



Bachelor of Biosystems Technology
Faculty of Technology
South Eastern University of Sri Lanka

BSE 11042 Principles of Irrigation

Sprinkler irrigation systems

- Water applied at point of use by system of nozzles
- water delivered by surface or buried pipelines.
- Pressure provided by pumps
- Application efficiencies 50 - 95%
- System losses
 - Direct evaporation – spray and soil
 - Wind drift (5 - 10%) - wind, temperature, drop size
 - Leaks and system drainage
 - Surface runoff and deep percolation
 - System application rate < maximum allowable rates
 - On sloping sites – runoff occur
- High capital costs and low labor costs
- Uses more energy
- Suitable for permeable soils - difficult to irrigate by other methods
- Shallow soils with terrain - prevent proper land leveling
- Undulating terrains that would be too costly to level for other methods
- Lands with steep slopes and easily erodible soils
- Impact sprinklers, Mini-sprinklers, gun-sprinklers

Various types of sprinkler systems available in response to economic, labor, topographic conditions, special water application needs, availability of water and land.

Types of sprinkler systems

Types based on arrangement of spraying water:

- 1) Rotating head system
 - nozzles on riser pipes
 - along laterals with uniform intervals
- 2) Perforate pipe system

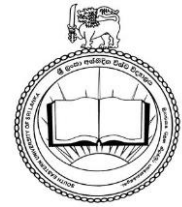
Types based on portability:

1) *Portable system*

Portable main lines, sub-mains, laterals and pumping units. (entire system can be moved from one field to another)

2) *Semi-portable system*

Same as portable system except location of water source and pumping plant is fixed



3) *Semi-permanent system*

Portable lateral lines, permanent mainlines, stationary water source and pumping plant
Main lines usually buried with riser for connecting laterals

4) *Permanent system*

Has buried mainlines, submains, laterals with stationary pumping plants and water source
Sprinklers permanently located on each riser

5) *Set-move irrigation system*

Moved from one set position to another by hand or mechanically after an application

a) Hand-move

Laterals are moved, Aluminum laterals

b) Tow-moved

Skids or wheels fixed to laterals and moved by a tractor

c) Side-Roll

Wheels fixed to laterals taking the lateral as axle of the wheel, an engine rolls the lateral along the field

Laterals are aluminum

d) Gun type

Large volume gun sprinkler mounted on a wheeled cart or a trailer and moved from place to place

6) *Solid set systems*

Has enough laterals and sprinklers to irrigate entire field simultaneously

Can be portable, semi-portable, semi-permanent or permanent

Portable system has underground laterals while other types with above ground aluminum pipes

Field could have blocks and a block is irrigated individually

Sprinkler heads can be moved from one lateral to another

7) *Continuous move system*

Laterals and sprinklers connected to mainline and move continuously

Three major types center pivot, traveler and linear move system

a) Center Pivot

Lateral rotates in a circle around a fixed pivot structure

Pivot point supplies water to lateral

Lateral supported by towers & trusses/ cables

Towers mounted on wheels

Driven by motors

Need a circular shape field (about 80% land irrigated)

b) Linear move system

Lateral is like in center pivot but moves in a linear fashion



Water supplied through a flexible hose or a traveling pumping system

c) Traveler sprinkler systems

Continuous move sprinkler system with a high capacity gun

Mounted on a cart

A hose conveys water from a buried mainline or a portable mainline

Cart is pulled by a winch and cable or hose

Sprinkler system components

Pump

- Centrifugal or turbine pumps used (for deep tube wells)
- Water needs to be pressurized
High pressure (830 – 1035 kPa) for big guns
Moderate pressure (275 – 485 kPa) for impact sprinklers
Low pressure (105 – 210 kPa) for rotating nozzles

Main line/laterals

- Buried or above ground
- Aluminum or LDPE

Sprinkler heads

- Suitability and efficiency depend on operating characteristics under optimum water pressure and climatic conditions (wind)

Types of sprinkler heads

1) Rotating impact sprinkler

- Most commonly used
Single Nozzle - For low water application rate
Two nozzles - High to medium rates
- Different diameter nozzles, pressure heads, discharge rates available
- Nozzles set at 20, 23, 25, 30° from horizontal (4 and 7 also available for under tree sprinkling)
- Operated by a drive arm (hammer) with a driving head at one end
- Rotated by the force of water action (ejecting jet strikes driving head, deflect drive arm, tension of spring returns drive arm, it strike main body of sprinkler with an impact, it is rotated)
- Some applying a part of a circle

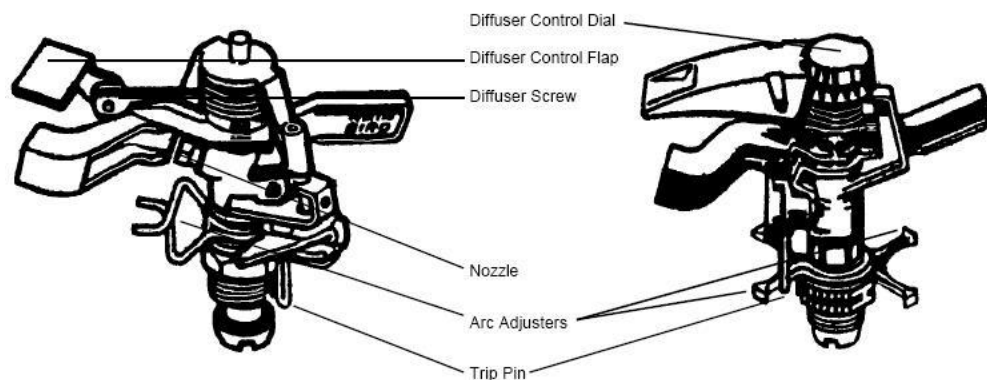


Figure Impact sprinkler

2) Gun-sprinkler

- Very large rotating sprinklers
- Some cover 1ha at a time with large application rates (pressure head exceeds 60m)
- Not suitable for heavy soils, sloppy lands
- More vulnerable to wind
- Drops are bigger and may cause damage to soil and crops

3) Low flow rate sprinklers

- 120 – 350 l/hr (pressure heads 15 – 25m)
- Under tree applications
- Need filters

4) Spitters (mini-sprinklers)

- Small heads 30-120 l/h (pressure heads 15 – 25m)
- Low diameter wetting (about 5m)
- A single tree can be irrigated by 1, can change nozzle size with age to supply more water
- May need pressure regulators along supply lines to regulate pressure
- Fixed to lateral through plastic tubes

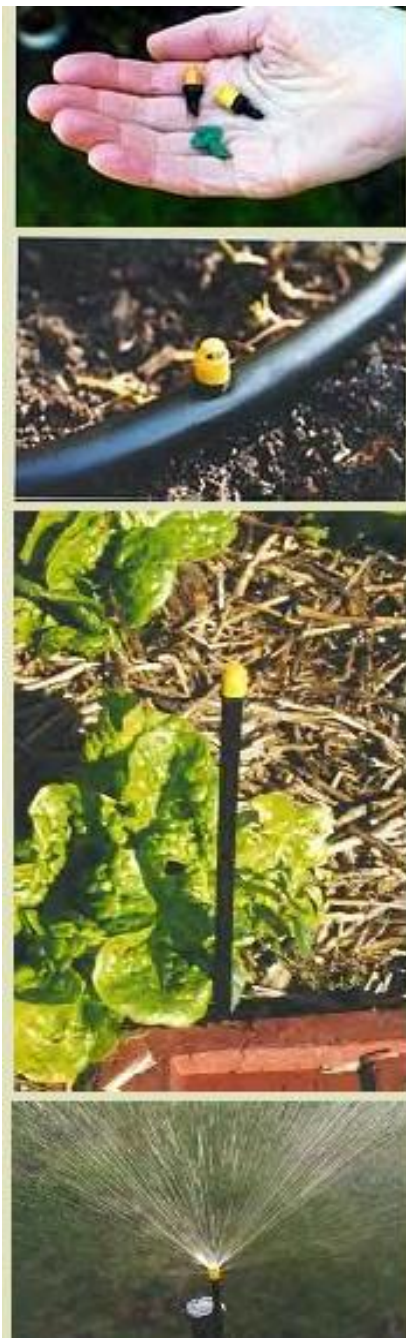


Figure: Micro sprays

Design objectives

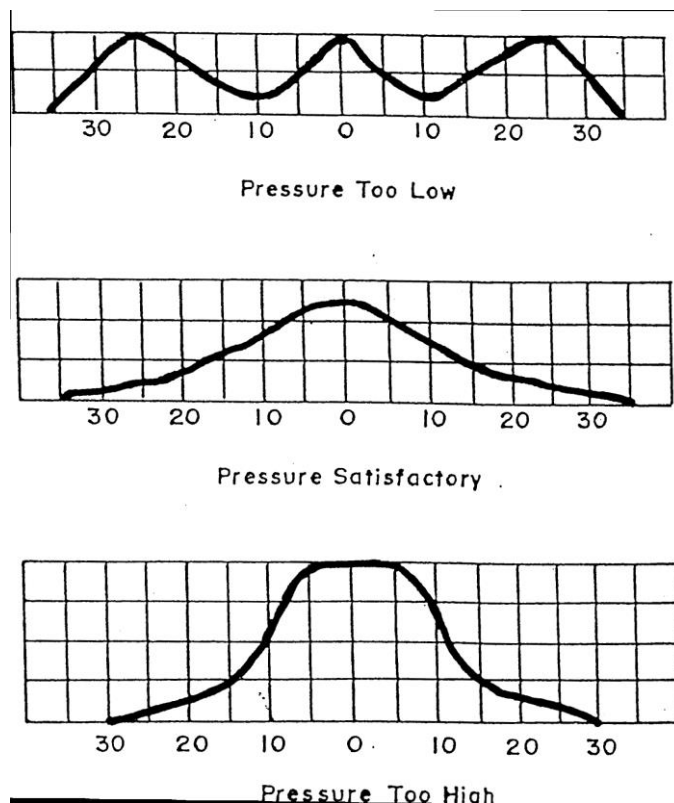
- Replace water used by plants during peak period
- Required depth of application depend on peak period evapotranspiration rate, water holding capacity, management allowed depletion



- Intake rate considered – avoid runoff
- Application rate depend on
 - nozzle size,
 - operating pressure,
 - spacing of sprinkler
- Reasonable uniformity of application needed – to reduce deep percolation
- Depend on
 - wind speed,
 - sprinkler spacing,
 - pressure variations (design criteria, topography, pump)
- Economic considerations
- Experience of grower

Principles of sprinkler operation:

- Available pressure at sprinkler nozzle head is converted to a velocity head
- Jet ejected is broken down to droplets
- In the absence of wind or light wind, wetted area is circular
- Under wind, it is shifted
- Wetted area and water distribution depend on
 - operating pressure,
 - type, angle and diameter of nozzles,
 - driving mechanism,
 - speed of rotation,
 - height of riser,
 - wind conditions



- Droplet size increases with diameter of nozzle, drop in pressure head
- Large drops fall closer to the boundary of wetted area
- Small drops fall close to the sprinkler

Uniformity of application

Pressure effect

- Depends on matching
 - Operating pressure with sprinkler nozzle diameter, wind effect, sprinkler spacing
 - With proper operating pressure: a pattern close to a triangle
 - Need overlapping - fairly uniform application



- Perfectly uniform pattern – difficult to achieve
- Need proper designing with lateral and sprinkler spacing

Figure Effect of pressure on sprinkler application

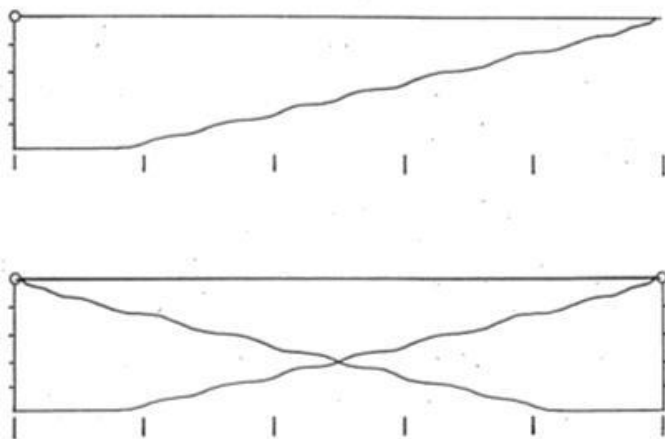


Figure Typical sprinkler distribution curve

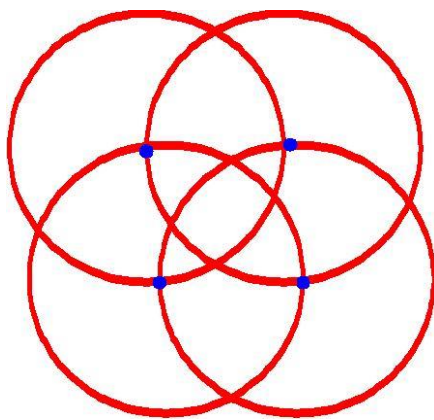


Figure Typical overlapping pattern

Wind effect

- Wind can have a tremendous effect on application pattern
- Skewed pattern is anticipated – decreasing spacing between sprinklers, lateral spacing



Wind conditions (km/h)	Lateral spacing
No wind	65% of design diameter
8.1 and less	60%
8.1 – 16.1	50%
> 16.1	22 – 30%

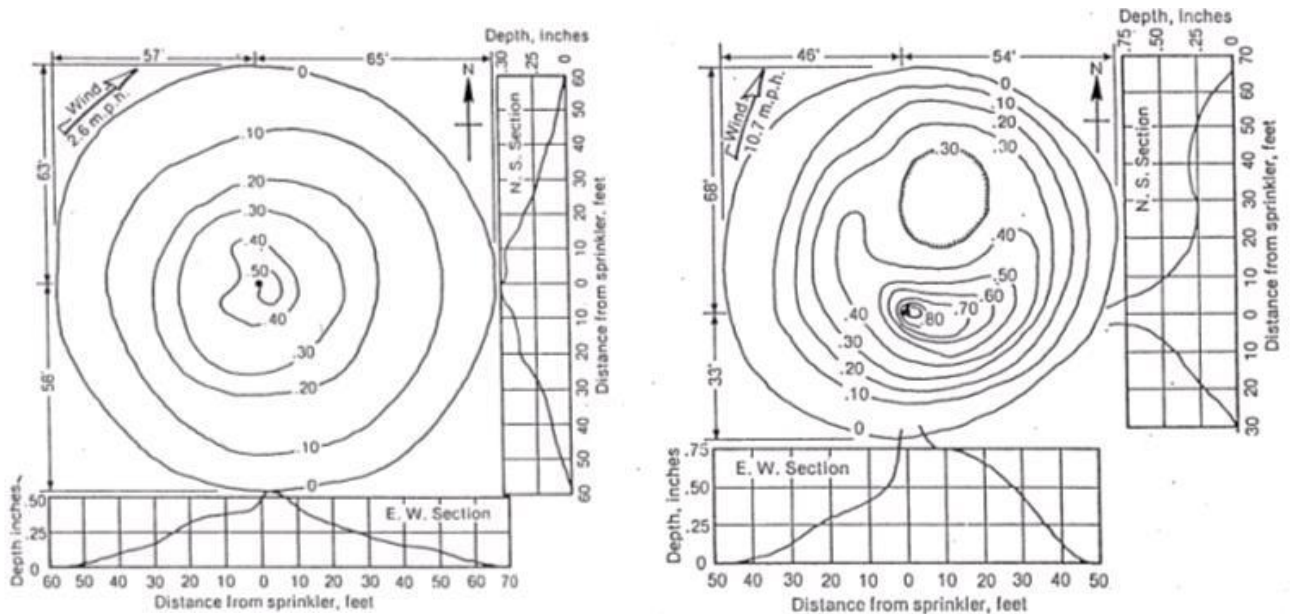


Figure. Distribution pattern distortion by wind

Uniformity coefficient

- to quantify uniformity of application
- Placement of catch cans in field
- Two formulas commonly used

1) Christiansen's uniformity coefficient

$$UC_c = 1 - \frac{\sum_{i=1}^n |x_i - \bar{x}|}{n\bar{x}}$$

UC_c = Christiansen's uniformity coefficient, fraction

x_i = Depth caught in can i , mm

\bar{x} = Mean depth caught, mm

n = Number of cans

- UC_c should be $\geq 80\%$
- Less than 80% could be due to wind or pressure head variations



2) Hawaiian Sugar Planters Association Coefficient

$$UC_H = 1 - \left[\frac{2}{\pi} \right]^{0.5} \left(\frac{s}{\bar{x}} \right)$$

UC_H = Hawaiian Sugar Planters Association Coefficient, fraction
 s = Standard deviation of depth caught, mm

Standard procedure for a single sprinkler

- Minimum 80 collect cans within wetted diameter
- Minimum collector diameter is 80 mm
- Sprinkler is placed
 - at the center of grid midway between 4 adjacent collectors
 - at 0.6m above average elevation of tops of 4 nearest collectors
- Discharge pressure, pressure in sprinkler riser, sprinkler flow rate, speed of rotation, wind speed and direction, wet and dry bulb temperatures
- Recommended duration is 1 h

Sprinkler system with rectangular spacing and overlapping

- Minimum of 24 collectors
- Minimum spacing between collectors – 3 m

Single lateral operating with no overlapping laterals

- Minimum of 24 collectors
- Minimum spacing between collectors – 3 m



Figure Sprinkler evaluation in the field

Adequacy

- Addresses the question of what portion of a field received at least the net irrigation requirement
- Sections received depths equal or greater than net irrigation requirement are said to be adequately irrigated
- Remaining sections under irrigated



Adequacy, uniformity and deep percolation

- Uniformity and Adequacy criteria depend on
 - Cost of sprinkler equipment
 - Value of crop
 - Total cost of water application
- Uniformity increased – increasing laterals and mains (costly)
- Adequacy – some crops less susceptible to water stress, so can go for a lower adequacy

Criteria:

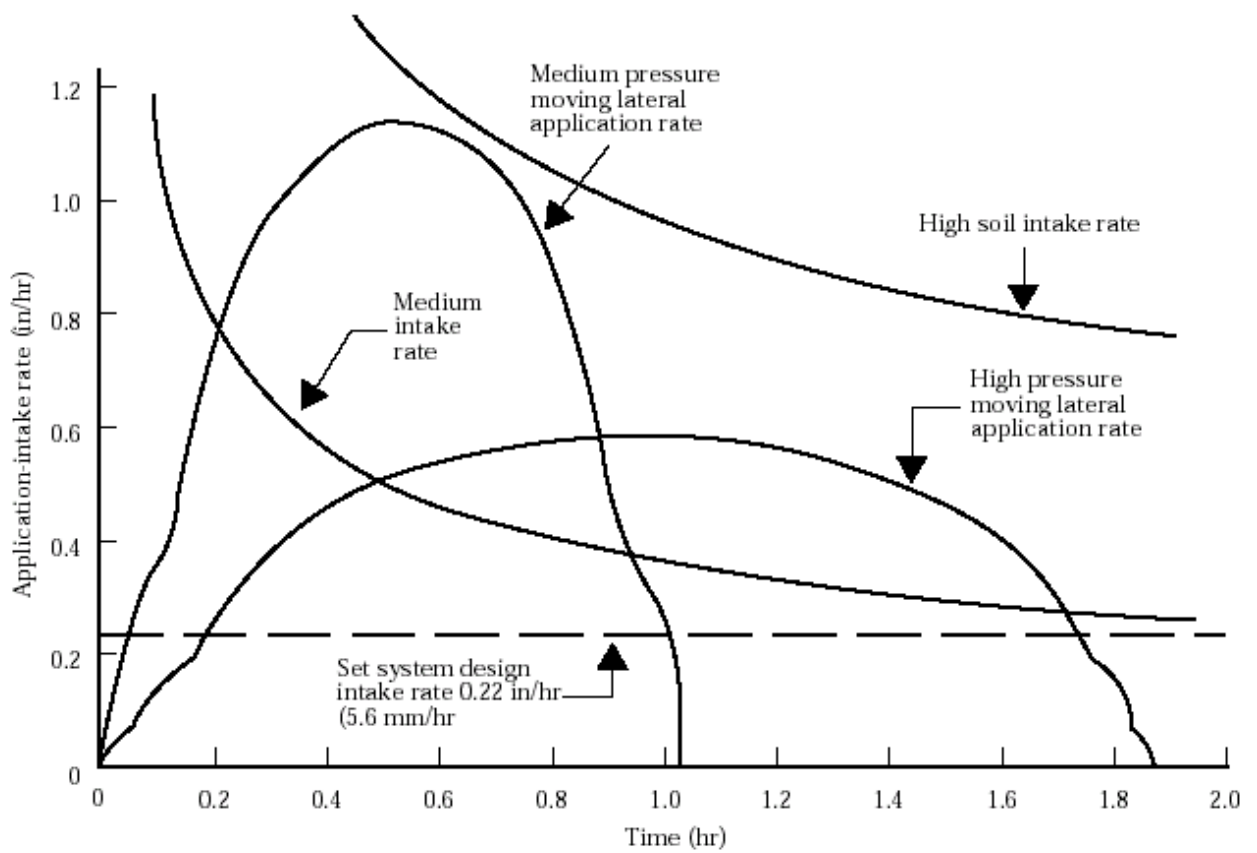
	UC (%)	Adequacy (%)
Field crops	80	75
Orchards	70	50

Advantages of sprinkler systems

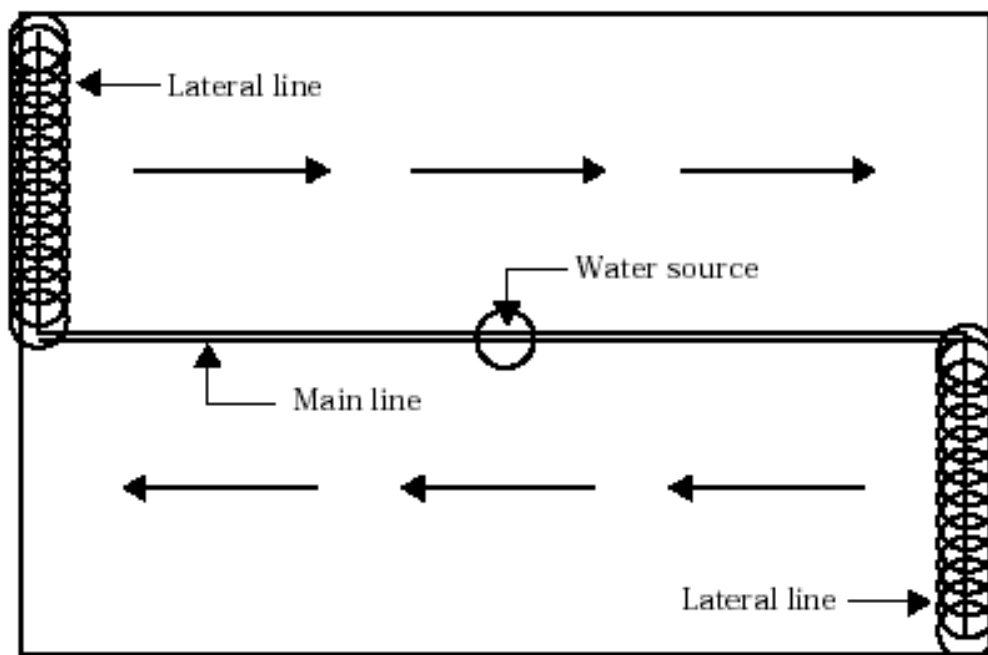
- Light wetting of soils to improve seed germination
- Fertilizer application (if uniformity of application is sufficient)
- Frost protection
- Elimination of canals so that less maintenance and water losses
- High application efficiency
- Closer control of water application
- Area located above elevation of water source can be irrigated
- Land difficult to level can be used
- High intake soils can be irrigated
- Highly erodible or impermeable soils can be irrigated
- When available water is less for surface irrigation
- Frequent light applications can be given
- Easily automate
- Crop cooling
- Does not interfere farm machinery
- Irrigation is possible in nights
- Saves time needed for irrigation
- Can be designed and installed quickly
- Easy water measurement

Disadvantages of sprinkler irrigation

- High winds cause uneven distribution
- Initial investment high
- High operation cost
- Need experienced labor
- Need energy to pressurize water
- Edges could not be irrigated in some cases (need additional sprinklers)
- Need filters or settling tanks when water has debris



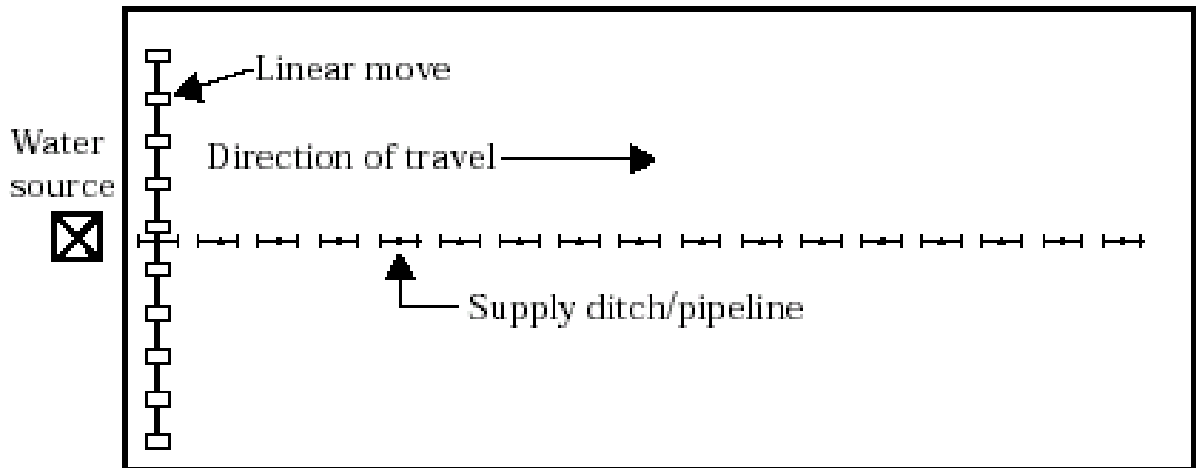
Typical soil intake and sprinkler application rate curves



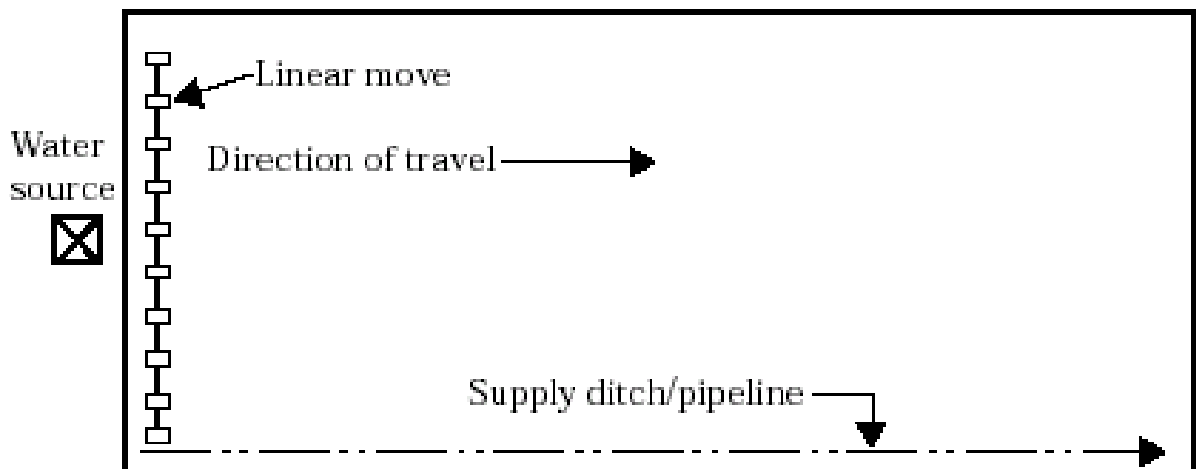


Side roll or hand move sprinkler system layout

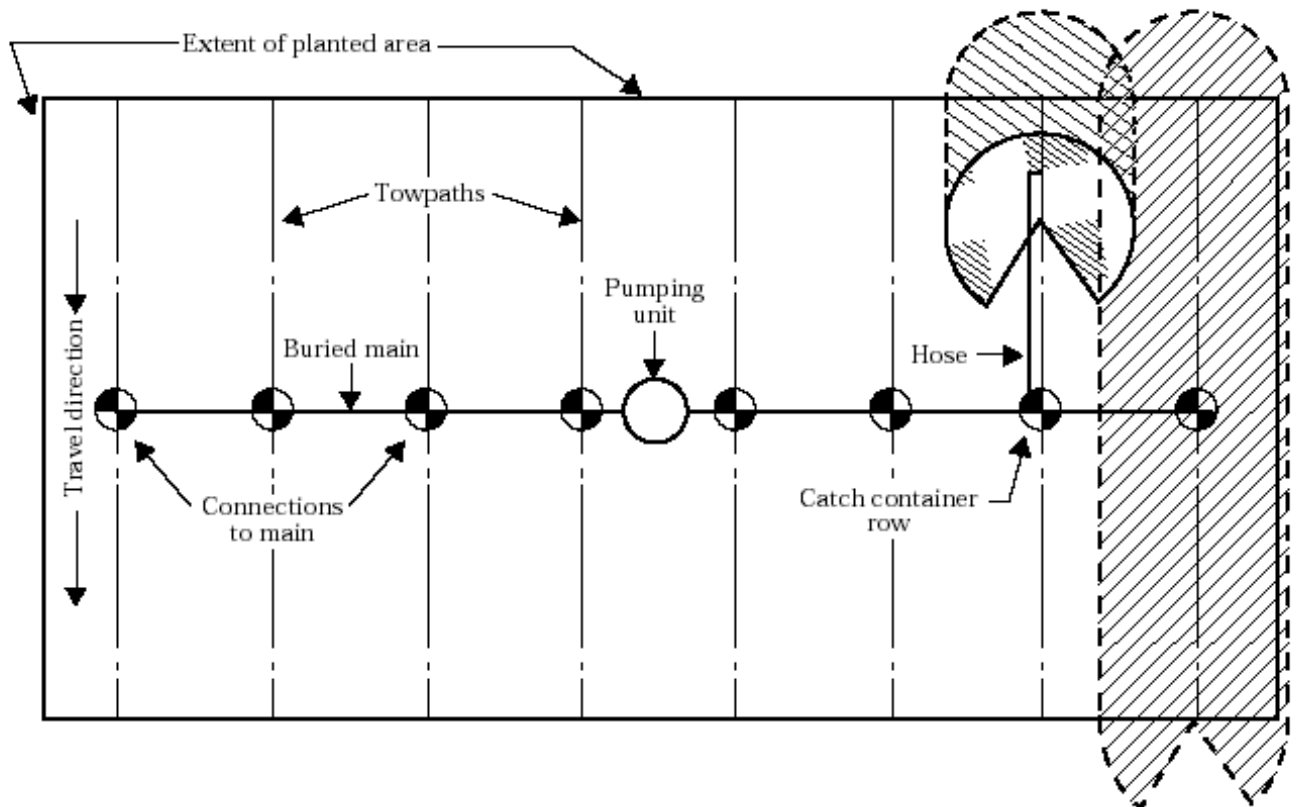
Supply ditch/pipeline center of field



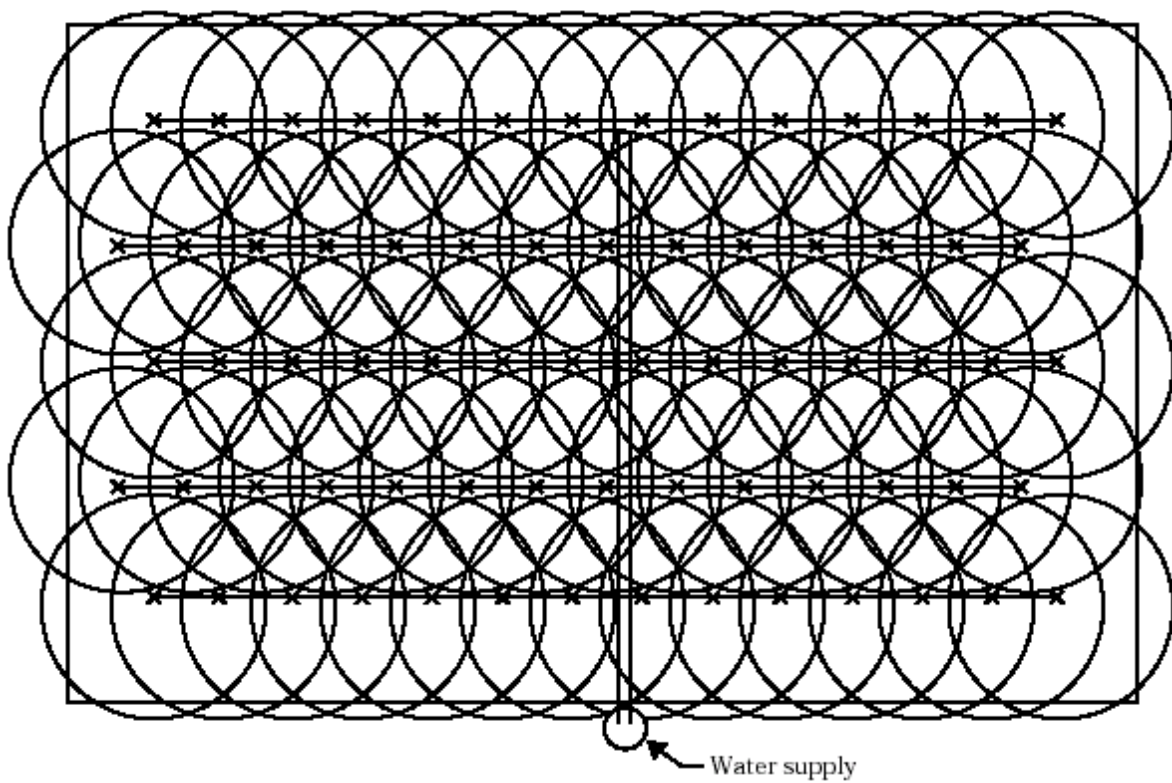
Supply ditch/pipeline along field edge



Typical field layout of linear systems



Traveling gun type sprinkler system layout



Solid set sprinkler system layout