SENSITIVITY ANALYSIS OF FARMERS' DEGREE OF FREEDOM (E) ON CANAL CAPACITY IN SECOND CLEMENT'S MODEL

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ABSTRACT

The on-demand delivery method, gives a considerable flexibility to farmers that can manage water in the best way and according to their needs. When the irrigation networks are designed On-demand, one of the proper tools for flow determination is Clement's model which has two sub models, namely First and Second, Clement's model(Monserrat et al. 2004). The latter is based on the Markovian stochastic theory of birth and death processes. In this paper, the impacts of variation of the parameter E on canal capacity were investigated. to this end, the real data of East-Aghili canal was studied and the Second Clement's model was applied. The results have shown that in general, the canal capacity increases by increasing E. Additionally, for higher values of E, in spite of the high discharge variations, its rate of change is constant. On the contrary, for lower values of E, the flow variations are less, and its rate of change vary for different E. Moreover, for high values of E and high values of irrigation time (T'), the canal capacity has the same sensitivity to both E and T'. Furthermore, it could be stated that the Clement's model can be used for On-systems by considering some limitation on input parameters of the model. It should be noted that in this paper the "On-request" method, is considered as a synonym of "Arranged" method.

Keywords : Second Clement's model, On-demandmethod,Farmerdgree of freedom, Water distribution networks.

1. INTRODUCTION

Among water distribution methods in the irrigation networks, the On-demand method has been developed during the recent decades with substantial profits. Higher distribution efficiency, saving a large quantity of water, and preventing water loses are some advantages of this method(Planells Alandi et al. 2001). By definition, in On-demand method, farmers can make decision for operating time and the quantity of water consumption without informing the system manager. Thus, the most important challenges for designing an irrigation network for On-demand system, is to determine the canal capacity.Since farmers are free for their own irrigation practices,it is not logical to consider accumulative discharge of all turnoutsfor determination of the canal capacity. Hence,one of the applicable tools for determination canal capacity is Clement's model. This model uses probablistic approaches for flow determination and it has two sub-models namely First and Second, Clement's model. In both models, the design capacity is determined with respect to short-term peak demand, considering an average cropping pattern for the whole system. Since farmers control their irrigation in On-demand method, the number and the positionof the turnouts which operating simultaneously is not known in advance.Clement's model uses probabilistic approach for estimating the accumulative discharge of intakes which receive water simultaneously(Sagardoy 2000).The Clement's model is based on three hypotheses (Pérez-Sánchez et al. 2018):

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- Hypothesis 1: A turnout can have only two states: open with a discharge di (nominal discharge of turnouts),orcompletly closed.
- Hypothesis 2: The probability of opening of a turnout(pi)is constant in a certain period, i.e. there isno priority for operation on certain days or times of day.
- Hypothesis3:Theturnoutoperation is independently and randomly.
- The FirstClement's model considers normal distribution, and the second modelis based on the Markovian stochastic theory of birth and death processes. Three main parameters in Second Clement's model are: farmer dgree of freedom (E), saturation probability (Psat), andthe operating time of the network (T').
- The main objective of this paper was to investigate the impacts of variation of the parameter E on canal capacity, considering different ranges of E, T', and Psat. To this end, the real data of the East Aghili canal, located in the Aghili irrigation network (south-west Iran), was studied and the Second Clement's model was applied.

2. METHODS

In this study,the real data of the East Aghili canal, located in the Aghili irrigation network (south-west Iran), was investigated.The length of this canal is about 16.215 KMequipped with 21 turnouts.Thecapacity is 5 m3/s. Table 1 gives the characteristics of East-Aghili's turnouts.

Table 1. Characteristics of East-Aghili's turnouts

Turnout number	Interval between turnouts (m)	Area(km)	Nominal discharge (l/s)
1	832	10.8	43.26
2	1098	18.73	80.74
3	460	24.16	76.41
4	845	25.72	99.53
5	1315	22.25	67.5
6	618	25.91	112.82
7	495	59.94	330.65
8	1260	28.73	142.02
9	125	35.04	176.7
10	1115	40.74	208.56
11	955	33.98	183.84
12	720	33.45	171.24
13	980	30.53	170.55
14	1115	35.65	210.28
15	965	36.92	191.57
16	1000	32.72	205.3
17	20	14.4	73.74
18	1545	49.86	274.19
19	47	8.63	51.02
20	1058	53.85	334.55
21	0.5	20.67	136.1

Equation 1, is defined as the Second Clement's formula to determine canal capacity(Clément 1966).

$$Q_k = \sum_{i=1}^{R} P_i d_i + u' \sqrt{\sum_{i=1}^{R} P_i (1 - P_i) d_i^2} \qquad (1)$$

Where:
Qk : the total discharge flows downstream of a section k (m3/s)
R: the total number ofturnoutsdownstream of section k
Pi:probability that a turnout is open
di:nominal discharge of a turnout (l/s)
u' :the standard normal variable
qi :probability that a turnout is closed

The probability (pi)that a turnout is open,is calculated with the equation (2) and (3).

$$P_i = \frac{t'}{T'} \qquad t' = \left(\frac{q_s\, A\, T}{R\, d}\right) \qquad T' = r\, T \qquad (2)$$

Where:
t': the average operation time of each turnout during the peak period (h)
T': the operating time of the network (h)
qs: the specific continuous discharge (l s-1 ha-1)
A: the irrigatedarea (ha)
T: the duration of the period ofanalysis (24 h)
r: thecoefficient of utilization of the network

$$P_i = \frac{q_s A_p}{r\, d_i} \qquad (3)$$

Where:
Ap: area of the plot irrigated by the turnout (ha)
Three important parameters in second Clement's model are the probability of saturation of a network (Psat), the operating time of the network (T'), and farmer degreeof freedom (E), which defined as below:

Psatis the probability that accumulative discharge of turnouts which receive water simultaneously, matches canal capacity, and it is calculated by equation (4) to (8).

$$u' = \frac{N - R\, P}{\sqrt{R\, p(1 - p)}} \qquad (4)$$

Where:
N: the number of turnouts simultaneously operating

$$P_{SAT} = \frac{1}{\sqrt{R\, p(1 - P)}} \frac{\Psi(u')}{\pi(u')} \qquad (5)$$

Where:
$\Psi(u')$and$\pi(u')$: the Gaussian probability distribution functions

$$F(u') = \frac{\Psi(u')}{\pi(u')} \, (6)$$

The equation(5) becomes as the equation (7):

$$P_{sat} = \frac{1}{\sqrt{R\,p(1-P)}}\,F(u') \tag{7}$$

$$F(u') = P_{SAT}\sqrt{RP(1-P)} \tag{8}$$

F(u') can be calculated from equation (8) or from the Figure 1 that representing F(u') as a function of u'(Sagardoy 2000).

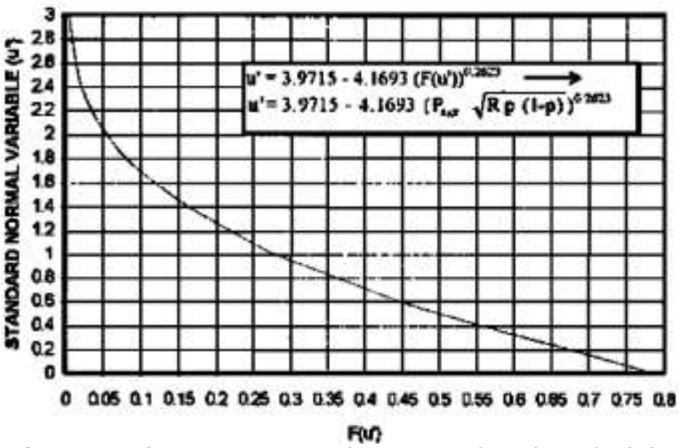

Figure 1. Diagram representing u' as a function of F(u')

E isFarmer dgree of freedom, which is the average elasticity of the turnout or the freedom granted to farmers toirrigate with a flow higher than nominal flow.Some effective parameters on determination of E are size of plots, the on-farm equipment, availability of labor, and frequency of irrigation.

For determination of canal capacity at the intake, the second Clement's model was applied for Psat= 5%, different irrigation time, ranging from4 to 20, hr., and, different values of E ranging from 1 to 8.

3. RESULTS AND DISCUSSION

Table 2 showes the canal capacity at the intake, for different Irrigation time and farmers degree of freedom, using Clement's second model. The saturation probability is considered to be 5%.

T' (h)	**4**	**8**	**12**	**16**	**20**
E	**Q (m3/s)**				
1	-	-	-	2682.12	2206.26
2	-	5364.24	3893.4	3201.24	2682.12
3	-	5970.34	4153.28	3504.33	3449.03
4	10382.4	6402.48	4845.12	4598.7	4598.7
5	11031.3	6921.6	5748.38	5748.38	5748.38
6	11680.2	7267.68	6898.06	6898.06	6898.06
7	12112.8	8047.73	8047.73	8047.73	8047.73
8	12458.9	9197.41	9197.41	9197.41	9197.41

Figure 2 shows the thedischarge variation fordifferent operational conditions.

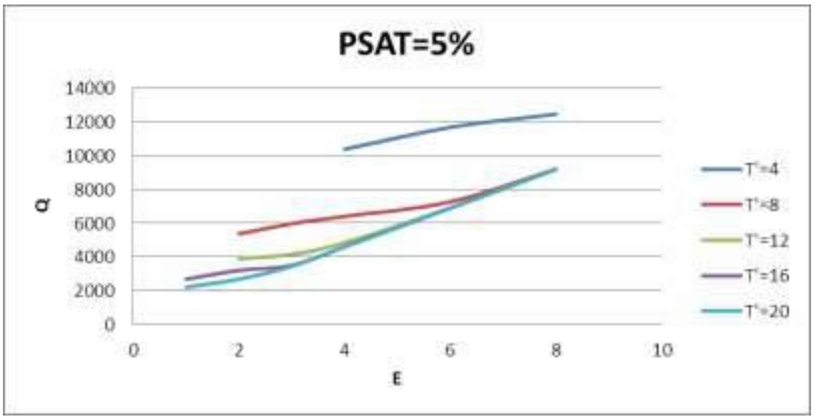

Figure 2. Diagram of the discharges in different operational condition

The results show that in general the canal capacity is increased by increasing E and decreasing T'. For a certain operation time, higher values of E results in higher canal capacity, however the rate of discharge variation remains constant. For instance, for T'=20h, for the values of E from 4 to 8, the slope of discharge variation is constant and ΔQ is equal to 1150 for one unit variation of E. On the contrary, for lower values of E the flow variations are less, and vary for different E. For example, for T'=20, one unit increase in E from 1 to 2, has resulted to ΔQ=475.86 l s-1, while for the variation of E from 2 to 3 ΔQ is increased to 766.91 l s-1. As a general conclusion it could be stated that for high values of E (more than 6) and high values of T' (more than 12h), the canal capacity has the same sensitivity to both E and T'. For lower values of E the operation time could be decreased down to certain level, for operation period less than that, the water requirement could not be satisfied.

4. CONCLUSION

It can be concluded that the Second Clement's model could be used for On-demandsystems by considering some limitations on the inputs parameters, E and T'. On-demand method is applicable on the constructed irrigation networks which are operated under manual upstream control, with rotational delivery schedule. In that case, the flexibility of the network is increased, and water losses reduced. To this end, considering physical conditions of the network, the Second Clement's model could be applied, using low values of E (1 to 3) and relatively high values of T' (8 to 20).Hence, this model could be applicable for achieving the optimum capacity of canals, considering the physical specifications of canals, environmental conditions, and the amount of available water.

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