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DESIGN OPTIMIZATION OF IRRIGATION PIPE NETWORK USING DIFFERENT CONVENTIONAL TECHNIQUES

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ABSTRACT

Conventional method for supplying water for irrigation in India by canal networks has certain limitations such as huge seepage losses, evaporation losses, land acquisition problems, thefts etc. To overcome these limitations canal network is replace by pipe network, if design efficiently and can reduce significant amount of water losses; but Cost of pipe network is almost 70% of the total project. This cost can be reduced by efficient and optimal design of piped irrigation network. In the present study design of the pipe distribution network has been carried out using EPANET 2.0 and critical path method for Bakhari Distributary of Pench, Irrigation Project, and the respective cost has been calculated. The design results obtained from critical path method have been optimized using linear programing and cost head loss ratio method, and respective cost has been compared. Both techniques resulted in to a distinct reduction in the overall cost of irrigation water distribution network over EPANET 2.0 based design. Total cost saving up to 18.64% has been achieved by using linear programing, whereas 17.81% using cost head loss ratio method for the design of present case study area. In cost head loss ratio method, a modified approach is adopted to convert obtained optimized diameters of pipe into commercially available sizes of pipe. The methodology can be further extended to large pipe irrigation networks to reduce the present canal losses, there by optimizing the water use.

Keywords: *Pipe Irrigation System, Critical Path Method, Cost Head Loss Ratio Method, EPANET 2.0, LINGO 17.0, Optimization.*

INTRODUCTION

Agriculture plays admirable role in India's economy almost 70% population relied on agriculture sector [1]. The maximum percentage of the rural households be contingent on agriculture as their principal means of livelihood [2]. Water demand in present scenario is increasing rapidly in all sectors like domestic, industrial and agricultural due to the various reasons [3]. It is crucial for irrigation engineer to design efficient irrigation system [4]. Existing irrigation canal system has various shortcomings such as 45%-50% of seepage losses [5] and evaporation losses, thefts are the serious issues along with maintenance of the canal. To overcome these issues existing canal system is to be replaced by pressurize system i.e., pipe network. The pressurize system consist of the key components as, reservoir, pipes, pumps, valves, hydrants etc. [6]. Irrigation system are generally two types viz. branch and loop network. Irrigation network system for existing irrigation projects is a branching type. Loop system is more reliable as alternate routes are available for conveying water to the demand nodes [7, 8]. But it is costlier than branch type network and complex in nature as far as design is concerned. Reliability is preferred to economy [1]. Therefore, branch systems are mostly used in irrigation network system [6]. The aim of the present work is to get the optimal design for given irrigation water distribution pipe network using both the optimization techniques and their comparison on the basis of cost (i.e. total cost of network using EPANET 2.0).

The main objective of the study is to minimize the global cost of the piped irrigation network without violating any design constraints and compare both optimization technique on basis of total cost of a given case study area. There are two types of constraint i.e. flexible and rigid constraint [9]. Flexible constraints include parameters flexible in nature i.e. minimum velocity (0.6m/s), maximum velocity (2.5m/s), minimum head (0.6m) requirement etc. [10] and rigid constraints includes parameters which cannot be violated i.e. minimum head loss[9], minimum pressure at junction node etc. Rigid constraint used in formulating a model in linear programing method [6] with LINGO 17.0 solver, which provide a global optimal solution on the basis of given constraint. In the present study the topology of the irrigation network, water requirement i.e. demand are predefined and the optimization is oriented to find the minimum cost of piped irrigation network. A case study of Bakhari distributary of Pench Irrigation Project is taken and design is carried out by EPANET 2.0 using flexible constraints [11]. This irrigation network is also designed by critical path method [9] and optimized by both optimization technique i.e. linear programing technique [6] and cost head loss ratio method [9]. In linear programing technique LINGO 17.0 solver is used in which flexible as well as rigid constraints are incorporated to solve optimization problem. Results obtained by both approaches have been compared.

METHODOLOGY

Study Area

The area selected for the present study is Bakhari distributary of Pench irrigation project (latitude and longitude are 21.326337, 79.187586). Index map of study area is shown in Fig. 1. The field data used in this study is collected from water resources department (irrigation

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department), Nagpur. Pench irrigation project is multipurpose project with objective of irrigation, domestic and industrial water supply. The main dam is constructed on river Pench, a distributary of river Kanhan in Godavari basin. Dam is located near NavegaonKhairy village in Nagpur district of Maharashtra, has left, and right bank canal (LBC & RBC) system to irrigate 104476 ha annually. The dam has the gross storage capacity of 230 Mm^3 and the live storage capacity is 180 Mm^3. The LBC has the total length of 32.850 km with design discharge of 90 cumec at a head to irrigate 73900 ha, while the RBC has a length of 484 km With design discharge of 28.4 cumec to irrigate 30576 ha annually. Besides irrigation, the RBC supplies water to Nagpur Municipal Corporation and thermal power stations at Koradi and Khaperkheda.

The distributary selected for study is located in the Kanhan branch canal of LBC of Pench irrigation project. Kanhan branch canal is the first branch canal off taking at running distance of 13.625 km at right side of LBC. Length of Kanhan branch canal is 14.5 km. It has two sub branches namely, Warada sub branch and Kanhan sub branch, and five distributaries namely Bakhari distributary, Warad, Tekadi distributary, Gahuhiwara distributary and Kanhan tail distributary. Bakhari distributary off takes from Warada sub branch canal of Bakhari Distributary at running distance of 5565 m on left side. Total length of this distributary is 18.865 km. The command area lies in Nagpur district. It is a ridged unlined canal having irrigation area on both side. The canal network of Bakhari distributary consist of 16 minors and 33 nodes from which 17 are direct outlets (DO). The off taking distances and lengths of all the channels in the Kanhan branch canal is shown in Table 1. Running distances of direct outlets, elevations and demands under each outlet are given in Table 2.

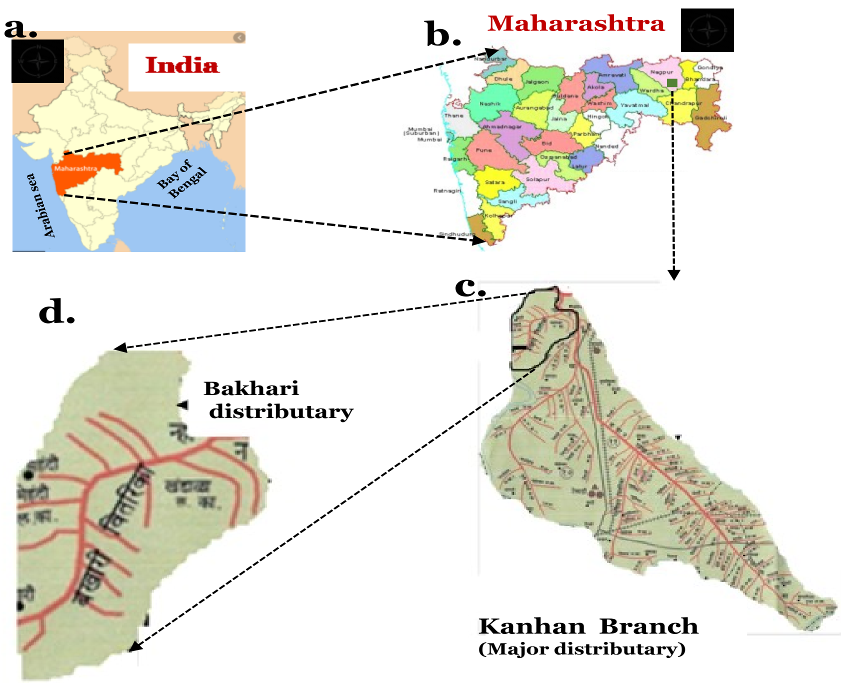

Fig. 1:Study area a. India; b. Maharashtra state; c. Kanhan Branch Panch Irrigation Network; d. Bakhari Distributary

Table 1: Details of Channels in Kanhan branch canal

(Source: Pench Irrigation Divison, Nagpur)

Name of Canal	Off taking Canal	Off taking Distance (m)	Length (m)
Kanhan branch	L.B.C	13625 (R) or (RD)	14500
Bakhari distributary	Kanhan branch	990(R)	5205
Warada sub branch	Kanhan branch	4710(R)	1380
Warada distributary	Warada sub branch	1410(R)	5940
Tekadi distributary	Warada sub branch	1410(L)	5910
Gahuhiwara distributary	Kanhan branch	9810(R)	7440
Kanhan sub branch	Kanhan branch	14500	5910
Kanhan tail distributary	Kanhan sub branch	5910	6360

Table 2: Details of Discharge Outlet, Nodes and Linksof Pipe Network

([12] Source: Pench Irrigation Divison, Nagpur)

Node ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Demand (L/s)	0	141	0	62	0	62	0	50	0	99	0	61	0	61	0	142	0
Elevation (m)	306.255	305.455	305.877	305	305.683	305.057	305.615	305	304.09	302	302.855	302.552	302.682	302.376	302.536	301.996	302.423
Link ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Length (m)	50	1200	685	825	390	940	135	500	155	2250	470	455	345	460	270	810	170
Flow (m^3/min)	84.654	8.46	76.194	3.72	72.474	3.72	68.754	3	65.754	5.94	59.814	3.66	56.154	3.66	52.494	8.52	43.974
Node ID	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	Reservoir 1
Demand (L/s)	132	0	61	61	0	61	0	31.5	0	78.7	0	138.7	0	0	56	113	-
Elevation (m)	301.763	301.97	301.564	301.67	301.597	301	301.31	300	301.083	300	300.96	300.36	300.784	300.684	300	300	308.48
Link ID	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
Length (m)	990	680	610	450	560	510	430	510	340	900	185	900	265	150	480	285	
Flow (m^3/min)	7.92	36.054	3.66	3.66	28.734	3.66	25.074	1.89	23.184	4.722	18.462	8.322	10.14	10.14	3.36	6.78	

Analysis of Network Using EPANET

The layout of pipe network is extracted from the base map of the study area and is prepared in EPANET version 2.0. The entire distribution network consists of 33 pipes, 33 junctions, 1 source reservoir from which water is transferred by pressure which is shown in Fig.2.Steps followed in EPANET**,** assigning the units of flow as L/s, fix the head loss formula to Hazen – Williams (H – W), Nodal demands and elevations of nodes are given to the network as an input and hydraulic properties like length, diameter, roughness etc. are to be assigned to the network based on the method of importing into EPANET platform [13, 14]. Input parameters are assigned for analysis using EPANET is shown in Table 2After assigning input data to network, thoroughly check the pipes and nodes are connected properly at intersections and reservoir nodes.Run the hydraulic analysis. Pipe diameters are given to the network by trial-and-error method. Combination of pipes should satisfy the following conditions. Sizes used should be available in market.Velocity range in all pipes should satisfy the minimum and maximum limits.All nodes should have positive pressures. Cost of pipe irrigation network is to be calculated.

Using Critical Path Method and Optimization by Linear Programing Technique

Using same input parameters as used in EPANET, the optimization of the network had been carried out to optimize the diameters and minimize the total cost of pipes, by formulation of linear programing model. Steps followed, Using the critical path method initial diameters as per given demands and minimum head available are calculated. Then objective function is defined to obtain the optimal solution [9].

Objective function: $\text{Min. } C = \Sigma C_{pipes}$ (1)

$$\text{Min T.C.} = \sum_{j=1}^{Nl} \sum_{j=1}^{Ncp} C_{ij} \, . \, L_{ij} \quad (2)$$

Where, $C \text{ pipes} = \sum_{n=1}^{N_l} k \, . \, L_x . D_x^m$ (3)

Constraints are, defined using minimum head available condition.

$H_j^{avl} \geq H_j^{min.}$

$h \leq H_o - H_j^{min.}$

$$H_o - H_j^{min.} \geq \sum_{x \in p} \frac{k_1 . L_x . Q_x^q}{C_{Hwx}^q . D_x^r} \quad (4)$$

$$H_o - H_j^{min} \geq \sum_{i=1}^{Nl} \sum_{j=1}^{Ncp} S_{ij} . L_{ij} \quad (5)$$

$$L_{ij} \geq 0 \quad (6)$$

Model formulation in the form of the objective function and constraints is solved using LINGO 17.0 solver as an input, shown in annexure 2.0. Program is run to get a global optimal solutionand outputs are total cost, lengths of links and corresponding diameter of pipes.

Using Critical Path Method and Optimization by Cost Head Loss Ratio Method

Using same input parameters as used in EPANET, the optimization of the network had been carried out to optimize the diameters and minimize the total cost of pipes.Using critical path method [9] initial diameters as per given demands and minimum head available are calculated. To optimize design, an optimality criterion as per cost head loss ratio method suggested by Bhave is given below.In the given optimization problem, decision variable is Hji.e. head at the junction (j=1,2……. n)

For optimality, $\frac{\partial C}{\partial H_j} = 0$, j=1,2,……..n (7)

Where, C = Total cost pipe = Σ $C_{ij} +$ Σ C_{jk} (8)

$C_{ij} = k L_x. D_x^m$ (9)

$h = H_i - H_j = \frac{k_1.L_x.Q_x^q}{C_{Hwx}^q.D_x^r} D_x^r = \left\{\frac{k_1.L_x.Q_x^q}{C_{Hwx}^q.H_f}\right\}$ (10)

$D_X = \left\{\frac{k_1.L_x.Q_x^q}{C_{Hwx}^q.H_f}\right\}^{\frac{1}{r}}$ (11)

From equation number 8, C = Σ C_{ij}+ Σ C_{jk}

$= \Sigma k L_x. \left\{\frac{k_1.L_x.Q_x^q}{C_{Hwx}^q.H_f}\right\}_{ij}^{\frac{m}{r}} + \Sigma k L_x. \left\{\frac{k_1.L_x.Q_x^q}{C_{Hwx}^q.H_f}\right\}_{jk}^{\frac{m}{r}}$ (12)

$= \Sigma Y_{ij}\left[H_i - H_j\right]^{-\frac{m}{r}} + \Sigma Y_{jk}\left[H_j - H_k\right]^{-\frac{m}{r}}$ (13)

Where,$Y_{ij} = \Sigma k L_x. \left\{\frac{k_1.L_x.Q_x^q}{C_{Hwx}^q}\right\}_{ij}^{\frac{m}{r}}$ (14)

For optimality at junction j

From equation (7),$\frac{\partial C}{\partial H_j} = 0$, j=1,2,……..n

$\frac{\partial}{\partial H_j}\left\{\Sigma Y_{ij}\left[H_i - H_j\right]^{-\frac{m}{r}} + \Sigma Y_{jk}\left[H_j - H_k\right]^{-\frac{m}{r}}\right\} = 0$, j=1,2,…..n

(15)

On simplification gives, $\Sigma\left(\frac{mC}{h}\right)_{ij} = \Sigma\left(\frac{mC}{h}\right)_{jk}$ (16)

As we assumed initial head for first iteration using the critical path method [9], this assumed head need to be corrected and hence correction at the junction head (i.e.ΔH_j) is apply,From equation number (16),

$\Sigma\left(\frac{m_{ij}C_{ij}}{H_i - (H_j + \Delta H_j)}\right)_{ij} = \Sigma\left(\frac{m_{jk}C_{jk}}{(H_j + \Delta H_j) - H_k}\right)_{jk}$ (17)

On simplification $\Delta H_j$is, $\Delta H_j = \frac{-\Sigma_{IJ}\frac{mC}{h} + \Sigma_{jk}\frac{mC}{h}}{\Sigma_{ij}\frac{mC}{h^2} + \Sigma_{jk}\frac{mC}{h^2}}$ (18)

Where, ΔHj Correction applies to the junction head so that optimal solution isobtained.

Iterations are carried out till the termination, termination criteria as per cost head loss ratio method is ΔH approximately zero or the total cost reduction in iteration is 50%[9]. After getting optimized diameter, these diameters are converted into commercial size of pipe available. In cost head loss ratio method optimal slope(S*) is calculated on the basis of minimum cost at a particular junction [9].

Where as in this present study optimal slope is calculated based on optimal diameter.

Where, $S^* = \frac{k_1.Q_x^q}{C_{Hwx}^q.(D^*)_x^r}$

S1 and S2 are the slope of energy line according to the larger diameter of pipe and smaller dimeter pipe which is commercially available. Total cost of irrigation is to be calculated.

RESULTS AND DISCUSSION

EPANET Version 2.0

Hydraulic analysis results from EPANET for network are shown in Table 3 and Fig. 2. Pressure and available head in each node, velocity, flow, diameter of pipes and head loss in each pipe is shown in Table 3. These data are used for the further analysis with minimum and maximum pressure head of 0.43 m and 2.4 m respectively. Fig. 2 shows elevation and pressure head available at junction in meter. By knowing these two hydraulic parameter analyses of the given network is carried out and corresponding diameter required for a water demand (as shown in Fig.2) is to be calculated.

Table 3 shows the details of cost, dimeter provided and corresponding length of link in mater and rate of pipe material in rupees per meter. Total thus cost is calculated. Network designed using EPANET satisfied the design criteria considered for pressurized pipe networks. Velocity of water in the network is almost more than 0.6 m/s for all the pipes and also satisfied minimum head required at node. Total cost of irrigation pipe network based on EPANET 2.0 design is 10.489 crore, (0.556 crore per km) of pipe length considering all diameters.

Critical path method and Linear programingtechnique with LINGO 17.0 Solver

Using same input hydraulic parameter i.e., demand, length, velocity, pressure head etc. and design is done by CPM and optimized by LP technique with LINGO solver 17.0. As per CPM, critical path for given network are found to be 0-1-3-5-7-11-13-15-17-19-22-24-26-28-29 and 28-30-31-33 respectively (as shown in appendix 1.0) corresponding to this critical path design is carried out further. After finding diameter model formulation in LINGO solver 17.0 and this model solve for global optimal solution. Output provided i.e., length and diameter by LP technique with LINGO solver 17.0 as tabulated below in table 4.

Optimal length obtained from LP technique [16] is in fractional form. Hence rounded this length to near values, so that it is easy to provide in the field. Length and corresponding diameter are provided in actual pipe irrigation based on commercially available pipe sizes network as shown in table 4. Network designed using CPM and LP approached [17] satisfied the design criteria considered for pressurized pipe networks. Velocity of water in the network is almost more than minimum requirement for all the pipes and also satisfied minimum head required at each node**.** Total cost of irrigation pipe network obtained based on the said approach is 8.533 crore (0.4523 crore per km) of pipe length considering all diameters.

Critical Path Method and Optimization using Cost Head Loss Ratio Method

Results in terms of obtained from critical path method and optimized by cost head loss ratio method and conversion of obtained optimal diameter in to commercially available

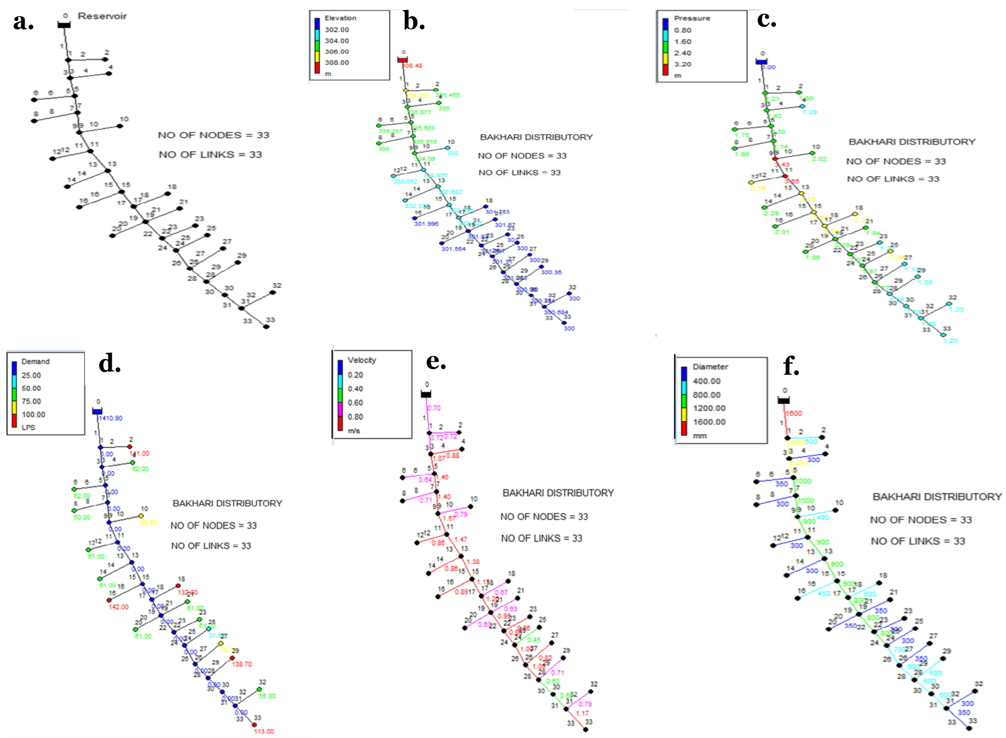

Fig 2: a. Pipe Network of Bakhari distributary (EPANET) b. Elevation at nodes c. Pressure at nodes d. Demand at nodes e. Velocity in each pipe (m/s) f. Design diameter of pipe (mm)

Table 3: Calculated Cost Details as per Commercial Sizes of Pipes

([12]Report on Schedule of Rates (2012), Maharashtra Jeevan Prabhakaran urban and rural schemes Aurangabad)

Link ID	Length (m)	Diameter (mm)	Rate (Rs/m)	Total cost (Rs)	Link ID	Length (m)	Diameter (mm)	Rate (Rs/m)	Total cost (Rs)
Pipe 1	50	1600	23347	1167350	Pipe18	990	500	4071	4030290
Pipe 2	1200	500	4071	4885200	Pipe 19	680	900	8969	6098920
Pipe 3	685	1500	20951	14351435	Pipe 20	450	350	3110	1399500
Pipe 4	825	350	3110	2565750	Pipe 21	610	350	3110	1897100
Pipe 5	390	1200	13964	5445960	Pipe 22	560	900	8969	5022640
Pipe 6	940	350	3110	2923400	Pipe 23	510	350	3110	1586100
Pipe 7	135	1200	13964	1885140	Pipe 24	430	900	8969	3856670
Pipe 8	500	350	3110	1555000	Pipe 25	510	250	1931	984810
Pipe 9	155	1100	12053	1868215	Pipe 26	340	800	7197	2446980
Pipe 10	2250	450	3635	8178750	Pipe 27	900	400	3407	3066300
Pipe 11	470	1100	12053	5664910	Pipe 28	185	700	5802	1073370
Pipe 12	455	350	3110	1415050	Pipe 29	900	500	4071	3663900
Pipe 13	345	1100	12053	4158285	Pipe 30	265	600	5035	1334275
Pipe 14	460	350	3110	1430600	Pipe 31	150	600	5035	755250
Pipe 15	270	1000	10505	2836350	Pipe 32	480	350	3110	1492800
Pipe 16	810	500	4071	3297510	Pipe 33	285	450	3635	1035975
Pipe 17	170	900	8969	1524730	Total cost (Rs)				104898515

diameter and cost of pipe, materials is refer from two regional reports [18, 19]. Table 5 shows the provided sizes of pipe and corresponding length. Optimal diameter got by using Cost Head Loss Ratio Method is as shown in table 5. In this study cost head loss ratio method is used to optimize pipe network design. This is an iterative method, in this present study 13 iteration are carried out. It is found that after iteration 11 (i.e., iteration 12, 13) cost reduction is negligible; hence iterations are stop. Table 5 show provided sizes of pipe and corresponding length. While converting discrete obtained pipe diameter in to commercially available pipe sizes using interpolation between slopes, length is divided into fraction form. Hence it is difficult to provide directly this obtained length, so need to be rounded off to nearest values. It is found that a negligible effect on total cost of network after rounding length of pipes.

Network designed using CPM and Cost Head Loss Ratio Method approach satisfied the design criteria considered for pressurized pipe networks. Velocity of water in the network is almost more than minimum requirement for all the pipes and also satisfied minimum head required at node. Total cost of pipe irrigation network is 8.62 crore, (0.4569 crore per km) of pipe length considering all diameters. But optimality loses due to conversion of obtained pipe diameters in to commercially available sizes of pipe. In table 5 (last column) shows the recommended diameter as adopted in the practice, so that it is convenient for joining larger diameter to smaller diameter. Total cost of pipe irrigation network as per recommended diameter is 8.81 crore, (0.4673 crore per km) of pipe length.

CONCLUSIONS

In the present study comparisons are made in optimization technique for a given case study area and following conclusions are drawn. The total cost of the irrigation pipe network at Bakhari distributary from EPANET 2.0 is 10.489 crore. Total cost of irrigation pipe network using linear programing and cost head loss ratio method is found to be 8.533 crore, 8.62 crore respectively. In optimization using linear programing, 18.64% of the total cost of the network is to reduced whereas a 17.81% using cost head loss ratio method of optimization. Thus, linear programing method is simple as well as convenient for irrigation pipe water distribution network optimization, provided that initial diameters are calculated by using critical path method. Analysis and design by EPANET 2.0 are simple and easy but it is time consuming, as it is trial and error process. It is observed that optimality loss in cost head loss ratio method due to conversion of pipe sizes, into commercial sizes. Minimum 35% to 45% amount of water can be saved by replacing existing Irrigation canal with pipe networks. All the nodes have sufficient head, so it is easy to provide required amount of water to tail end users is assured. Pipe materials selected for study satisfied the design requirement with minimum cost.

Table 4: Output of LP Technique (Length and Diameter)

Pipe	Link	Length (m)		Diameter (mm)		Pipe	Link	Length (m)		Diameter (mm)	
		Actual	Provided	Actual	Provided			Actual	Provided	Actual	Provided
01	L11	50	50.00	1200	1200	17	L172	170.00	170.00	900	900
02	L21	318.160	318.00	500	500	18	L181	763.30	763.00	400	400
	L22	881.140	882.00	400	400		L182	226.70	227.00	350	350
03	L31	394.550	394.00	1100	1100	19	L192	680.0	680.00	800	800
	L32	290.450	291.00	1000	1000	20	L201	561.20	561.00	300	300
04	L41	816.720	816.00	300	300		L202	48.80	49.00	200	200
	L42	8.280	9.00	200	200	21	L211	382.00	382.00	300	300
05	L51	390.00	390.00	1100	1100		L212	68.00	68.00	200	200
06	L61	481.70	481.00	350	350	22	L222	560	560	700	700
	L62	458.30	459.00	300	300	23	L231	475.90	475.00	300	300
07	L71	111.87	111.00	1100	1100		L232	34.10	35.00	200	200
	L72	23.13	24.00	1000	1000	24	L242	430.00	430.00	700	700
08	L81	425.00	425.00	300	300	25	L251	119.55	119.00	300	300
	L82	75.00	75.00	200	200		L252	390.45	391.00	200	200
09	L92	155.00	155.00	1000	1000	26	L261	340.00	340.00	700	700
10	L101	1366.50	1366.00	400	400	27	L271	617.25	617.00	400	400
	L102	883.50	884.00	350	350		L272	282.75	283.00	350	350
11	L111	470.00	470.00	1000	1000	28	L281	185.00	185.00	700	700
12	L121	302.91	302.00	300	300	29	L291	690.67	690.00	500	500
	L122	152.09	153.00	200	200		L292	209.33	210.00	400	400
13	L131	345.00	345.00	1000	1000	30	L301	265	265.00	500	500
14	L141	322.50	322.00	300	300	31	L311	150.00	150.00	500	500
	L142	137.50	138.00	200	200	32	L322	480.00	480.00	300	300
15	L152	270.00	270.00	900	900	33	L332	285.00	285.00	350	350
16	L161	503.40	503.00	400	400						
	L162	306.60	307.00	350	350						

Table 5: CalculatedDiameter and Commercially Length and Sizes of Pipe Recommended

Link	Length m)	$D_{optimum}$(mm)	S*	Calculated diameter (D)		S_1	S_2	Calculated length ($L_{i,j}$) (m)		Recommended diameter (D) (mm)	
1	50	1170.55	0.001142	1200	1100	0.001012	0.001546	37.81	12.188	1200	1200
2	1200	416.38	0.002473	450	400	0.001695	0.00300	488.06	711.93	450	450
3	685	1115.62	0.001187	1200	1100	0.00083	0.001272	131.60	553.39	1200	1100
4	825	289.74	0.003163	350	250	0.00126	0.00648	524.72	300.27	350	250
5	390	1083.187	0.001250	1100	1000	0.00116	0.001845	338.56	51.431	1100	1100
6	940	312.26	0.002196	350	300	0.00126	0.00267	315.51	624.48	350	300
7	135	1050.39	0.001317	1100	1000	0.001052	0.001673	77.404	57.595	1100	1100
8	500	255.92	0.00388	300	250	0.001793	0.00435	91.524	408.47	300	250
9	155	1032.471	0.001318	1100	1000	0.00096	0.001541	60.155	94.844	1100	1000
10	2250	376.24	0.002106	400	350	0.001563	0.00299	1396.6	853.38	400	350
11	470	978.9	0.001434	1000	900	0.001293	0.00216	393.28	76.718	1000	1000
12	455	239.73	0.007722	250	200	0.00629	0.018664	402.50	52.494	250	200
13	345	959.9	0.001404	1000	900	0.001151	0.001922	231.50	113.49	1000	1000
14	460	244.85	0.006967	250	200	0.00629	0.018664	435.01	24.981	250	200
15	270	938.38	0.001384	1000	900	0.001016	0.001697	123.79	146.20	1000	900
16	810	378.95	0.00396	400	350	0.00304	0.00583	543.70	266.29	400	350
17	170	885.88	0.001320	900	800	0.001223	0.00217	152.43	17.568	900	900
18	990	383.88	0.003252	400	350	0.00266	0.0051	750.31	239.68	400	350
19	680	817.35	0.001353	900	800	0.00084	0.001503	154.55	525.44	900	800
20	610	273.08	0.00409	300	250	0.002591	0.00629	362.29	247.70	300	250
21	450	258.85	0.005314	300	250	0.002591	0.00629	119.16	330.83	300	250
22	560	745.43	0.001397	800	700	0.00098	0.001892	308.96	251.03	800	800
23	510	268.16	0.004474	300	250	0.002591	0.00629	250.71	259.28	250	200
24	430	706.249	0.001408	800	700	0.00076	0.001471	38.096	391.90	800	700
25	510	201.9	0.00524	250	200	0.001854	0.00549	34.634	475.36	250	200
26	340	686.04	0.001403	700	600	0.001272	0.00269	308.66	31.33	700	700
27	900	334.48	0.00244	350	300	0.001959	0.004151	701.10	198.89	350	300
28	185	620.03	0.001507	700	600	0.00083	0.001768	51.785	133.21	700	600
29	900	445.1	0.001733	450	400	0.001644	0.002917	836.37	63.62	450	400
30	265	457.59	0.002183	500	450	0.001418	0.00236	51.648	213.35	500	450
31	150	458.27	0.002168	500	450	0.001418	0.00236	31.717	118.28	450	450
32	480	302.26	0.002132	350	300	0.001044	0.002212	32.629	447.37	350	300
33	285	355.08	0.00356	400	350	0.001997	0.00382	40.397	244.60	350	300

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