CHAPTER IV
PROGRAM TESTING

4.1   Part I: Pipe and pump system

4.1.1 Data input

The program was used to simulate the piping system of water transmission tunnels in the area at East Bangkok, in the Metropolitan Waterworks Authority. This particular network, which shown in Figure 4.1, is a part of the treated water transmission and distribution systems and is supplied from a surge tank connected to the transmission pumping station.

The system contains 37 nodes and 36 nodal connections. Nodes 1 and 23 are connected to the pumping station with specified pressures of 7.75 and 7.59 bars respectively.

The PICCOLO code, a commercial package designed for the water transmission tunnel system, is normally used for computing the pressures and flow distribution of the pipeline network. The model network, as shown in Figure 4.2, have been used for calibrating parameters by comparing computed pressures and flows with those measured in the field test according to operational demand supplied to the customers.

The test of the Pipe, Pump and Channel Network Simulator (PCN) was done by simulating the pipeline network in Figure 4.2, and comparing the results with those obtained from PICCOLO.

The initial data used in the simulation are as follows:

Number of nodes $\quad = \quad 37$

Viscosity $\qquad\qquad\qquad = \qquad 1.0 \qquad$ mPa-s

Density $\qquad\qquad\qquad = \quad 1000.0 \qquad$ kg/m^3

Number of pipelines $\qquad = \qquad 36$

Number of pumps and channels $=\qquad 0$

Maximum number of iteration $\quad = \qquad 50$
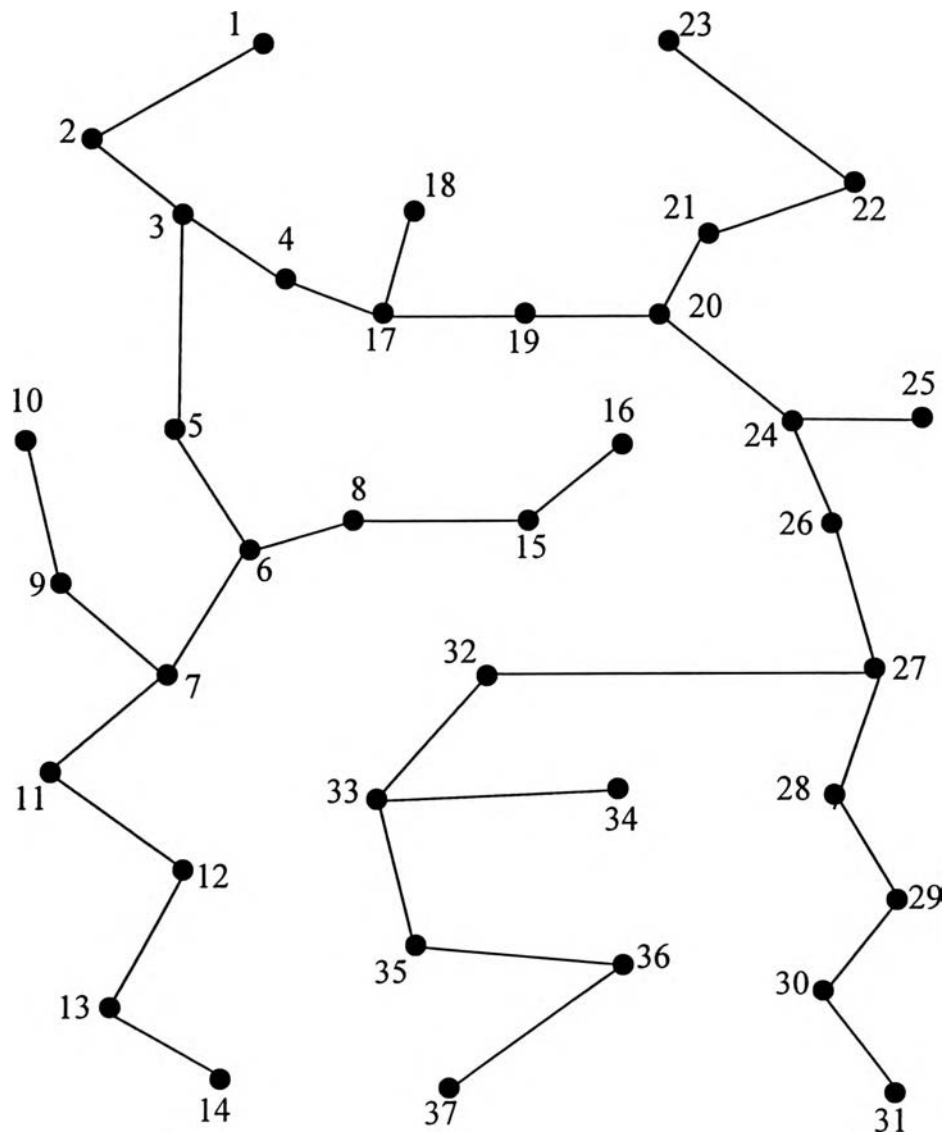
Figure 4.1 Sketch of the network of water transmission tunnel system
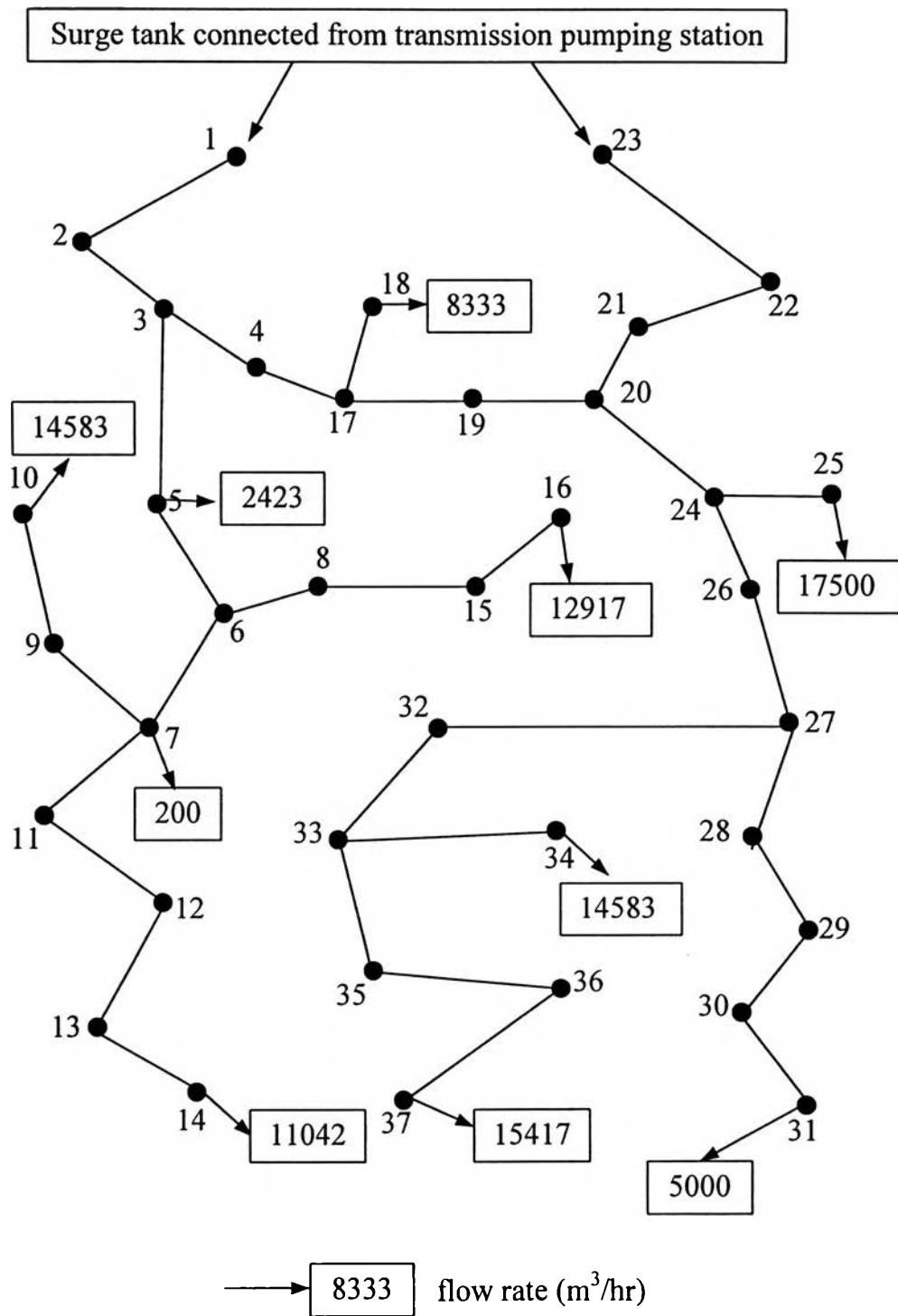
Figure 4.2 Water transmission tunnel system with demand flow rate

The other data that are used as the input parameters in the program are shown in Tables 4.1 through 4.5.

Table 4.1 Data for water transmission pipeline connections

I	J	C(I , J)	D(I , J)	L(I , J)	FF(I , J)	E(I , J)
1	2	1	3200	2892.00	0.0075	0.5
2	3	1	3200	1770.00	0.0075	0.5
3	4	1	2000	520.80	0.0075	0.5
4	17	1	2000	1619.21	0.0075	0.5
5	6	1	2800	5400.00	0.0075	0.5
6	7	1	2000	650.00	0.0075	0.5
6	8	1	2500	538.37	0.0075	0.5
7	9	1	2000	3680.00	0.0075	0.5
7	11	1	1500	4278.00	0.0075	0.5
8	15	1	2500	1859.63	0.0075	0.5
9	10	1	1800	290.00	0.0075	0.5
11	12	1	2000	1740.00	0.0075	0.5
12	13	1	1500	3180.00	0.0075	0.5
13	14	1	1500	250.00	0.0075	0.5
15	16	1	2000	700.00	0.0075	0.5
17	18	1	1800	290.00	0.0075	0.5
17	19	1	2000	1485.48	0.0075	0.5
19	20	1	2000	514.52	0.0075	0.5
20	21	1	3000	2230.00	0.0075	0.5
20	24	1	3000	3058.00	0.0075	0.5
21	22	1	3200	2459.00	0.0075	0.5
22	23	1	3200	4008.00	0.0075	0.5
24	25	1	2000	3025.00	0.0075	0.5
24	26	1	2300	50.00	0.0075	0.5
26	27	1	2300	1200.00	0.0075	0.5
27	28	1	2000	200.00	0.0075	0.5
27	32	1	2300	2500.00	0.0075	0.5
28	29	1	2000	9000.00	0.0075	0.5
29	30	1	2000	11000.00	0.0075	0.5
30	31	1	1800	400.00	0.0075	0.5
32	33	1	2300	3377.00	0.0075	0.5
33	34	1	1800	130.00	0.0075	0.5
33	35	1	2000	169.00	0.0075	0.5
35	36	1	2000	3178.00	0.0075	0.5
36	37	1	2000	2976.00	0.0075	0.5

where: I   =   upstream node

J   =   downstream node

C(I , J)   =   node connection type (1 means connected by a pipeline)

D(I , J)   =   pipeline diameter (mm)

L(I , J)   =   pipeline length (m)

FF(I , J) =   initial guess for the Fanning friction factor

(default = 0.0075)

E(I , J)   =   pipeline roughness (mm).

Table 4.2 Initial estimates and fixed pressures for water transmission system

I	P(I)	I	P(I)	I	P(I)
1	7.75	14	5.90	27	6.99
2	6.04	15	4.98	28	6.97
3	6.02	16	4.96	29	6.95
4	6.00	17	4.94	30	6.93
5	6.98	18	4.92	31	6.91
6	6.96	19	5.93	32	5.99
7	6.94	20	3.98	33	5.97
8	6.92	21	3.96	34	5.95
9	6.90	22	3.94	35	5.93
10	5.98	23	7.59	36	5.91
11	5.96	24	5.59	37	4.99
12	5.94	25	6.31	-	-
13	5.92	26	6.01	-	-

where: P(I)   =   nodal pressure at node I (bar)

Table 4.3 Node-types for water transmission system

I	T(I)	I	T(I)	I	T(I)
1	1	14	2	25	2
5	2	16	2	31	2
7	2	18	2	34	2
10	2	23	1	37	2

where: T(I)   =   node-type (1 = fixed pressure, 2 = fixed flow rate)

Table 4.4 Specified withdrawal rates for water transmission system

I	V(I)	I	V(I)	I	V(I)
5	2423.00	16	12917.00	34	14583.00
7	200.00	18	8333.00	37	15417.00
10	14583.00	25	17500.00	-	-
14	11042.00	31	5000.00	-	-

where: V(I) = specified withdrawal rate at node I (m^3/hr)

Table 4.5 Node elevations for water transmission system

I	Z(I)	I	Z(I)	I	Z(I)
1	20.80	14	38.40	27	33.10
2	23.18	15	23.99	28	33.10
3	23.63	16	37.28	29	30.00
4	26.64	17	36.00	30	36.00
5	23.97	18	38.23	31	37.30
6	23.98	19	33.92	32	30.00
7	30.00	20	33.20	33	36.00
8	23.98	21	33.10	34	38.29
9	36.00	22	33.10	35	22.06
10	38.48	23	33.00	36	30.00
11	41.00	24	33.10	37	39.50
12	41.00	25	37.70	-	-
13	36.00	26	33.10	-	-

where: Z(I) = nodal elevation at node I (m)

4.1.2 <u>Data output</u>

By setting the tolerance (ε) equals to 10^{-5}, the Newton-Raphson method gave convergence after 29 iterations. The results are shown in Tables 4.6 through 4.8.

Table 4.6 Calculated pressures for water transmission system

I	P(I)	I	P(I)	I	P(I)
1	7.75	14	2.12	27	5.31
2	7.28	15	5.98	28	5.31
3	7.09	16	4.63	29	5.49
4	6.80	17	5.88	30	4.76
5	6.75	18	5.65	31	4.63
6	6.04	19	6.11	32	5.07
7	5.24	20	6.19	33	3.74
8	6.03	21	6.65	34	3.50
9	4.26	22	7.00	35	5.07
10	3.96	23	7.59	36	3.91
11	2.95	24	5.69	37	2.63
12	2.84	25	4.77	-	-
13	2.42	26	5.67	-	-

Table 4.7 Calculated flow rates for water transmission system

I - J	Q(I , J)	I - J	Q(I , J)	I - J	Q(I , J)
1 - 2	43969.57	11 - 12	11041.98	24 - 26	34999.68
2 - 3	43968.92	12 - 13	11042.01	26 - 27	35000.07
3 - 4	2804.06	13 - 14	11042.01	27 - 28	5000.05
3 - 5	41165.09	15 - 16	12916.91	27 - 32	30000.20
4 - 17	2804.08	17 - 18	8332.99	28 - 29	5000.03
5 - 6	38741.75	17 - 19	-5529.05	29 - 30	5000.01
6 - 7	25825.04	19 - 20	-5528.83	30 - 31	4999.99
6 - 8	12917.09	20 - 21	-58028.65	32 - 33	29999.99
7 - 9	14583.01	20 - 24	52500.12	33 - 34	14583.01
7 - 11	11041.94	21 - 22	-58028.64	33 - 35	15417.50
8 - 15	12917.31	22 - 23	-58029.65	35 - 36	15417.02
9 - 10	14583.23	24 - 25	17500.03	36 - 37	15416.81

Note: minus sign (-) represents reverse flow direction.

Table 4.8 Calculated Fanning friction factors for water transmission system

I - J	FF(I , J)	I - J	FF(I , J)	I - J	FF(I , J)
1 - 2	0.00585	11 - 12	0.00671	24 - 26	0.00636
2 - 3	0.00585	12 - 13	0.00720	26 - 27	0.00636
3 - 4	0.00716	13 - 14	0.00720	27 - 28	0.00690
3 - 5	0.00604	15 - 16	0.00668	27 - 32	0.00637
4 - 17	0.00716	17 - 18	0.00692	28 - 29	0.00690
5 - 6	0.00605	17 - 19	0.00687	29 - 30	0.00690
6 - 7	0.00661	19 - 20	0.00687	30 - 31	0.00704
6 - 8	0.00636	20 - 21	0.00592	32 - 33	0.00637
7 - 9	0.00667	20 - 24	0.00592	33 - 34	0.00684
7 - 11	0.00720	21 - 22	0.00583	33 - 35	0.00666
8 - 15	0.00636	22 - 23	0.00583	35 - 36	0.00666
9 - 10	0.00684	24 - 25	0.00665	36 - 37	0.00666

4.2   Part II: Open channel network

4.2.1 Data input

The program was used to simulate the open channels system, which is the example network for *Open Channel Flow* (Chaudhry, M. H., 1993)

The system contains 6 nodes and 8 channels that are shown in Figure 4.3.

The author of this book used different assumptions and methods of calculation. The flow type of all channels in the network was considered as gradually varied flow and the results were computed by using a fourth-order Runge-Kutta method.

The Pipe, Pump and Channel Network Simulator (PCN) was tested by simulating a network with open channels so that its results would be compared with the results with the available data from the *Open Channel Flow*.

The initial data that are used in the simulation are

Number of nodes	=	9	
Viscosity	=	1.0	mPa-s
Density	=	1000.0	kg/m^3
Number of pipelines	=	1	
Number of pumps	=	0	
Number of channels	=	6	
Maximum number of iteration	=	50	
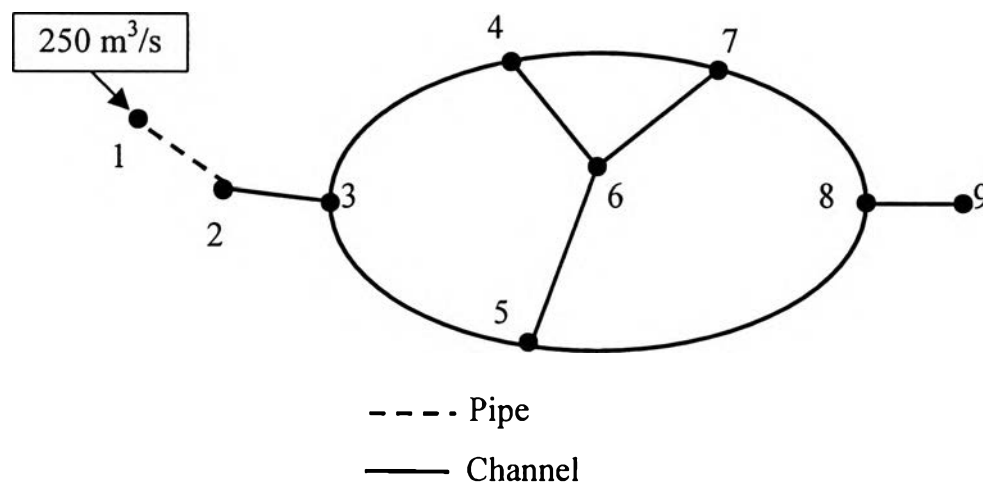
Figure 4.3 Network of example 6-3 from "Open Channel Flow"

The nodes used for comparison are nodes 3 to 8 and the other data that were used as the input parameters to the program are shown in Tables 4.9 through 4.13.

Table 4.9 Data for the example network

I	J	C(I , J)	w(I , J)	L(I , J)	FF(I , J)
3	4	3	30.0	200.0	0.08
3	5	3	40.0	200.0	0.06
4	6	3	20.0	100.0	0.12
4	7	3	20.0	200.0	0.10
5	6	3	25.0	100.0	3.00
5	8	3	50.0	300.0	0.12
6	7	3	20.0	100.0	0.11
7	8	3	30.0	100.0	0.07

where: I   =   upstream node

J   =   downstream node

C(I , J) =   node connection type (3 means connected by a channel)

w(I , J) =   channel bottom width (m)

L(I , J) =   channel length (m)

FF(I , J) =   Fanning friction factor

Table 4.10 Node elevations for the example network

I	Z(I)
3	10.00
4	9.90
5	9.90
6	9.85
7	9.80
8	9.75

where: Z(I) =   nodal elevation at node I (m)

The pressure at all node, P(I), in open channels system are 1 atmosphere so all node types, T(I), are equal to 1 because the pressures are fixed.

4.2.2 Data output

Table 4.7 Calculated flow rates and depths for the example network

I - J	Q(I , J)	h(I , J)
3 - 4	96.58	4.82
3 - 5	153.42	4.82
4 - 6	46.09	4.56
4 - 7	50.49	4.56
5 - 6	13.02	4.87
5 - 8	140.40	4.87
6 - 7	59.11	5.32
7 - 8	109.60	5.03

where: $Q(I , J) =$ flow rate from node I to J (m^3/s)

$h(I , J) =$ depth of channel I , J (m)