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DEVELOPMENT OF COMPUTER ALGORITHM FOR A NUMERICAL MODEL TO OPTIMIZE THE PERFORMANCE OF MULTI-OUTLET PRESSURIZED IRRIGATION IN SLOPING AND NON-SLOPING TERRAINS

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ABSTRACT

Computer modeling is a new tool to solve and assess many engineering and scientific problems. The issue of selecting an optimum length of multiple-outlet pipes depends on the operating head, viscosity of fluid, material of pipe and the ground slope, A computer model developed in the paper is a tool to select the highest length of pipes without compromising the uniformity of distribution and high efficiency. The drip irrigation fits into this problem and so this paper runs the model based on the data of drip irrigation system and comes out with the design of laterals satisfying the criteria of uniformity distribution coefficient and Distribution Uniformity.

INTRODUCTION

This paper deals with the use of a computer based numerical model to test the performance of water application in drip irrigation. As every engineering system has a some performance indicator so does the drip irrigation System. The discharge of water from emitters (small outlet from which water drips) is based upon the pressure head at the inlet of pipes. The term used for measuring their efficiency is Uniformity Coefficient. This paper develops a computer based model for getting the UCC and Pressure head for different length of pipes and varying other input parameters on sloping and non-sloping grounds. This exercise also allows us to select a combination of maximum length of lateral with the optimum uniformity coefficient. The computer algorithm is provided in the paper. The wireless sensor network for this system is to have piezometric sensors which measure the pressure head are interfaced with the sensor board of Wireless Mote called a Node in the sensor network. The sensors report the actual in-situ picture of the whole drip irrigation system in terms of pressure heads over the inlet points of laterals manifold and sub-mains. The results from numerical model and data given by WSN are compared to have a feedback system to localize the area of poor performance to initiate a prompt action. This paper is an effort to put forward a model to the engineers and researchers in field of computer science and water resource engineering to develop such applications. This analogy will be useful for other multi-outlet conditions like urban water supply system, Industrial fluid conveyor pipes or Gas distribution System etc.

Related Work

The development of computer model required the clear understanding of complete science behind the flow in multiple outlet pipes. As Trickle Irrigation is taken as an example case for this model so works of various researchers were taken in consideration.

Clemmens *et al* describes about irrigation uniformity. Two of the causes of Trickle Irrigation non-uniformity are variation in emitter properties and variation of pressure at the emitters. A simple algebraic equation for assuming the combined effects has been previously proposed by Bralts *et. al* for the case when

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both emitter and hydraulic properties are normally distributed and independent. A simulation model was developed to evaluate these assumptions for a simple lateral. First, it was found that the emitter and hydraulic properties are independent for practical purposes. Second, it was shown that the nature of pressure contribution can have an impact on the assessment of uniformity. In term of distribution uniformity, DU assuming a normal pressure distribution for a single lateral gave lower values of uniformity.

A simple procedure is presented for developing an equivalent co-efficient of hydraulic variation which will give a more accurate estimate of the combined effects. Finally, it is shown that the proposed variation only gives an estimate of the actual uniformity. The variation in this estimated combined uniformity, DU is greater when it is caused by emitter variation than when it is caused by hydraulic variation, at least for a simple example. Thus this paper helps to refine analysis of irrigation uniformity for either the design or evaluation of trickle irrigation system. Holzptal *et al* develop a nonlinear optimization model for the design and management of drip irrigation system. Decision variables are pipe diameter, pipe lengths, number of emitters in each lateral, number of laterals in a manifold, total number of subunits operating simultaneously, irrigation time per set and emitter discharge. The model is solved using GAMS-MINO5 package. To illustrate the capability of the model, an orchard field of pears is selected.

The price effect on the result of the model shows that the cost of the system and its operation are relatively small compared with the benefit obtained. The model shows that the results do not yield the minimum cost of the system when the marginal benefit is greater than the marginal cost. The pioneering work in the field of design of trickle irrigation system has been done by Christiansen. To account for the friction loss through multiple outlet pipe Christiansen gave a multiplying factor "F". When it is multiplied with friction loss in a blind pipe of same size, length and carrying the same inlet discharge actual head loss in the multiple outlet pipe, is obtained. The classical method of a trickle design usually employs the Hazen - Williams or Scobby's equation to find head loss and then it is multiplied by Christiansen's correction factor which depends on number of emitters per lateral. Among numerous papers published till date, conclusions of some of the papers which are related to the present study has been summarized. A. Amoozegar - Ford *et al* gave Nomographs to be used in the design and operation of trickle irrigation system.

Monographs relates the plant rooting geometry, uptake rate, soil properties and the Trickle Irrigation design parameters to the soil moisture status. The nomographs are easy to use and provide solutions without tedious calculation. Gillespie *et al* discuss about the five pressure profiles which represent design conditions resulting from a lateral line (or sub main) laid on uniform slopes. Procedures were developed to identify pressure profiles by land slope and total friction drop at the end of the line. Equations for designing lateral length (or sub main) based on a given criterion, pressure variation were derived.

These equations cannot be solved directly, but solutions can be obtained using a Trial and Error Technique on a pocket - calculator or by using Newton's method of approximation in a computer program. Bralts *et al* and Kang and Nashiyama give a method for using the finite element approach to analyze drip irrigation sub-main units. The method is based on the iterative solution of a set of linearised flow equations. Either the Darcy - Weisbach or Hazen - William equation can be used. The finite element method results in a symmetric banded matrix which requires minimal computer storage. The advantage of this technique include, possible implementation through existing finite element computer programs, simplicity of application to large irrigation hydraulic networks, quickness of convergence and the potential for use with small computers. Scaloppi *et al* determines an adjusted 'F' factor to compute pressure head loss in pipes having multiple, equally spaced outlets for any given spacing of the first outlet from the inlet.

The proposed factor is dependent on the number of outlets and is expressed as a function of the Christiansen's 'F' factor. The friction head loss between successive emitters is estimated by the Darcy -Weisbach formula, taking into account the variation of the Reynolds number, the different zones on Moody diagram and the frictional coefficient formula corresponding to each zone. In addition the change of velocity head is accounted for at different emitters.

As the net pressure head at each emitter is evaluated the corresponding emitter discharge is estimated accordingly. A computer program is presented for analyzing and designing trickle irrigation laterals. Laminar flow prevails in a considerable length at the downstream end of the lateral where as upstream length may subject to fully turbulent flow. Gellespie *et al* and Watters and Keller. In their analysis, they generally neglected the change in the velocity head and assume an initial uniform emitter outflow. Hathoot *et al* provided a solution based on uniform outflow but took into account the change in the velocity head and the variation of the Reynolds number along the lateral pipe.

Assuming the lateral acts as a homogeneous system of a main tube and a longitudinal slot, Yitayew and Warrick presented an alternative treatment that includes a spatially variable discharge function as part of the basic solution. In addition, Yitayew and Warrick provided distribution uniformity measures and charts for designing trickle irrigation systems. Yitayew and Warrick showed that the velocity head had no significant effect on trickle lateral design, and therefore assume a hydraulically smooth flow along the lateral pipe and disregarded the laminar flow at occurs at a downstream part of the pipe. Furthermore, they disregarded the fully turbulent flow that may occur at an upstream reach of the pipe. In the following analysis, the individual emitters are considered taking into account the velocity head change and the variation of the Reynolds number, which affects the selection of the proper friction coefficient formula to be applied along the different reaches of the lateral pipe.

Terms and Definitions

Fig 1 shows a standard layout of a drip irrigation system. The layout of Main, Sub main, Manifold and Laterals are given in that. Emitters or drippers from which the water trickles are placed on laterals.

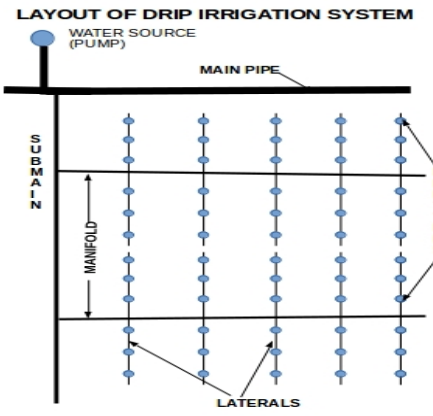

Fig 1 Layout of Statndard Drip Irrigation System

1. ***Drip Irrigation***: The Irrigation System where water is applied directly to the plants by drippers/ emitters.
2. ***Main*** : This is the highest capacity of pipe and must carry the discharge and pressure of water to satisfy all the plants in the command
3. ***Sub main***: The pipes originating from Main. They must carry the discharge and pressure of water to satisfy all the plants in the sub-command
4. ***Manifolds***: Water carrying pipes originating from Sub mains.
5. ***Lateral***: They are the pipes which carry adequate pressure to satisfy one row and all the emitters
6. ***Emitters***: They are the nozzles placed on the lateral which finally apply water to the crop.
7. ***Pressure Head***: This is the pressure of water at any point in the pipe, the water flows in the pipes on account of this head. The head also has relationship with the discharge carries by the pipes and emitters. The required pressure head can be calculated with the requirement of discharge in emitters, laterals, manifolds and sub mains.
8. ***UCC (Christiansen's Uniformity Coefficient)***: This is an indicator of performance. It is calculated by taking one minus the total each sample deviates from the mean divided by the total of all samples.
9. ***Distribution Uniformity (DU)***: It is a measure of the average of the lowest quarter of emitter dischargers, divided by the average of all emitter discharges on lateral. The higher the DU, the better the performance of the system. If all samples are equal, the DU is 100%. If a proportion of the area greater than 25% receives zero application the DU will be 0%. There is no universal value of DU for satisfactory system performance but generally a value >80% is considered acceptable.

Development of Numerical Model for Performance Measurement

Following is the development of numerical model to find the pressure head on laterals, uniformity coefficient and distribution uniformity

Design of Lateral to estimate the Pressure Head

The estimation of pressure head is done by matrix shown in fig. 2. The detailed derivation of this matrix is given in proof of concept.

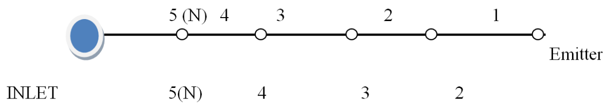

Fig.2 Single Lateral in Pressurized Irrigation

$$\begin{bmatrix} \overset{(1)}{Kp+Ke} & \overset{(1)}{-Kp} & & & \\ \overset{(1)}{-Kp} & \overset{(1)(2)}{Kp+Kp+Ke} & \overset{(2)}{-Kp} & & \\ & \overset{(2)}{-Kp} & \overset{(2)(3)}{Kp+Kp+Ke} & \overset{(3)}{-Kp} & \\ & & \overset{(3)}{-Kp} & \overset{(3)(4)}{Kp+Kp+Ke} & \overset{(4)}{-Kp} \\ & & & \overset{(4)}{-Kp} & \overset{(4)(5)}{Kp+Kp+Ke} \end{bmatrix} \begin{bmatrix} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \end{bmatrix} = \begin{bmatrix} \overset{(1)}{Kp\,\alpha\,S} \\ \overset{(2)}{Kp\,\alpha\,S} - \overset{(1)}{Kp\,\alpha\,S} \\ \overset{(3)}{Kp\,\alpha\,S} - \overset{(2)}{Kp\,\alpha\,S} \\ \overset{(4)}{Kp\,\alpha\,S} - \overset{(3)}{Kp\,\alpha\,S} \\ \overset{(5)}{Kp\,\alpha\,S} + \overset{(5)}{Kp\,\alpha\,S} - \overset{(4)}{Kp\,\alpha\,S} \end{bmatrix}$$

Fig.3 Matrix Equation for lateral shown in Fig. 2

$$K_e = Ch^{x-1} \tag{1}$$

where C = emission coefficient; h = inlet pressure head of the emitter (m); and x = emission exponent. When the emitter has a riser, the friction loss within the emitter riser may be insignificant, or the difference between the inlet and outlet of the emitter may be noticeable, K_e is determined by Kang and Nishiyama (15).

$$K_e = C(h - h_o)^x / h \tag{2}$$

where h_o = height of the emitter riser (m). When emitter has the riser, and the friction loss due to the emitter riser is significant, the following equations (Kang *et al*. (15) can be used to determine the coefficient K_e in order to write the stiffness matrix as a symmetrical tridiagnol matrix.

Finite Element Procedure

1. The procedure of the finite-element method (FEM) for analysis of the hydraulics of a trickle irrigation lateral is outlined as
2. Arrange nodes on the lateral using the method as shown in Fig.2.
3. Let *all* the initial estimates of nodal pressure heads equal the operating pressure head of the lateral.
4. Obtain various coefficients from the equations mentioned previously.
5. Solve the matrix equation to obtain nodal pressure heads.
6. If the solution obtained in step 4 is equal to the initial estimates of nodal pressure heads, this solution would be the final result; otherwise use them as new estimates of nodal pressure heads and repeat steps 2-4 until the final result is obtained.

After this procedure is performed, all the pressure heads at the emitters and the emitter discharge are obtained. The flow to the lateral from the sub main is also determined.

Steps To Calculate Uniformity Coefficient and Distribution Uniformity

Christiansen's uniformity coefficients (UCC) and the lower quarter distribution uniformity (DU) are used here to express uniformity of water application. UCC and DU are defined as

N

$UCC = 1 – 1/Nq_{avg}\sum | qi\text{-}q_{avg} |$ (3)

i=1

where,

q_{avg} = Average discharge of emitter

q_i = Discharge of $i^{t''}$ emitter on lateral

N = No. of emitters

UCC = Uniformity coefficient

Hathoot *et al*. presented a procedure for the design of the unknown parameter with the operating pressure head of a single lateral when one parameter (either the lateral diameter or length) and the other conditions are given. There are four steps in the procedure:

1. to give a series of values for the design parameter from smallest to largest
2. to find the required operating pressure head (li_n) that can create the required average emitter discharge ($q_{r,i}$) and
3. to evaluate the uniformity of water application for each given value.

The hydraulic analysis in the second step was performed using the finite-element method. The golden section search, which is one of the optimization methods for univariate minimization Gill *et al*.; Liu and Meng, was improved for quickly finding H. The golden section search (GSS) for quickly finding H, can be simply described as follows:

4. Determine a pressure head range [A, B], in which H_i, is located. In [A, B], A = minimum pressure head, and B = maximum pressure head.
5. Obtain a pressure head (Al)) by

$Al = B - k(B - A)$ (4)

where k, = 0.618

If Al can produce Ci_{req}, whiich means that

$Q = Nq_{req}$ (5)

where Q = flow to the lateral from the submain (m^3/s), and N number of emitters along the lateral, then Al would be the required operating pressure head of the lateral. Otherwise, if Q > Nq_{reci}, then $H,_n$ is located in pressure range [A, Al]. When you let B = Al , then the pressure head range is reduced. Repeat the calculation from step b.

If Q < Nq_{req}, obtain another pressure head (A2) by

$A2 = A + (B - A)$ (6)

If A2 can produce q_{req}, then A2 would be the operating pressure head of the lateral. Otherwise, if Q > $Nq_{r,,q}$ then $H,_n$ is located in pressure range [Al , A2]. If you let A = Al and B = A2, then the pressure head range is reduced. Repeat the calculation from step b. Otherwise, H,, is located in pressure range j[A2, B]. If you let A = A2, then the pressure head range is reduced. Repeat the calculation from step b.

Using this procedure, $H,_n$ can be found quickly. The details of GSS were illustrated in a flowchart shown in Fig. 5.3 Eq. (4.28) is defined as the constrained condition. For the single lateral shown in Fig. 2.

$Q = Qp(N)$ (7)

where Qp(N) = discharge of lateral element N (m^3/s). Therefore, the constrained condition of GSS is

$Qp(N) = Nci_{req}$ (8)

After H_{it}, is obtained, the hydraulics is also analyzed. The uniformity of water application can be evaluated using one coefficient of UCC, DU and VHM. Since the design procedure for UCC is the same as for DU and VHM, only UCC is used. For this reason, the increments of the values for the design parameter can be small, and the relationships between UCC and the design parameter, and between H, and the design parameter within two adjacent points can be considered to be linear relations. Therefore, the results of step 3 and 4 can be directly obtained by computer calculations.

Computer Algorithm

The computer model to achieve the UCC and DU and thus to derive the best performing lateral length is called LAT-GOLD Input for the program LAT-GOLD:

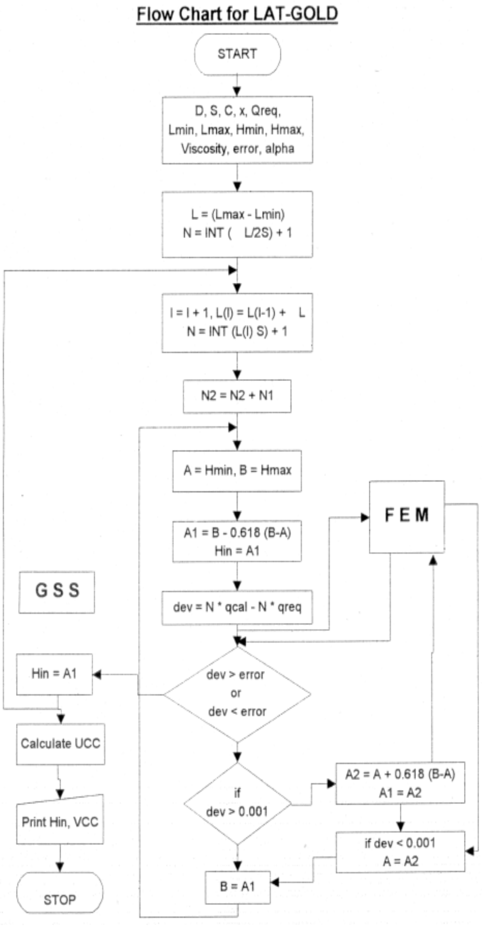

Fig.4 Flow Chart of Computer Algorithm

1. Maximum possible operating head (B)
2. Minimum possible operating head (A)
3. error level for convergence

Procedure

The program starts with a selection of range of pressure head [A, B]. A trial operating head is found as A_1 = 0.618 (B - A). With this operating head pressure head is calculated at all the emitters and discharge is worked out.

Table No. – 1 Variation of Optimum head on Lateral Inlet & Uniformity Coefficient in Combination of different Lengths & Slopes

Length of	**Slope**	**= 0%**	**Slope**	**= 2%**	**Slope**	**= 4%**	**Slope**	**= 6%**	**Slope ;**	**= 10%**
Lateral in m	**Hin**	UCC	**Hin**	UCC	**Hin**	UCC	**Hin**	UCC	**Hin**	UCC
1.500	10.024	1.000	9.966	1.000	9.908	1.000	9.886	1.000	9.662	1.000
31.500	10.040	0.999	9.743	0.992	9.518	0.980	9.415	0.972	9.212	0.970
61.500	10.106	0.998	9.678	0.986	9.312	0.974	8.912	0.920	8.423	0.915
91.500	10.310	0.993	9.514	0.982	9.034	0.967	8.630	0.883	7.713	0.863
121.500	10.650	0.984	9.726	0.980	8.724	0.956	8.245	0.840	7.416	0.802
151.500			10.014	0.981	8.825	0.943	8.025	0.836	7.103	0.785
181.500			10.518	0.982	9.131	0.944	8.125	0.833	6.923	0.762
211.500			10.714	0.983	9.457	0.946	8.462	0.832	6.746	0.750
241.500			11.074	0.984	10.223	0.948	9.071	0.834	6.643	0.744
271.500					10.741	0.948	9.823	0.835	6.718	0.741

Outer diameter of Lateral	= 16 mm	Emitter spacing	= 3.0 m
Inner diameter of Lateral	= 12.77 mm	Slope direction	= downward

Table 2 Maximum permissible length of trickle laterals in combination of lateral diameters, different emitter spacing and different slopes (upward & downward slope

Outer diameter of lateral mm	**Outlet spacing m**	**Slope 0%**	**M**									
			Slope	**= 2%**	**Slope**	**= 4%**	**Slope**	**= 6%**	**Slope**	**= 8%**	**Slope**	**= 10%**
			up slope	**down slope**	**up slope**	**down slope**	**up slope**	**down slope**	**up slope**	**down slope**	**up slope**	**down slope**
12 *	0.5	23.25	20.25	27.25	18.25	31.25	16.25	32.25	14.25	36.25	12.2	45.250
	1.0	36.50	29.50	42.50	22.50	52.50	18.50	60.50	14.50	70.50	12.5	80.50
	1.5	46.75	36.75	57.75	26.25	72.25	0.250	82.75	15.00	94.75	13.0	112.75
	2.0	55.00	40.00	73.00	27.00	91.00	21.00	105.0	14.00	112.75	11.0	118.00
	2.5	63.75	43.75	88.75	28.25	108.75	18.75	118.75	13.75	121.25	8.75	131.25
16	3.0	73.50	46.50	96.50	28.50	128.50	18.50	141.5	13.50	152.50	7.50	158.50
	0.5	42.25	33.25	55.25	28.25	65.20	20.70	82.25	15.25	97.25	13.2	110.00*
	1.0	66.50	45.50	85.50	29.50	112.50	21.50	138.50	16.50	160.50	12.2	65.50*
	1.5	81.75	50.75	116.75	33.75	161.75	22.50	173.75	17.75	176.75	11.2	75.75*
	2.0	99.00	55.00	151.0	34.00	225.00	20.00	261.00	16.00	296.00	10.0	91.00*
	2.5	113.75	58.75	196.25	31.25	261.50	19.75	296.25	13.75	331.50	10.75	111.25*
	3.0	123.50	60.50	211.50	30.25	271.50	20.50	311.50	12.50	361.50	10.50	121.50*

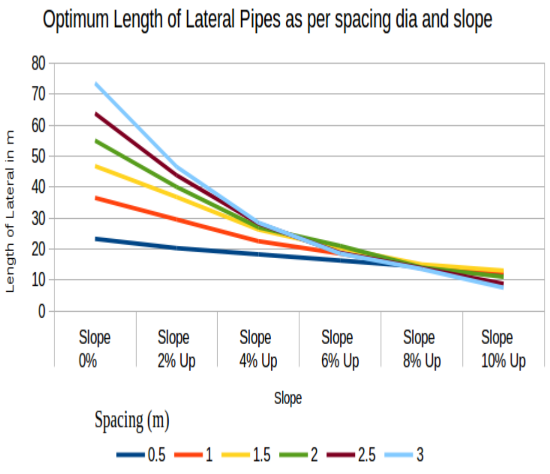

Fig.5 Optimum Length of Lateral Pipes as per spacing and lope for 12 mm pipe for upward slope per spacing and slope

The total discharge of lateral is compared with the desired discharge in the lateral: The difference of calculated and desired discharge gives the error. Depending on mathematical sign of error again a trial optimum head is worked out by modifying the range of pressure head so as to come closer to the real operating head. The procedure is repeated again and again till the error comes within the prescribed limit of ± 0.0001. The concerned operating head is optimum operating head.

With this optimum operating head, pressure head at every emitter is worked out and discharge of every emitter on lateral is found by head-discharge relationship. Uniformity coefficient is worked out by Eq. (3) the optimum operating head can be obtained for several combinations of lateral diameters, slopes, lengths, emitter spacing. The flowchart of this computer model is given in Fig.4

RESULTS: TESTING THE NUMERICAL MODEL FOR PERFORMANCE

The sample run of the model for 16mm dia laterals with different slopes and emitter spacing as giben below

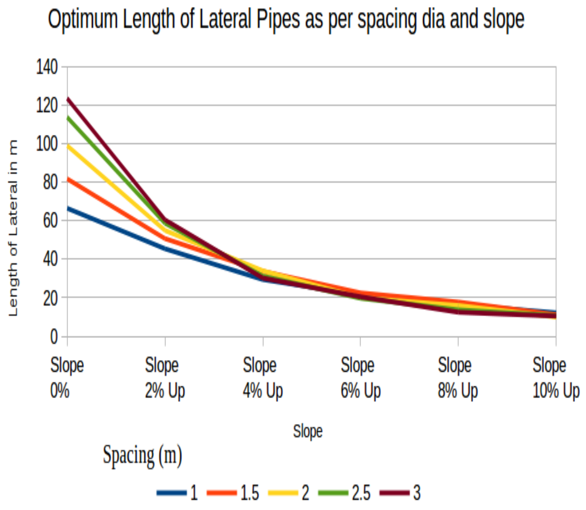

Fig.6 Optimum Length of Lateral for 16 mm pipe for upward slope

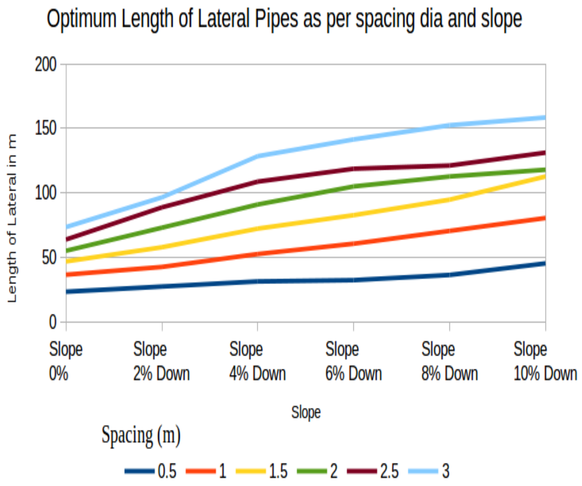

Fig. 7 optimum length of lateral pipes for 12 mm at downward slopes

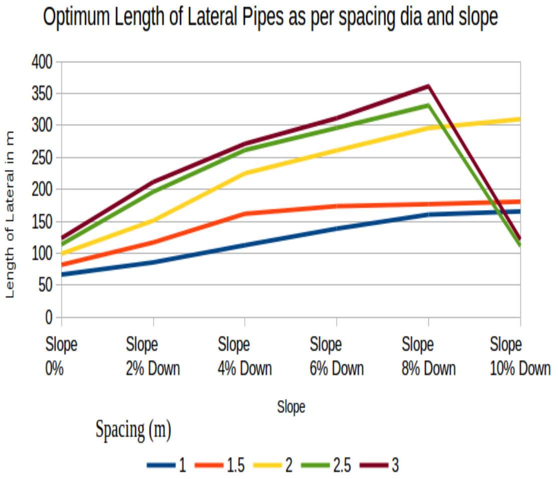

Fig 8 optimum length of laters for16mm at downward slopes

It is very clear from table 1 , table 2 and Fig 5, 6, 7, and 8 that the daimeter and slope are the decising factor for the selection of length of lateral in pressurized irrigation. In upward slope the optimum length of lateral decreased with slope on given discharge and diameter while in downward slope the trend is increasing with the slope. Although pressure head is available for greater length but uniformity coefficient decreases below 80% i.e. lateral performs poorly, hence length of lateral is limited.

CONCLUSION

The exercise to find the optimum length of the pipes in pressurised flow is worked out for irrigation using drip system by using computer model based on numerical method derived to achieve the inlet pressure of pipes, the length of lateral and uniformity coefficient. This work can be used to develop nomograms for design of multioutlet pressurised irrigation system.

References

Amoozeger - Ford A., Warrick A. W. and Lomen D. O., 1 Nomographs for Trickle and Subsurface Irrigation", *Journal of i and drainage*, ASCE, 110 (IR2)

Bralts V. F., Larry J. S., 1985 "Finite Element Analysis of Drip I Submain Units", published by ASAE Vol:28(3)

Clemmens A. J., 1986 "A Statistical Analysis of Trickle Irrigation Uniformity", ASAE, *Journal*

Cuenca R. FI., Irrigation system Design, an engineering approach, Prentice Hall Publication

Christiansen J. F., 1942, "Irrigation by Sprinkling", University of California, Agr. Irp. Stc. Bulletin

Drip Irrigation - Water and Land Management Institute, Aurangabad, India, Publication no. 34

Finkel H. J., CRC Handbook of irrigation Technology Vol: 1, 1982 ed CRC Press, Inc. Boca Raton, Florida

Gill, P. E,, Murray, W. and Wright M. H. (1989), "Practical Optimization", Academic Press Inc., San Diego, California (90-91)

Gillespie V. F., Allan L. Phillips and I. Pai. WU, 1979, "Drip Irrigation Design Equations", *Journal of irrigation and Drainage*, ASCE, Vol: 105(1 R3)

Hathoot H. M., Ahmed I. Al. A., Mohammad F. S., 1993 "Analysis and Design of Trickle Irrigation Laterals", journal of Irrigation and Drainage, Vol; 119

Hathoot H. M., Abo. Ghober H. M., Ahmed I. Al. A., Mohammad F. S., "Analysis and Design of Trickle Irrigation Laterals", *journal of Irrigation and Drainage*, Vol: 120, No: 3 May/June 1994, ASCE

Holzptal E. A., Migvel A. Marino and Alejandro V. Z., 1990, "Drip Irrigation Non Linear Optimization Model", *Journal of Irrigation and Drainage*, Vol: 116, July/Aug 1990.

Liu, H. and Meng, S. "Optimizaion of Mechanical Design", Tsinghua University Press, Beijing China (45-52)

Kang and Nishiyama, March/Apr 1996, "Analysis and Design of Microirrigation Laterals, ASCE Vol: 122 No.2 Journal of Irrigation and Drainage.

Nakayama F. S. and D. A. Bucks, 'Trickle Irrigation for Crop Production", Design Operation and Management, ed Elsevier, Tokyo

Scallopi Edmor J., 1988, Adjusted "F" Factor for Multiple outlet pipes, *Journal of Irrigation Drainage*, ASCE Vol: 114

Warrick A. W. and Yitayew, 'Trickle Lateral Hydraulics-I: Analytical Solution" and 'Trickle Lateral Hydraulics-ll : Design and Examples", 1988, *Journal of Irrigation and Drainage*, Vol : 114, No. 2, May 1988

Watters, G. Z. and Keller J. (1978), "Trickle Irrigation Tubing Hydraulics", ASAE paper no. 78-2015 American

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