An-Najah Univ. J. Res., Vol. 11, (1997) 1-21

Comparative Analysis of Techniques for Solving the Hydraulics of Pressurized Irrigation Pipe Networks

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Abstract

This study presents a comparative analysis for three techniques in analyzing the hydraulics of pressurized irrigation systems: Linear Theory, Newton Raphson, and Iterative Distal Outlet. It was found that the iterative distal outlet method uses less computer time and memory than Newton Raphson and Linear theory methods in analyzing the hydraulics of pressurized irrigation systems. The study shows that using an approximate initial solution for such systems, which can be obtained using Wu-Gitlin approach, will significantly improve the convergence rate of this iterative method as well as the other methods.

Introduction

Pressurized irrigation is used through trickle (drip) and sprinkler irrigation systems. Both systems utilize closed conduits or pipelines to transport water from the irrigation supply to individual outlets. Those outlets are emitters in trickle irrigation and sprinklers in sprinkler irrigation.

Analyzing the hydraulics of pressurized irrigation systems is necessary to estimate the pressure heads and discharge of individual outlets. The hydraulic and topographic situation of the system causes variations in pressure heads at each outlet. Therefore, variations in discharge are observed at individual outlets (excluding pressure compensating emitters where discharge is pressure independent). As the pressure variation increases, the uniformity of the system is reduced (Solomon, 1984).

Reducing the uniformity reduces the application efficiency at the farm (Mizyed, 1988) and thus increases water losses. To conserve water at the farm level, outlet discharge variations should be minimized to get a more uniform water application.

Evaluating the uniformity of any pressurized irrigation system is either done during design or operation. In the design stage, pressurized irrigation systems should be evaluated theoretically through evaluating their hydraulic performance to determine their uniformity. This evaluation is done to study the possibility of improving the design and asses the suggested design in an attempt to reach a better performance of the system. During operation, the system should be analyzed to evaluate its performance. As it is not always possible to measure outlet discharge in the field, analyzing the hydraulics of the irrigation system is essential in evaluating its uniformity (Mizyed and Kruse, 1989).

This study discusses and compares the performance of three different approaches in analyzing the hydraulics of pressurized irrigation systems. Performance parameters included memory requirements, number of iterations, computer time needed for analysis, and effects of improved initial solutions on the performance parameters for these iterative methods.

The importance of this study is related to the wide use of pressurized irrigation systems in the region. Most irrigated agriculture in the West Bank and Gaza is done through pressurized irrigation systems (Haddad and Mizyed, 1993). Also, more than 70% of fresh water is used in agriculture in the area. As water resources are limited, water conservation practices are highly needed especially in the agricultural sector. Thus, evaluating the hydraulics of irrigation systems will help in improving the design of irrigation systems and increasing control of irrigation water to achieve better application efficiencies and thus conserve water. Therefore, efficient methods for analyzing the hydraulics of such systems are necessary.

Hydraulics of Pressurized Irrigation Systems

Pressurized irrigation systems are usually a special type of pipe network known as a tree or branch type. Analyzing such systems can be done by several methods. These methods are based on solving energy and continuity equations for flow (Jeppson, 1976). These equations are usually written using two standard forms which are node and loop equations. As there are no loops in tree pipe networks (we usually have dead ends) the only form of equation applicable here is node equations.

Node equations are equations of continuity at each node, in the form of pressure heads at different nodes which are the unknowns. Therefore, the number of unknowns should be equal to the number of nodes with unknown heads in the system which is equal to the number of continuity equations. The continuity equation at each node is based on the principle of mass balance which means the total inflow rate into the node should be equal to the total outflow from the node. Inflow rates are expressed in terms of pressure heads at nodes in nonlinear relations. Thus, the result will be a system of nonlinear equations.

There is no direct general method to solve such systems of nonlinear equations. However, there are different methods available to solve such systems using trial and error. In all these methods, an initial solution is assumed and then a better solution is obtained. The process continues until the right solution is converged. The difference between these methods is usually related to how the current solution is improved. Thus, the convergence rates of these methods vary.

General Node equations

To illustrate the continuity equations, let us consider a pressurized irrigation system with 3 laterals and 2 outlets per lateral as shown in **Figure 1.**

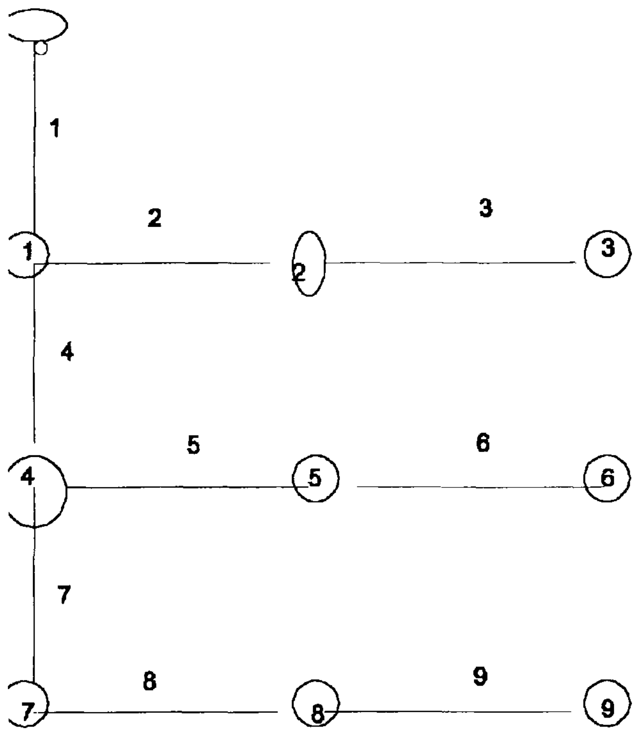

Figure 1: *Typical pressurized irrigation system*

In the above system, point "0" is the head of the system where a certain pressure head is applied. The vertical line (0 1 4 7) is manifold line where water is distributed to the laterals. Circles with the numbers 2, 3, 5, 6, 8, and 9 inside them shown in Figure 1 are outlets where water is discharged to the plant. The outlet discharge is given by (Keller and Karmeli, 1974):

$$q_j = K(H_j - EL_j)^X \tag{1}$$

Where: q_j: Outlet discharge rate at outlet j,

H_j: Hydraulic head at outlet j,

EL_j: Elevation of ground at outlet j,

K and X: Outlet constants determined experimentally.

Flow rate in any pipe is taken from friction head loss in the pipe which is given by Hazen Williams formula:

$$hf_j = C_j * Q_j^{1.85} \tag{2}$$

Where: Q_j : Flow rate in pipe number j,

hf_j: Head loss in pipe number j,

C_j: Pipe coefficient given by:

$$C_j = \frac{1.21 * 10^{10} * L_j}{CHW_j^{1.85} * D_j^{4.872}} \tag{3}$$

Where: L_j: length of pipe j in meters,

D_j: Diameter of pipe j in mm,

CHW_j: Hazen-Williams coefficient for pipe j.

To determine flow rate in a pipe from head loss along that pipe, Hazen-Williams can be written as:

$$Q_j = (\frac{hf_j}{C_j})^{0.54} \tag{4}$$

The head loss along the pipe can be written as the difference in head between the two nodes connected by the pipe. Considering nodes 1 and 2 connected by pipe #2 in Figure 1, the following equation gives flow rate in pipe #2:

$$Q_2 = (\frac{H_1 - H_2}{C_2})^{0.54} \tag{5}$$

Applying continuity equation to a node located on the manifold line such as # 4 in Figure 1, results:

$$Q_4 = Q_5 + Q_7 \tag{6}$$

Or,

$$\left(\frac{H_1 - H_4}{C_4}\right)^{0.54} = \left(\frac{H_4 - H_5}{C_5}\right)^{0.54} + \left(\frac{H_4 - H_7}{C_7}\right)^{0.54} \tag{7}$$

Applying continuity equation to a node located on a lateral line (outlet) such as #5 results in:

$$Q_5 = Q_6 + q_5$$

$$\left(\frac{H_4 - H_5)}{C_5}\right)^{0.54} = \left(\frac{H_5 - H_6}{C_6}\right)^{0.54} + K(H_5 - EL_5)^X \tag{8}$$

From the above equations, a set of simultaneous nonlinear equations can be formulated. Thus, solving the hydraulics of a pressurized irrigation system requires solving such a set of nonlinear equations. The following are three iterative methods for solving the hydraulics of pressurized irrigation systems. These are linear theory, Newton-Raphson and the iterative distal outlet methods.

Linear Theory method

Linear theory is based on linearizing the above set of nonlinear equations (Jeppson, 1976). Then, the set of resulting simultaneous linear equations will be solved using matrix analysis. The resulting matrix is a symmetric banded matrix which can be solved using its symmetry and banded characteristics to minimize computer time and memory (Bralts and Segerlind, 1985). The number of rows in the resulting matrix will be equal to the number of nodes in the system. The band width of the matrix is equal to the number of outlets per lateral plus two. Thus, a system with 30 laterals and 20 outlets in each lateral results in a matrix with 630 (30*21) rows and a band width of 22. Thus, a symmetric banded matrix with a size of 630X22 has to be constructed to solve such a system. However, if this property is not utilized, the size of the resulting matrix will be 630X630 which will require much more memory and computer time for processing. Therefore, solving large irrigation units might cause computer memory problems when using this method.

This method was used for the analysis and design of microirrigation laterals (Kang and Nishiyama, 1996a) where the band width of the resulting matrix is usually 2. To avoid running into computer memory problems resulting from large matrices, it is possible to approximate lateral lines into equivalent outlets and manifold line into a lateral (Kang and Nishiyama, 1996b). This approximation reduces the size of matrices significantly. In this study, all outlets and laterals in the system are considered in solving its hydraulics.

To explain how nonlinear equations are linearized, consider node #4 shown in Figure 1 where:

$$hf_4 = H_1 - H_4 = C_4 Q_4^{1.85} \tag{9}$$

In the above equation, $Q_4^{1.85}$ could be taken as $Q_{40}^{0.85} * Q_4$, where Q_{40} is the previous estimate of discharge in pipe #4. At convergence both the current estimate of discharge (Q_j) and the previous estimate of discharge in any pipe (Q_{j0}) are nearly equal (the difference is less than acceptable error) in all pipes of the system. Therefore, the flow rate in pipe #4 is given by:

$$Q_4 = \frac{H_1 - H_4}{C_4 Q_{4o}^{0.85}} \tag{10}$$

Applying continuity equation at node #4 as shown in eq. 7 and linearizing results:

$$-A_1 H_1 + A_4 H_4 - A_5 H_5 - A_7 H_7 = 0 \tag{11}$$

Where:

$$A_1 = \frac{1}{C_4 Q_{4o}^{0.85}} \tag{12}$$

$$A_5 = \frac{1}{C_5 Q_{5o}^{0.85}} \tag{13}$$

$$A_7 = \frac{1}{C_7 Q_{7o}^{0.85}} \tag{14}$$

$$A_4 = A_1 + A_5 + A_7 \tag{15}$$

Applying continuity equation to a node located on a lateral line such as node #5 (eq. 8) and linearizing results in:

$$A_4(H_4 - H_5) = A_6(H_5 - H_6) + K(H_5 - EL_5)^{X-1}(H_5 - EL_5) \tag{16}$$

Where H_{5o} is a previous estimate of head at node 5. The above equation is reduced to:

$$-A_4 H_4 + (A_4 + A_6 + K(H_{5o} - EL_5)^{X-1}) H_5 - A_6 H_6 = K * EL_5 * (H_{5o} - EL_5)^{X-1} \tag{17}$$

From the above equations, a system of nonlinear equations has been turned into a system of linear equations with a vector of unknowns H. The resulting system will be in the form of A H = B, in which A is a symmetric banded matrix. Each time the system is solved, matrix A is updated and the system is solved again until convergence. Convergence occurs when the maximum difference between the new vector H and the last calculated value for H is less than a certain specified value or allowable error (this was taken as 5 mm in the computer simulations for this study).

Newton Raphson Method

The set of nonlinear node equations is written in the form of F(H)=0 through moving all non zero terms to the left side of the equation. The solution is obtained using Newton Raphson technique utilizing the formula:

$$H^{m+1} = H^m - F(H^m)/F'(H^m) \tag{18}$$

The above formula is written as:

$$H^{m+1} = H^m - D^{-1} F(H^m) \tag{19}$$

Where D is the Jacobian matrix consisting of the derivative elements or,

$$D = \begin{pmatrix} \frac{\partial F_1}{\partial H_1} & \frac{\partial F_1}{\partial H_2} & \cdots \\ \frac{\partial F_2}{\partial H_1} & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{pmatrix} \tag{20}$$

The iterative formula could be written as:

$$H^{m+1} = H^m - Z \tag{21}$$

Where:

$$Z = D^{-1} * F(H^m)$$
$$D * Z = F(H^m) \tag{22}$$

Applying the above iterative method to a node located on the manifold line such as node #4, results in (see eq. 7):

$$F_4(H) = -(\frac{H_1 - H_4}{C_4})^{0.54} + (\frac{H_4 - H_5}{C_5})^{0.54} + (\frac{H_4 - H_7}{C_7})^{0.54} \tag{23}$$

while at a node located on a lateral line (node 5 for example), gives (see eq. 8):

$$F_5(H) = -(\frac{H_4 - H_5}{C_5})^{0.54} + (\frac{H_5 - H_6}{C_6})^{0.54} + K(H_5 - EL_5)^X$$

(24)

Taking the derivatives of eq. 24 gives:

$$\frac{\partial F_5}{\partial H_4} = -\frac{0.54}{C_5}(\frac{H_4 - H_5}{C_5})^{-0.46} \tag{25}$$

$$\frac{\partial F_5}{\partial H_6} = -\frac{0.54}{C_6}\left(\frac{H_5 - H_6}{C_6}\right)^{-0.46} \qquad (26)$$

$$\frac{\partial F_5}{\partial H_5} = -\frac{\partial F_5}{\partial H_4} - \frac{\partial F_5}{\partial H_6} + K * X * (H_5 - EL_5)^{X-1} \qquad (27)$$

The resulting Jacobian matrix will be a banded symmetric matrix which is utilized in solving the hydraulics of irrigation systems to minimize computer memory and time. The size of matrix needed will be equivalent to that needed using linear theory method.

Iterative Distal Outlet Method

Distal outlet method is used to estimate pressure and discharge distribution along a lateral or a manifold when pressure or discharge from the last distal outlet is known (Walker, 1980). However, if pressure is known at the inlet point (first point of a lateral or a manifold) the procedure has to be iterative. Therefore, solving a system as shown in Figure 1 where head at inlet point "0" is known and heads at all other nodes are unknowns will be as follows:

1. Start with an initial assumption for heads at all outlets in the system (could be taken as H_o or less).
2. From the head estimates above, discharge from each outlet is estimated using equation 1.
3. Using continuity principle and starting from the distal ends of laterals (the last outlet) discharge is estimated in each pipe segment or:

   $Q_9 = q_9$, $Q_8 = Q_9 + q_8$, $Q_7 = Q_8$

   $Q_6 = q_6$, $Q_5 = Q_6 + q_5$, $Q_4 = Q_5 + Q_7$, and

   $Q_3 = q_3$, $Q_2 = Q_3 + q_2$, $Q_1 = Q_2 + Q_4$.
4. From discharge and pipe characteristics, friction head losses are estimated in each pipe using equation 2.

5. Starting from inlet point "0", head at each outlet is estimated by subtracting friction losses from head at previous outlet, or:

   $H_1 = H_O - hf_1$, $H_2 = H_1 - hf_2$, $H_3 = H_2 - hf_3$,

   $H_4 = H_1 - hf_4$, $H_5 = H_4 - hf_5$, $H_6 = H_5 - hf_6$, and

   $H_7 = H_4 - hf_7$, $H_8 = H_7 - hf_8$, $H_9 = H_8 - hf_9$.

6. The new estimates of heads of step 5 are used for the following iteration and steps 3 to 5 are repeated until convergence (the maximum difference between heads estimated in step 5 and last estimates of heads is below a certain acceptable error value which was taken as 5 mm in this study).

It was found that it is possible in some cases to overshoot the answer or oscillate around it especially in poorly designed systems and poor initial solutions. Therefore, to improve the convergence of this method, it is recommended to use the average value of the pervious two iterations in the following iteration (instead of utilizing the new estimate for the next iteration) especially in the first few iterations. When convergence is reached, the last two iterations give equal estimates of heads and discharge (within allowable error).

Computer Simulation

The above three methods were used to formulate three computer programs (one for each method). These programs were compiled using microsoft FORTRAN compiler version 5.10. Then these programs were tested to solve several hypothetical examples of pressurized irrigation systems. Although these examples were hypothetical, they were taken from common practices and systems that farmers use in the West Bank. Characteristics of pipes and outlets were taken from the properties of irrigation systems in the field. Only dimensions of the systems were assumed. The assumptions for dimensions were made in a way to show most common sizes of irrigation systems in the field, starting from the smallest to the largest. Then, the three programs were used to analyze the hydraulics of these systems using the personal computer (main processor 80386DX-40 mhz with an 83D87 math processor). All programs used the same initial solutions for each system. Then computer time and memory were compared for the three methods.

Although changing computer speed and hardware affected computer time for the three methods, however, there was a trend for the three methods when they were compared with each other. The trend was in the pattern for the computer time and memory needed according to the size of the system and the method used in the analysis. The trend was clearly shown in the 14 systems shown in Table 1 (which were not the only systems analyzed but show a general trend which will be discussed later).

Table 1:
General description of the 14 irrigation systems used to show the trend of the performance of the different methods in analyzing the hydraulics of the systems.

System #	Number of laterals	Number of outlets /lateral	Total outlets	Total nodes	Inlet flow rate (l/s)
1	15	15	225	240	1.486
2	15	20	300	315	1.96
3	15	25	375	390	2.41
4	15	30	450	465	2.82
5	15	35	525	540	3.185
6	20	15	300	320	1.97
7	20	20	400	420	2.60
8	20	25	500	520	3.184
9	20	30	600	620	3.72
10	25	15	375	400	2.46
11	25	20	500	525	3.22
12	25	25	625	650	3.93
13	30	15	450	480	2.93
14	30	20	600	630	3.83
Diameter of laterals = 14 mm Diameter of manifold= 50 mm Spacing between laterals = 2 m Spacing between outlets = 2 m K = 0.0015 (l/m^x) X = 0.5 Inlet pressure head = 20 m Land slope 0 both directions			Flow rate was found from the three methods which converged to the same flow rate for each system regardless to initial solution. Number of nodes is the number of unknown heads in the system.		

Results of Computer Simulation

The three methods succeeded in converging to the same results for each system used. It was found that Newton Raphson method used the minimum number of iterations while the iterative distal outlet method used the maximum number of iterations. However, iterative distal outlet method used minimum time while linear theory method used the maximum computer time. This result could be attributed to the fact that Newton Raphson method is a efficient technique which usually converges fast to the solution. However, it requires evaluating the first derivative at each node with respect to each unknown (the Jacobian matrix shown in equation 20). The result is a large matrix which requires a significant computer time to evaluate its inverse. Linear theory method required evaluating the inverse and multiplying large matrices which requires a significant amount of computer time. The iterative distal outlet method is an iterative method which does not utilize a lot of theory in deciding how to go to the next solution. Thus, it needed the maximum number of iterations. However, this method does not require finding the inverse of large matrices. Thus, computer time needed for each iteration is minimal. Therefore, the net time needed for such method is lower than other methods.

With computer memory, iterative distal outlet method required the least amount of memory. This method required memory to save hydraulic head, flow rates, pipe characteristics and physical characteristics of the system. The maximum matrix needed for this is usually a row matrix with a size equal to the number of nodes in the system. Newton Raphson and Linear Theory methods required large memory to store additional matrices. In addition to the characteristics of the system, nodal heads, nodal discharge and pipe flow rates needed in iterative distal outlet, the Jacobian matrix was needed in Newton Raphson method. In linear theory method, a linearized matrix A which is equal in size to the Jacobian matrix was needed. These matrices were symmetric and banded which reduced their sizes. The sizes of these matrices were still large even after utilizing their symmetry and sparse characteristics. These matrices had rows equal to the number of nodes in the system and band widths equal to the number of outlets per lateral plus two. Thus, a system with 650 nodes and 25 outlets per lateral required a matrix of size 650X27, or a matrix with 17550 elements. Thus, the biggest setback for

Newton Raphson and Linear theory methods in analyzing the hydraulics of pressurized irrigation systems is the size of memory needed. This problem is high especially in drip irrigation if we want an exact solution considering all outlets in the system. Memory requirements restrict the use of linear and Newton Raphson methods when large irrigation systems with thousands of laterals are to be analyzed. Such systems require approximation by reducing the number of outlets in them to be solved using linear and Newton Raphson methods. However, no approximation for such systems is needed when iterative distal method is used as long as vectors of sizes equal to the number of outlets could be fit in the computer memory.

Table 2 illustrates the above results, showing number of iterations, computer time and memory needed for the three methods when applied to the 14 systems mentioned above. Table 2 clearly shows that the number of iterations needed in analysis was minimum for Newton Raphson technique and maximum for iterative distal method. However, the time needed for iterative distal outlet method was minimum and was maximum for linear theory method. Time needed by linear theory was always more than that needed by iterative distal outlet and Newton Raphson methods.

Table 2:
Results of Hydraulic analysis for the 14 systems using an arbitrary initial solution for the three methods of analysis.

	Computer Time			Number of iterations			Size of Matrix	
System	Linear	Newton	Distal	Linear	Newton	Distal	Linear & Newton	Distal
1	6.0	5.2	1.5	10	8	25	4080	240
2	12.5	9.8	1.9	10	8	25	6930	315
3	19.0	17.0	2.1	9	8	24	10530	390
4	37.0	27.0	2.5	11	8	24	14880	465
5	60.0	40.6	2.7	12	8	23	19980	540
6	9.2	10.3	2.4	11	12	31	5440	320
7	15.7	13.2	2.8	10	8	30	9240	420
8	24.8	22.8	3.1	9	8	27	14040	520
9	48.8	27.3	3.8	11	6	29	19840	620
10	11.2	8.5	3.3	11	8	36	6800	400
11	20.3	12.4	3.6	10	6	31	11550	525
12	31.3	21.4	4.7	9	6	34	17550	650
13	14.0	10.3	3.7	11	8	35	8160	480
14	24.0	14.9	6.6	10	6	49	13860	630
Avg.	23.8	17.2	3.2	10.2	7.7	30.1		

Effect of Initial Solution

To study the effect of a better initial solution on the time needed for the three methods, an approximate initial solution was estimated for each system. This solution was taken using Wu-Gitlin approach (Wu and Gitlin, 1975) which gives an approximate solution assuming uniform flow along lateral lines and exponential pressure head distribution. Initial solutions using Wu-Gitlin approach were estimated for each system in the simulation and then each system was solved using the three methods. The results for the 14 systems are shown in Table 3.

Table 3 shows the effect of improving the initial solution on computer time and number of iterations for the three methods. As expected, an improved initial solution increases convergence speed for the three methods. Thus, computer time (in Table 3, the time needed for estimating the initial solution was included in total computer time) needed to analyze each system reduced as we improved the initial solution. However, the sensitivity of Newton Raphson and Linear theory methods was less than that for iterative distal outlet method. The time needed for distal outlet method reduced significantly when the initial solution was improved. From Table 3, we can also see the effect of improving the initial solution on the number of iterations needed by each method. The number of iterations reduced significantly for the three methods. However, the reduction in number of iterations for distal method was much more than the reduction for other methods (Newton-Raphson and linear theory methods). As a result of improving initial solution, the number of iterations needed by distal outlet method became competitive to that needed by Newton Raphson method. Thus, improving initial solution made the distal outlet method superior to Newton-Raphson and Linear theory methods in terms of computer time, and similar in terms of number of iterations. Iterative distal method is always superior to the other two methods in terms of computer memory requirements.

Table 3:
Results of Hydraulic analysis for the 14 systems starting with approximate initial solutions (obtained using Wu-Gitlin method) for the three methods of analysis.

System	*Computer Time*			*Number of iterations*		
	Linear	*Newton*	*Distal*	*Linear*	*Newton*	*Distal*
1	5.8	4.7	0.2	5	3	3
2	9.7	6.5	0.3	6	3	3
3	13.1	8.3	0.4	5	3	4
4	26.1	12.2	0.3	7	3	3
5	47.6	17.5	0.7	9	3	5
6	6.4	4.3	0.3	5	3	3
7	9.9	6.8	0.5	5	3	5
8	16.0	10.9	0.5	5	3	4
9	43.4	15.5	0.6	9	3	4
10	7.9	5.2	0.4	5	3	5
11	12.1	8.4	0.6	5	3	5
12	24.2	12.6	0.4	6	3	3
13	8.2	6.3	0.5	5	3	5
14	14.8	9.4	0.7	5	3	5
Average	**17.5**	**9.2**	**0.5**	**5.9**	**3.0**	**4.0**

Considering the type of initial solution used in the solution, we found that in general any initial solution could be assumed for iterative distal outlet (considering only possible values of pressure heads). The better the initial solution, the better is the convergence rate. In linear theory and Newton Raphson, we cannot assume equal pressure heads in the system as these heads will indicate zero flows in pipes and thus problems with division by zero. Other than that, any initial solution could be assumed.

Conclusions

It was found through analyzing the hydraulics of many pressurized irrigation systems that iterative distal outlet method requires less computer time, less computer memory and less mathematics compared with linear theory and Newton Raphson methods starting from the same initial solution. Thus, it is recommended to use iterative distal outlet method in analyzing pressurized irrigation systems. An approximate initial solution improves the convergence rate of this method as well as the other methods. It was shown in this study that Wu-Gitlin approach could be used to estimate an initial approximate solution. Although using fast computers reduces the time needed by any method, computer memory remains a constraint especially in large irrigation systems. As the iterative distal method requires minimum memory, it is suitable for use in analyzing such large systems to reach exact solutions.

Acknowledgment

The author would like to acknowledge Dr. Abdul Razzaq Touqan for providing a computer subroutine to solve linear systems with symmetric banded matrices and for his ideas regarding the use of finite element method in solving the hydraulics of pipe networks.

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Notations

q_j:	Outlet discharge rate at outlet j
H_j:	Hydraulic head at outlet j
EL_j:	Elevation of ground at outlet j
K and X:	Outlet constants determined experimentally
Q_j :	Flow rate in pipe number j
hf_j:	Head loss in pipe number j
C_j:	Pipe coefficient
L_j:	Length of pipe j in meters
D_j:	Diameter of pipe j in mm
CHW_j:	Hazen-Williams coefficient for pipe j
Q_{j0}:	Previous estimate of discharge in pipe #j

مقارنة تحليلية لطرق مختلفة في تحليل هيدروليكا انظمة شبكات الري المضغوط

نعمان مزيد

ملخص

تعرض هذه الدراسة مقارنة تحليلية لثلاث طرق في تحليل هيدروليكا شبكات الري المضغوط. تشمل هذه الطرق : النظرية الخطية وطريقة نيوتن-رافسون وطريقة المخرج الأخير المتكـــررة. وجد ان طريقة المخرج الأخير المتكررة تستخدم زمن وذاكرة حاسوب اقل من طريقتي النظريـــة الخطية ونيوتن - رافسون في تحليل هيدروليكا شبكات الري المضغوط . تبين هذه الدراسة ان استعمال حل ابتدائي تقريبي لهذه الانظمة بواسطة طريقة وو-جتلن التقريبية تحسن كثـــيرا مـــن سرعة الوصول الى الحل عند استعمال هذه الطريقة والطرق الأخرى.