



Sprinkler Irrigation - Uniformity, Efficiency, and Layout

Sprinkler and Micro irrigation Systems

Factors Affecting Sprinkler Application Efficiency

- Variation of individual sprinkler discharge throughout the lateral line.
- Variation of water distribution efficiency within the sprinkler-spacing area, primarily by wind.
- Loss of water by direct evaporation from the spray.
- Evaporation from soil surface before the water is used by the plants.

Q. How to deal with all these factors?

Uniformity

Distribution Uniformity

- Indicates uniformity of application throughout the field
- Computed by: $DU = \frac{\text{Average low-quarter depth of water received}}{\text{Average depth of water received}} \times 100$
- Average low-quarter depth of water indicates average of the lowest one-quarter of the measured values, where each value represents an equal area.

Coefficient of uniformity

- $CU = \left\{ 1 - \frac{\sum X}{nm} \right\} \times 100$
 - X = absolute deviation of individual observations from the mean (mm)
 - m = mean depth of observation (mm)
 - n = number of observations

Uniformity

➤ System CU = $CU \times \frac{1+(P_n/P_a)^{0.5}}{2}$

➤ System DU = $DU \times \frac{1+(P_n/P_a)^{0.5}}{4}$

➤ P_n = minimum sprinkler pressure (kPa)

➤ P_a = average sprinkler pressure (kPa)

Design Criteria

- Data generated by independent testing agencies regarding sprinklers operating under various simulated and actual field conditions.
- These data can be used for selecting various combination of spacing, discharge, nozzle size, and operating pressure that will result in highest practical DU or CU for the anticipated operating conditions.

Interpretation of CU

The water distribution efficiency given in table represent values of different CUs assuming water requirement at the time of irrigation is met on 95, 90, 85, , 50% of the irrigated area.

- ✓ If a sprinkler system has a CU of 86%, then, from table, $DE_{80} = 85\%$.
- ✓ i.e., for each unit of average application of water received by the crop or soil, 80% of area would receive 85% of the average application or more.

Design water distribution efficiency values,¹ DE_{pa} , expressed as percentages for various CUs and percentages of land area adequately irrigated, pa ²

CU, %	Land area adequately irrigated – pa , %								
	95	90	85	80	75	70	65	60	50
	Water distribution efficiencies – DE_{pa} , %								
94	88	90	92	93	95	96	97	98	100
92	83	87	90	92	93	95	96	97	100
90	79	84	87	89	92	93	95	97	100
88	75	81	84	87	90	92	94	96	100
86	71	77	82	85	88	91	93	96	100
84	67	74	79	83	86	89	92	95	100
82	63	71	77	81	85	88	91	94	100
80	59	68	74	79	83	87	90	94	100
78	55	65	71	77	81	86	89	93	100
76	50	61	69	75	80	84	88	92	100
74	46	58	66	73	78	83	87	92	100
72	42	55	64	70	76	82	86	91	100
70	38	52	61	68	75	80	85	90	100
68	34	49	58	66	73	79	85	90	100
66	30	45	56	64	71	78	84	89	100
56	9	29	43	54	63	71	79	86	100

¹ Adapted from Hart and Reynolds (1965).

² Example: $DE_{80} = 85\%$ is the distribution efficiency when the water requirement at the time of irrigation is met or exceeded in 80% of the area irrigated for a CU = 86%.

Interpretation of CU

Relative percentages of optimum productivity (where overwatering does not reduce yields) for various values of CU and percentages of land area adequately irrigated

CU, %	Land area adequately irrigated – %							
	95	90	85	80	75	70	65	60
Relative production – $100(Y_a/Y_p)$, %								
90	100	99	99	98	98	97	97	96
86	100	99	98	98	97	96	96	95
82	99	99	98	97	96	95	94	93
78	99	98	97	96	95	94	93	91
74	98	97	96	95	94	93	91	90
70	98	97	95	94	92	91	90	89
64	97	97	95	94	91	90	88	87

- This gives an understanding of CU to give a feel of relative productivity of forage and other vegetative crops.
- For these crops, the yield must be a linear function of available water, and overwatering doesn't reduce yield.

with a CU of 86 and 80% of the area adequately irrigated 98% of optimum yield might be obtained with an average net application 1.18 times the net depth required after allowing for wind drift and evaporation losses. With a CU of only 70%, 94% of the optimum yields might be obtained if 80% of the area were adequately irrigated. However, the average net application would need to be 1.47 times the adjusted net requirement. If $CU = 70\%$ and only 1.18 times the required net depth were applied, to give $DE = 85\%$, the adequacy of the irrigation would be $pa = 65\%$ and at best only 90% of optimum yields could be expected.

Layout of Set Sprinkler Systems

Number of Sprinklers

- System must provide for simultaneous operation of the average number of sprinklers that will satisfy the required system capacity.
- The required average number is: $N_n = \frac{Q_s}{q_a}$
 - N_n = minimum average number of sprinkler operating
 - Q_s = total system discharge capacity (lps)
 - q_a = average sprinkler discharge (lps)
- On odd shaped field, where it is required to operate less than average number of sprinklers for one or more lateral setting, *engine driven pumps can be throttled down to reduce the discharge.*
- Where two or more number of laterals operating with different number of sprinklers, *valves can be used to control their inlet pressure.*

Layout of Set Sprinkler Systems

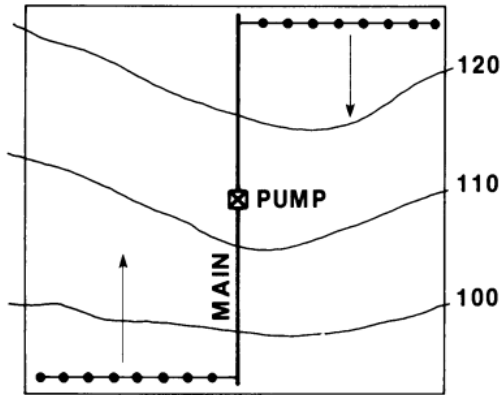
Number of Lateral Position

- Number of position of that each periodic-move lateral can handle depends on the
 - Number of moves per day
 - Number of operating days allowed for completing one irrigation cycle during the peak use period, f .
- The required number of positions per lateral must not exceed the product of these two factors.

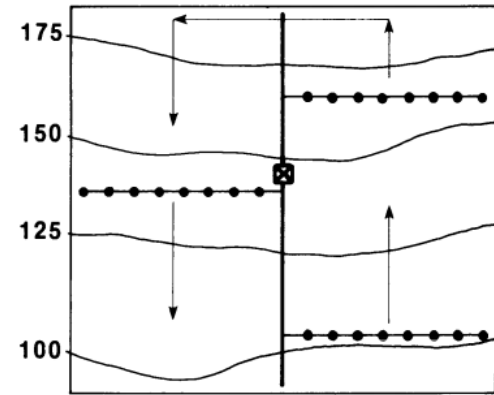
Topographic Effects (lateral layout)

- For uniform application along the lateral, the pipe diameter, length and alignment must be so selected to result in **minimum variation in discharge** (*variation shouldn't exceed 10%*).
- The pipe sizes and layout should be so selected that the **pressure variation along the lateral will not exceed 20%** of average design operating pressure.
- To meet the pressure variation criterion the laterals should be preferred to be laid *on contours or across prominent land slopes*.

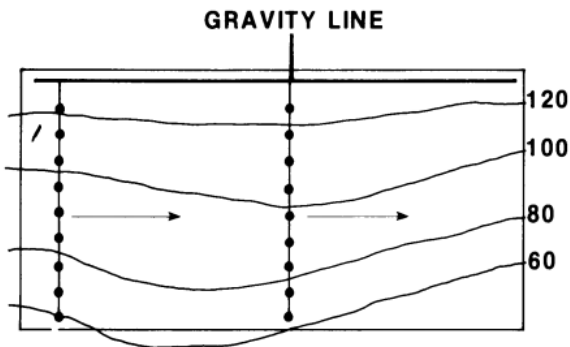
Topographic Effects (lateral layout)



A - Layout on moderate, uniform slopes with water supply at center



B - Layout illustrating use of odd number of laterals to provide required number of operating sprinklers.



C - Layout with gravity pressure where pressure gain approximates friction loss and allows running lateral downhill.

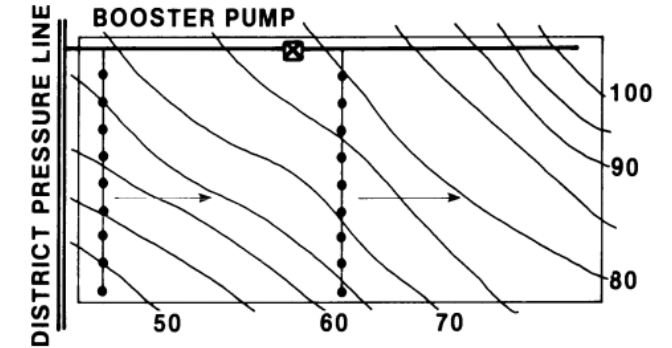
The lateral length is limited to the length in which the friction loss equals 20% of average operating pressure.

- Running laterals uphill should be avoided.
- The lateral length in such case should be limited only to that length in which friction loss equals to *20% of P_a minus the pressure loss due to elevation difference.*

Running laterals downhill is a distinct advantage, provided that the slope is fairly constant and not too steep.

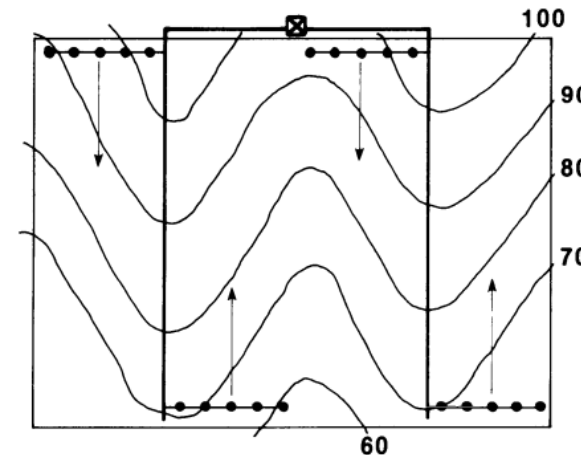
Topographic Effects (lateral layout)

- ❖ In downslope condition difference in elevation between the two ends results in gain in pressure head.
- ❖ Downslope laterals may be longer than similar laterals laid on level grounds.

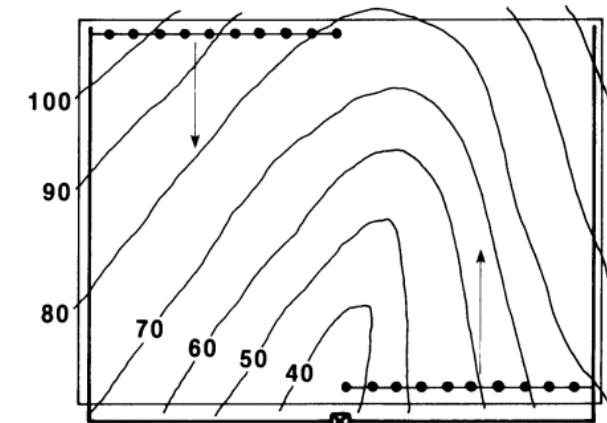


D - Layout illustrating area where laterals have to be laid downslope to avoid wide pressure variation caused by running laterals upslope.

Where ground slope along the lateral is about equal to the friction loss gradient, the pressure along the lateral would be nearly constant.



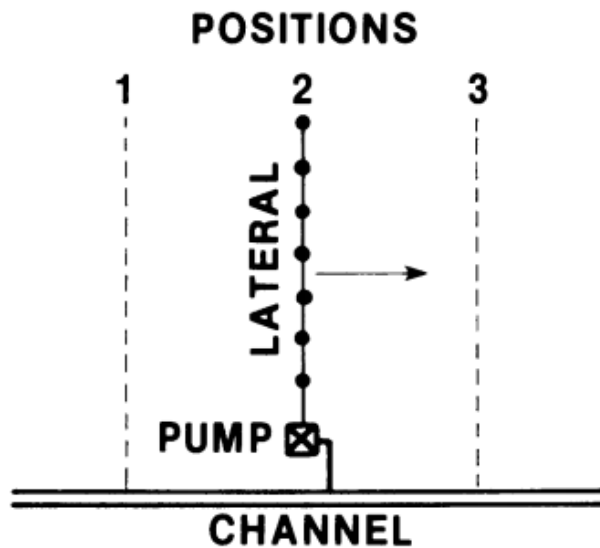
E - Layout with two main lines on ridges to avoid running laterals uphill



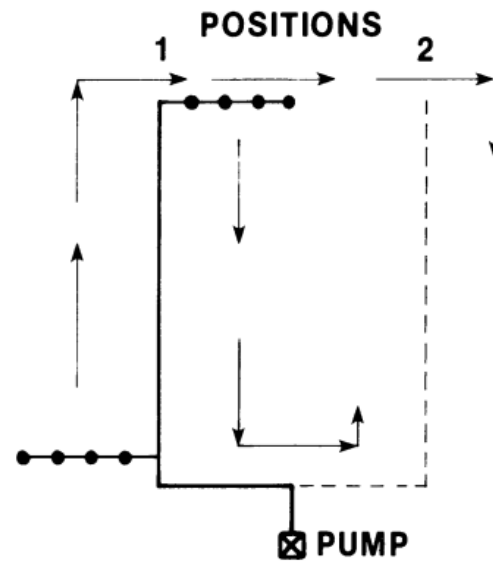
F - Layout with split main lines to avoid running laterals uphill.

Topographic Effects (main line layout)

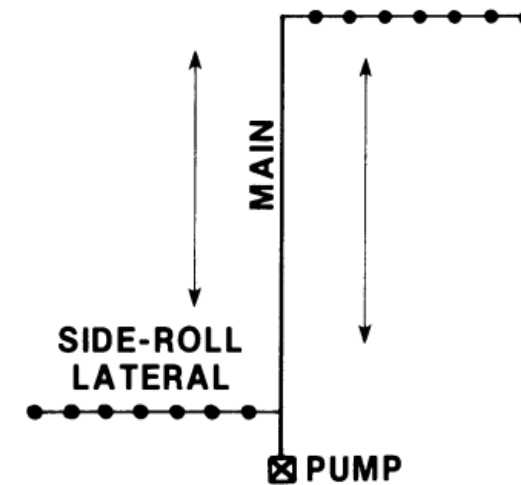
- Main lines and sub-mains should **usually run up and down slopes**.
- **Where laterals are downslope, the main line will often be located along a ridge**, with laterals sloping downward on each side or in split main line fashion (previous slide image E and F).



A - Fully portable sprinkler system with portable lateral and movable pumping plant.

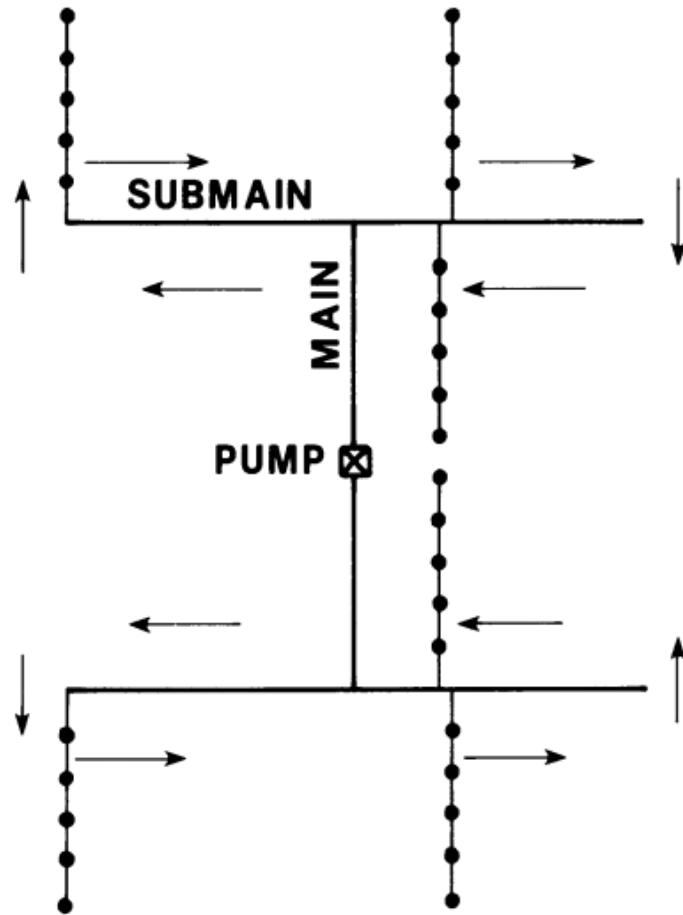


B - Portable laterals and main lines with stationary pumping plant.

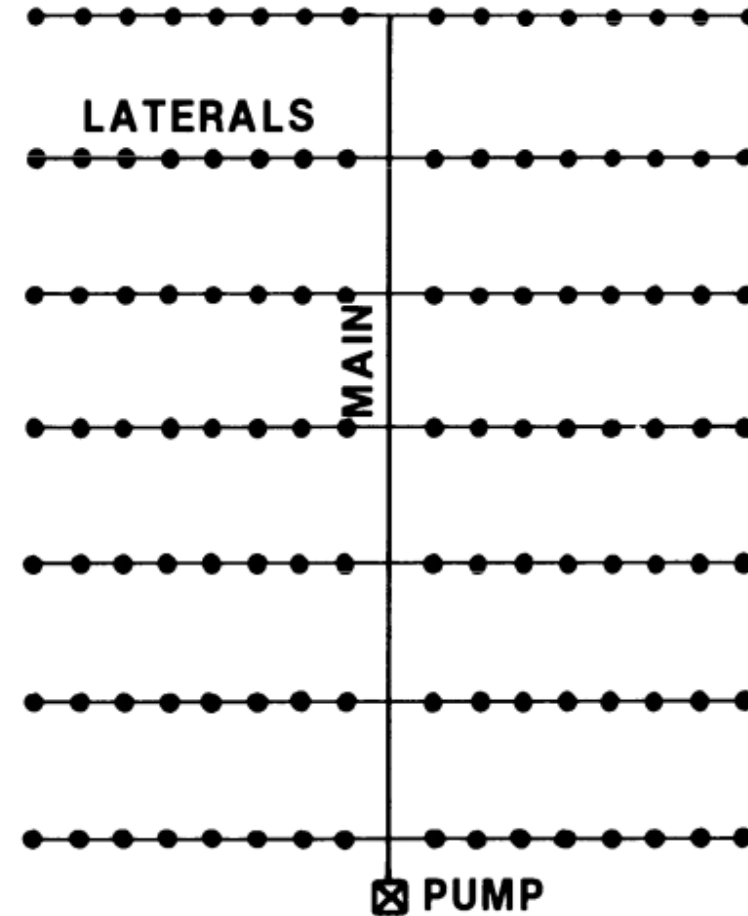


C - Portable laterals, buried main line, and stationary pumping plant.

Topographic Effects (main line layout)



D - Buried mains and submains with portable laterals.



E - Buried main lines and fixed laterals.

Water Source and Pumping Plant

- Water supply should be **located near the center of the design area.**
- On sloping fields the well should be located **uphill from the center to better balance up- and downhill pressures** and minimize the pipe sizes.

After completing the preliminary layout of laterals and main lines, it is often necessary to adjust one or more of the following variables:

- Number of sprinklers operating, N_n
- Water application rate, I
- Gross depth of each irrigation, d
- Average sprinkler discharge, q_a
- Spacing of Sprinklers, S_e and/or S_l
- Actual operating time per day, T

!!!-Thank you-!!!

