetter Soil Area[3] (Se' x W), m x m		
	homogeneous	stratified	layered[4]
Depth 0.75 m:			
Coarse	0.4 x 0.5	0.6 x 0.8	0.9 x 1.1
Medium	0.7 x 0.9	1.0 x 1.2	1.2 x 1.5
Fine	0.9 x 1.1	1.2 x 1.5	1.5 x 1.8
Depth 1.50 m:			
Coarse	0.6 x 0.8	1.1 x 1.4	1.4 x 1.8
Medium	1.0 x 1.2	1.7 x 2.1	2.2 x 2.7
Fine	1.2 x 1.5	1.6 x 2.0	2.0 x 2.4

NOTE:
1 Coarse – coarse to medium sands; Medium – loamy sand to loam; Fine – sandy clay to loam
to clay (if clays are cracked, treat like coarse to medium soils)
2 Stratified – relatively uniform texture but having some particle orientation or some
compaction layering, which gives higher vertical than horizontal permeability;
Layered – changes in texture with depth as well as particle orientation and moderate
compaction
3 W – long area dimension, equal to the wetted diameter; Se'wetted area dimension = 0.8 x W
4 For soils with extreme layering and compaction that causes extensive stratification, Se' and
W may be as much as twice as large

SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

8.7 Emitter Selection - The following parameters shall be considered in selecting the type of emitter

8.7.1 Types of Emitters – Different types of emitters are shown in Annex A.

8.7.2 Discharge and Pressure Relationship – a lower value of x indicates that the flow will be less affected by pressure variations

$$q = K_d \times H^x$$

where:

q	is the emitter discharge (L/h)
K_d	is the discharge coefficient that characterizes each emitter
H	is the emitter operating pressure head (m)
x	is the emitter discharge exponent

Table 4. Emitter Discharge Exponents for Various Types of Emitter

Emitter Type	x
Fully-compensating emitter	0
Long-path emitter	0.7-0.8
Tortuous-path emitter	0.5-0.7
Orifice type emitter	0.5
Vortex emitter	0.4

SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

8.7.3 Coefficient of Variation

Table 5. Coefficient of Variation for Different Emitter Types

Emitter Type	Cv Range	Classification
Point-source	<0.05	excellent
	0.05 to 0.07	average
	0.07 to 0.11	marginal
	0.11 to 0.15	poor
	>0.15	unacceptable
Line-source	<0.10	good
	0.10 to 0.2	average
	>0.2	marginal to unacceptable
Note: While some literature differentiates between 'point-source' and 'line-source', based on the distance between the emitters, in this Module the difference is based on the material used for the dripline or lateral. The thick wall material is considered as being 'point-source', while the tape type of material is considered as being 'line-source'.		

SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

8.7.4 Temperature and Discharge Relationship – as an emitter is subjected to a higher temperature, discharge increases as well, except for vortex-type emitter

8.7.5 Head and Discharge Relationship Between Two Emitters with the Same Characteristics

$$H_a = H\left[\frac{q_a}{q}\right]^{1/x}$$

where:

q_a	is the average emitter flow rate obtainable under pressure H_a (L/h)
q	is the emitter flow rate obtainable under pressure H (L/h)
x	is the emitter exponent

8.8 Design Emission Uniformity

$$EU = 100 \times \frac{1 - 1.27Cv}{\sqrt{N_p}} \times \frac{q_m}{q_a}$$

where:

EU	is the design emission uniformity (%)
N_p	is the number of emitters per plant
Cv	is the manufacturer's coefficient of variation
q_m	is the minimum emitter discharge for minimum pressure in the sub-unit (L/h)
q_a	is the average or design emitter discharge for the sub-unit (L/h)

8.9 Allowable Pressure Variation

$$\Delta H_s = 2.5 \times (H_a - H_m)$$

$$H_m = H_a \times \left(\frac{q_m}{q_a}\right)^{1/x}$$

where:

ΔH_s	is the allowable pressure variation that will give an EU reasonably close to the desired design value (m)
H_a	is the pressure head that will give the q_a required to satisfy EU (m)
H_m	is the pressure head that will give the required q_m to satisfy EU (m)

8.10 Pipe Size Determination - pipe sizes shall be selected depending on the layout, selected material and number of outlets. These pipes shall not exceed the allowable pressure variation.

8.10.1 Friction Loss in Main Lines – can be determined using Hazen-Williams Equation, Darcy Weisbach or other friction loss formula. The formula given below is based on Hazen Williams

$$H_f = \frac{1.21 \times 10^{10}\, L \left(\frac{Q}{C}\right)^{1.852}}{D^{4.87}}$$

where:

H_f	is the total friction loss in pipe with the same flow throughout (m)
L	is the length of pipe (m)
Q	is the total discharge (L/s)
C	is the pipe roughness coefficient 145 to 150 for plastic pipe 120 for aluminum pipe with couplers and new or coated steel pipe
D	is the inside diameter of pipe (mm)

8.10.2 Friction Loss in Laterals and Manifolds

$$h_f = H_f \times F$$

where:

h_f	is the friction loss in the lateral (m)
H_f	is the total friction loss in pipe with the same flow throughout (m)
F	is the correction factor depending on the number of outlets in the lateral or manifold (Table 6)

Table 6. F factors for various number of outlets

Number of outlets	F	Number of outlets	F
1	1.000	14	0.387
2	0.639	16	0.382
3	0.535	18	0.379
4	0.486	20	0.376
5	0.457	25	0.371
6	0.435	30	0.368
8	0.415	40	0.364
10	0.402	50	0.361
12	0.394	100	0.356

SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

8.11 Total Head Requirement - The total head requirement shall be computed as the sum of the following:

- Suction lift
- Supply line
- Control head
- Mainline
- Manifold
- Laterals
- Operating pressure
- 10% of the sum of the above heads for fittings
- Difference in elevation

8.12 Pump and Power Selection – the pump power requirement shall be computed as follows:

$$P = \frac{Q \times TDH}{360 \times E_p}$$

where:

P	is the power requirement (kW)
Q	is the system capacity (m^3/h)
TDH	is the total dynamic head against which the pump is working (m)
E_p	is the pump efficiency from the pump performance chart

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ANNEX A
(informative)

Types of Emitters

A.1 Based on pressure dissipation mechanism

A.1.1 Long–path – water is routed through a long, narrow passage at laminar flow to reduce the water pressure and to create a more uniform flow; flow areas: 1 mm^2 to 4.5 mm^2.

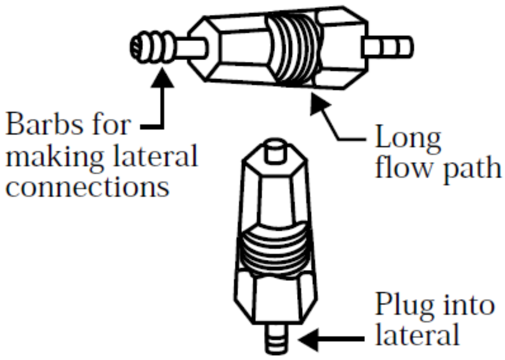

Figure A.1. Long-Path Emitter
SOURCE: NRCS-USDA, Part 652: Irrigation Guide – National Engineering Handbook, 1997

A.1.2 Tortuous – have relatively long flow paths with larger path cross-section with turbulent flow regime

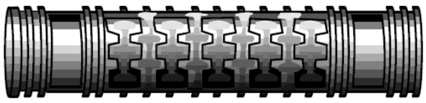

Figure A.2. Tortuous-Path Emitter
SOURCE: NRCS-USDA, Part 652: Irrigation Guide – National Engineering Handbook, 1997

A.1.3 Short-path – almost similar with long-path emitters but with shorter water path; ideal for use in very low pressure systems.

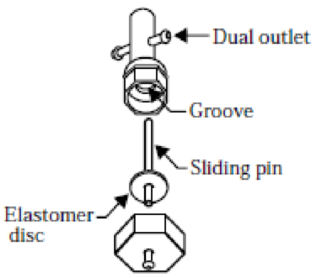

Figure A.3. Short-Path Emitter
SOURCE: NRCS-USDA, Part 652: Irrigation Guide – National Engineering Handbook, 1997

A.1.4 Orifice – the fully turbulent jet emitted at the outlet of the emitter is broken and converted into drop by drop flow; flow area: 0.2 mm^2 to 0.35 mm^2

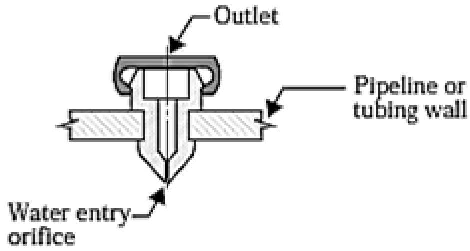

Figure A.4. Orifice Type Emitter
SOURCE: NRCS-USDA, Part 652: Irrigation Guide – National Engineering Handbook, 1997

A.1.5 Vortex – its flow path is a round cell that causes circular flow. The fast rotational motion creates a vortex which results to higher head losses that allow for larger openings

A.2 Based on the ability to flush

A.2.1 On-off flushing – flushes for a few moments each time the system is started and again when turned off

A.2.2 Continuous flushing – eject large particles during operation since this type has relatively large-diameter flexible orifices in series to dissipate pressure

A.3 Based on the connection to the lateral

A.3.1 On-line – intended for direct or indirect installation in the wall of the irrigation lateral

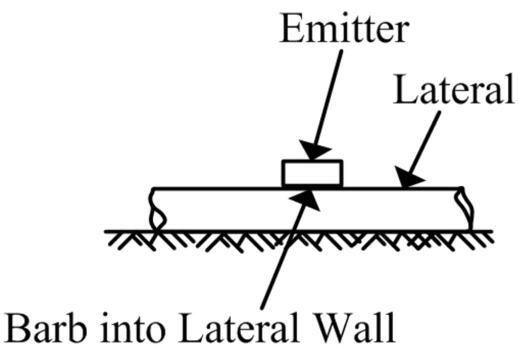

Figure A.5. On-Line Emitter
SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

A.3.2 In-line – intended for installation between laterals

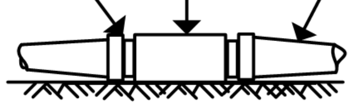

Figure A.6. On-Line Emitter
SOURCE: Savva and Frenken, FAO Irrigation Manual – Localized Irrigation Systems Planning, Design, Operation and Maintenance, 2002

A.4 Based on field application

A.4.1 Line-source – water is discharged from closely spaced perforations, emitters or a porous wall along the lateral line.

A.4.2 Point-source – water is discharged from emission points that are individually and relatively widely spaced, usually over 1 m (3.3ft). Multiple-outlet emitters discharge water at two or more emission points.

ANNEX B
(informative)

Sample Computation

Parameter	Value
Area to be irrigated, A	300 m x 150 m
Soil	Loamy
Crop	Mature Citrus
Actual Evapotranspiration, ET_a	7.1 mm/day
Percentage groundcover	70%
Rainfall	0
Application Efficiency	0.86
Tree spacing, area per plant	6 m x 6 m
Percentage Wetted Area, P_w	50%
Area wetted by one emitter, A_w	4 m^2

B.1 Compute for the crop water requirement.

$ET_{crop-loc} = ET_a \times k_r = 7.1 \times 0.82 = 5.8$ mm/day (Keller and Karmelli)

6.04 mm/day (Freeman and Garzoli)
5.7 mm/day (Decroix CTGREF)
5.9 mm/day (Keller and Bliesner)

$ET_{crop-loc} = ET_a \times [0.1(P_d)^{0.5}] = 7.1 \times [0.1(0.7)^{0.5}] = 5.9$ mm/day

B.2 Compute for the irrigation requirements.

$$IR_n = ET_{crop-loc} - R + LR = 6.0 - 0 + LR = 6.04\frac{mm}{day} + LR$$

$$IR_g = \frac{IR_n}{E_a} = \frac{6.04\frac{mm}{day}+LR}{0.86} = 7.02\frac{mm}{day} + LR$$

B.3 Compute for the leaching requirement.

$$LR_t = \frac{EC_w}{2\times[maxEC_e]} = \frac{2}{2\times[8]} = 0.13$$

$$LR = LR_t \times \left[\frac{IR_n}{E_a}\right] = 0.13 \times [7.02] = 0.91$$

B.4 Compute for the irrigation requirements.

$$IR_n = ET_{crop-loc} - R + LR = 6.0 - 0 + 0.91 = 6.95\frac{mm}{day}$$

$$IR_g = 7.02\frac{mm}{day} + LR = 7.93\frac{mm}{day}$$

B.5 Determine the number of emitters per plant

$$N_p = \frac{\text{Area per plant} \times P_w}{A_w} = \frac{(6 \text{ x } 6) \times 0.5}{4} = 4.5 \text{ or } 5 \text{ emitters}$$

B.6 Determine the emitter spacing.

$$S_e = \frac{S_p}{N_p} = \frac{6}{5} = 1.2 \text{ m}$$

B.7 Check to see if P_w is within the recommended limit.

$$P_w = \frac{100 \times N_p \times S_e \times W}{S_p \times S_r} = \frac{100 \times 5 \times 1.2 \times 2.26}{6 \times 6} = 38\%$$

Lower P_w suggests that one line of emitter is not satisfactory. Because of this, use two emitter lines. For uniformity, add another emitter. Moreover, adjust the wetted width between the laterals, where the spacing between the laterals should not excedd 80% of the wetted width $0.8 \times 2.26 = 1.81$

$$P_w = \frac{100 \times N_p \times S_e \times W}{S_p \times S_r} = \frac{100 \times 6 \times 1.2 \times 1.81}{6 \times 6} = 60\%$$

B.8 Compute for the irrigation frequency and duration. Choose from the options below for the operation.

$$IR_g = 7.03 \frac{\text{mm}}{\text{day}} \times 6\text{m} \times 6\text{m} = \frac{0.285 \frac{\text{m}^3}{\text{tree}}}{\text{day}} = \frac{285\text{L}}{\text{tree}} /\text{day}$$

$$T_a = \frac{IR_g}{N_p \times q} = \frac{285}{6 \times 8} = 5.94 \frac{\text{h}}{\text{day}} \text{ for 8 L/h drippers}$$

T_a = 7.92 h/day for 6 L/h dripper
T_a = 11.88 h/day for 4 L/h dripper

B.8.1 6 L/h dripper with 2 sub-units operating for 15.8 h/day
B.8.2 8 L/h dripper with 3 sub-units operating for 17.8 h/day, as long as no runoff occurs
B.8.3 4 L/h dripper with increased discharge by sligtly increasing the pressure such that T_a=11 h/day, q = 4.32 L/h operating for 22 h/day

B.9 Select a 4 L/h emitter for option B.8.3. From manufacturer's catalogues, x = 0.42, q = 4 L/h at H = 10 m, Cv = 0.07.

B.10 Determine the pressure required to deliver 4.32 L/h.

$$H_a = H \left[\frac{q_a}{q}\right]^{1/x} = 10 \left[\frac{4.32}{4}\right]^{1/0.42} = 12.0 \text{ m}$$

B.11 Determine q_m such that EU of 90% will be attained.

$$q_m = \frac{EU \times q_a}{100 \times \frac{1-1.27Cv}{\sqrt{N_p}}} = \frac{90 \times 4.32}{100 \times \frac{1-1.27 \times 0.07}{\sqrt{6}}} = 4.03 \text{ L/h}$$

$$H_m = H_a \times \left(\frac{q_m}{q_a}\right)^{1/x} = 12 \times \left(\frac{4.03}{4.32}\right)^{1/0.42} = 10.2 \text{ m}$$

B.12 Compute for the allowable pressure variation.

$$\Delta H_s = 2.5 \times (H_a - H_m) = 2.5 \times (12 - 10.2) = 4.5 \text{ m}$$

The design process provisions should be made so that the head losses and elevation difference within each hydraulic unit do not exceed the 4.5 m.

B.13 Compute for the allowable pressure variation when EU = 95%, ΔH_s = 1.0 m.

B.14 Layout the pipe network.

B.15 Determine the size of laterals, manifolds and mainline.

B.15.1 Lateral – Since there are 6 emitters per plant, 3 emitters per lateral will be considered. The first row of plants will start half the spacing from the boundary. The emitters are of in-line type which losses are equivalent to 0.22 m per emitter.

$$Q = \text{No. of trees} \times q_a \times \frac{N_p}{\text{plant}} = 25 \times 4.32 \times 3 = 324 \frac{L}{h} = 0.09 \text{ L/s}$$

L = 148 m; F = 0.358 (75 outlets);

C=150 (soft polyethylene pipe); D = 16mm

$$h_f = 0.358 \times \frac{1.21 \times 10^{10} \times 148 \times \left(\frac{0.09}{150}\right)^{1.852}}{16^{4.87}} = 0.946 \text{ m}$$

Adding the losses from the emitter: $h_f = 0.946 \text{ m} + 0.156 \text{ m} = 1.1 \text{ m}$
The selected size for the laterals is acceptable.
The remaining head for maintaining the allowable pressure variation of 4.5m is 3.4 m.

B.15.2 Manifolds – There will be 4 manifolds (M_1, M_2, M_3, M_4) where 2 operates at a time so that the total irrigation duration is 22 hours. M_1 and M_3 will supply 13 rows (26 laterals) while M_3 and M_4 will supply 12 rows (24 laterals). Additional 10% head loss will be added to account for the manifold-to lateral connection.

Parameter	M_1	M_2	M_3	M_4
Q (L/s)	2.34	2.16	2.34	2.16
L (m)	78	72	78	72
F	0.37	0.372	0.37	0.372
C (uPVC 4)	150	150	150	150
D (mm)	50	50	50	50
h_f (m)	0.92	0.74	0.92	0.74
Elevation Difference (m)	0.70	0.70	1.20	0.70
Total Head	1.62	1.44	2.12	1.44

Since the maximum head in the manifold is less than the remaining allowable pressure variation, the selected size for the manifolds is acceptable.

B.15.3 Main – It should be sized such that it will allow for the separate use of the first two manifolds from the last two manifolds. Consider 2 cases:

Case 1: Last 2 manifolds in operation (M_3 and M_4)
D = 75 mm
L = 150 m (distance between M_1 and M_3)
C = 150 (uPVC 4)
Q = Q_3 +Q_4 = 4.5 L/s
H_f = 2.03 m

D = 63 mm
L = 78 m (distance between M_3 and M_4)
C = 150 (uPVC 4)
Q_4 = 2.16 L/s
H_f = 0.63 m

Total H_f = 2.66 m

Case 2: First 2 manifolds in operation (M_1 and M_2) Since M_1 offtake is at the beginning of the mainline, the flow in the mainline will be the flow required in M_2.

D = 75 mm
L = 75 m
C = 150 (uPVC 4)
Q_2 = 2.16 L/s
H_f = 0.34 m

Size the mainline based on Case 1.

B.15.4 Compute for the total head requirement.

Component	Head (m)	Remarks
Suction Lift	2.00	Assumed
Supply Line	0.40	D = 75 mm; L = 25 m
Control Head	7.00	Assumed based on filtration and chemigation requirement
Mainline	2.66	
Manifold	0.92	
Laterals	1.1	
Operating Pressure	12.00	
SUBTOTAL	26.08	
Fittings	2.6	
Elevation Difference	8.20	
TOTAL	36.9	

B.15.5 Compute for the power requirement. Assume E_p = 55%

$$P = \frac{Q \times TDH}{360 \times E_p} = \frac{16.2 \times 36.9}{360 \times 0.55} = 3.02 \text{ kW}$$

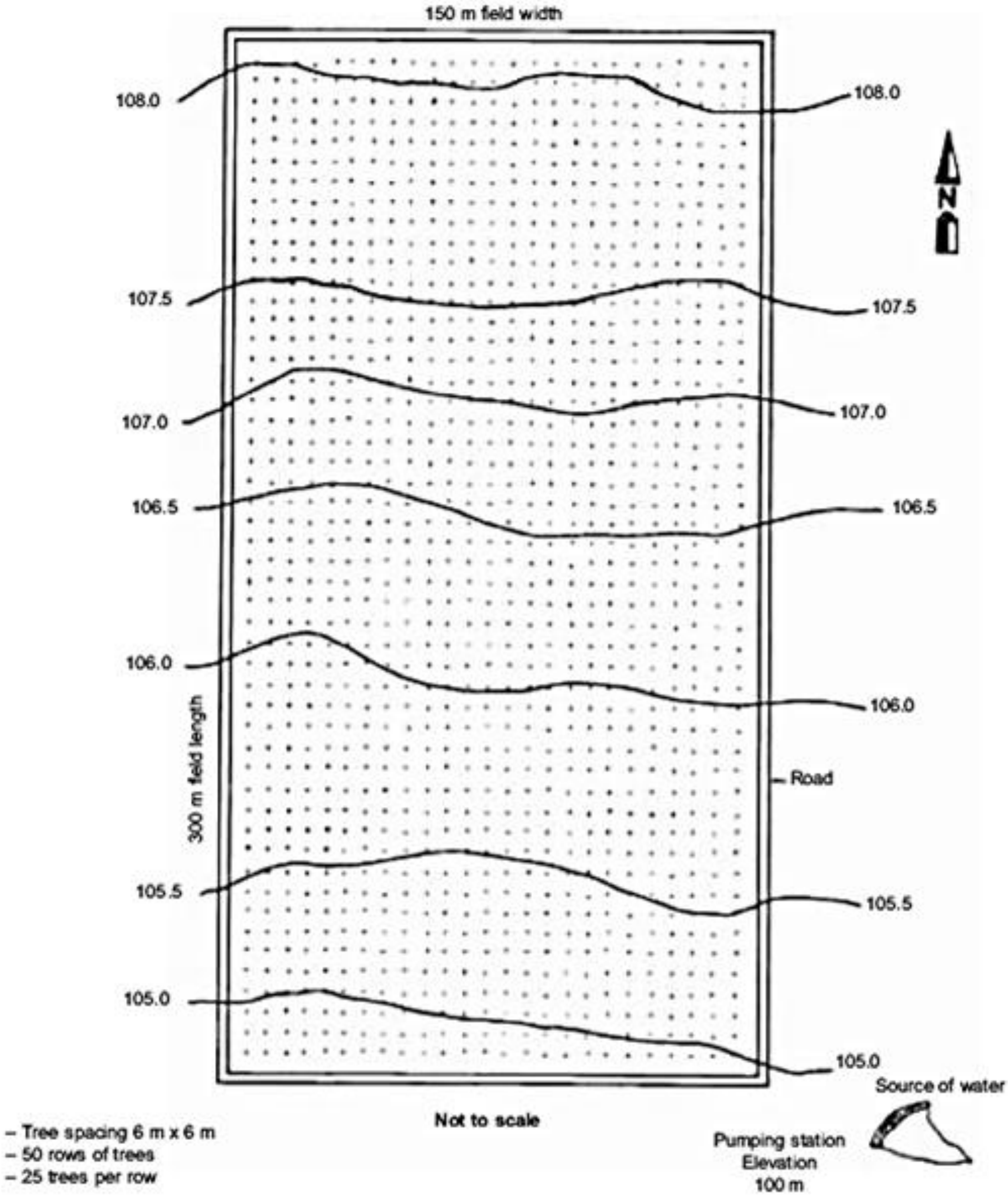

Figure B.1. Field Map

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