PART II

DESIGN CALCULATIONS – HYDRAULIC

MALIGAKANDA RESERVOIR SITE –
GRAVITY DRAIN FOR OVERFLOW / WASHOUT

Maligakanda Reservoir Site
Design of Gravity Drain for Overflow / Washout

R2 - Existing Circular Reservoir
R3 - New Maligakanda Reservoir

Scenario 1 - R2 and R3 Reservoirs Overflowing

Design Flow : MH1 - MH2 = 74,000 m3/day = .856 m3/s
: EMH - MH3 - MH4 - MH2 = 22,000 m3/day = .255 m3/s
: MH2 - Outfall = 96,000 m3/day = 1.111 m3/s
Manning N for RCC Hume Pipes : 0 .012

Segment No.	From MH	To MH	Length m	Flow m3/s	H/L	Dia m(")	d m	Full Cap. m3/s	Q max m3/s	% full	V m/s
1	MH1	MH2	40	0.856	0.025	.6 (24")	0.41	1.05	1.13	68.79	4.15
2	EMH	MH3	6	0.255	0.038	.375 (15")	0.23	0.36	0.38	63.31	3.62
3	MH3	MH4	32	0.255	0.038	.375 (15")	0.23	0.36	0.38	63.31	3.62
4	MH4	MH2	32	0.255	0.038	.375 (15")	0.23	0.36	0.38	63.31	3.62
5	MH2	MH5	14	1.111	0.025	.6 (24")	0.53	1.05	1.13	88.27	4.20
6	MH5	MH6	31	1.111	0.025	.6 (24")	0.53	1.05	1.13	88.27	4.20
7	MH6	MH7	30	1.111	0.050	.6 (24")	0.39	1.49	1.60	64.42	5.77
8	MH7	MH8	23	1.111	0.050	.6 (24")	0.39	1.49	1.60	64.42	5.77
9	MH8	MH9	52	1.111	0.050	.6 (24")	0.39	1.49	1.60	64.42	5.77
10	MH9	MH10	52	1.111	0.050	.6 (24")	0.39	1.49	1.60	64.42	5.77
11	MH10	MH11	47	1.111	0.050	.6 (24")	0.39	1.49	1.60	64.42	5.77
12	MH11	Outfall	116	1.111	0.019	.75 (30")	0.45	1.65	1.78	59.99	4.81

Scenario 2 - R3 Reservoir Overflowing

Design Flow : MH1 - MH2 = 74,000 m3/day = .856 m3/s
: EMH - MH3 - MH4 - MH2 = No Flow
: MH2 - Outfall =74,000 m3/day = 0.856 m3/s
Manning N for RCC Hume Pipes : 0 .012

Segment No.	From MH	To MH	Length m	Flow m3/s	H/L	Dia m(")	d m	Full Cap. m3/s	Q max m3/s	% full	V m/s
1	MH1	MH2	40	0.856	0.025	.6 (24")	0.41	1.05	1.13	68.55	4.15
2	EMH	MH3	6		0.038	.375 (15")					
3	MH3	MH4	32		0.038	.375 (15")					
4	MH4	MH2	32		0.038	.375 (15")					
5	MH2	MH5	14	0.856	0.025	.6 (24")	0.41	1.05	1.13	68.55	4.15
6	MH5	MH6	31	0.856	0.025	.6 (24")	0.41	1.05	1.13	68.55	4.15
7	MH6	MH7	30	0.856	0.050	.6 (24")	0.33	1.49	1.60	54.58	5.45
8	MH7	MH8	23	0.856	0.050	.6 (24")	0.33	1.49	1.60	54.58	5.45
9	MH8	MH9	52	0.856	0.050	.6 (24")	0.33	1.49	1.60	54.58	5.45
10	MH9	MH10	52	0.856	0.050	.6 (24")	0.33	1.49	1.60	54.58	5.45
11	MH10	MH11	47	0.856	0.050	.6 (24")	0.33	1.49	1.60	54.58	5.45
12	MH11	Outfall	116	0.856	0.019	.75 (30")	0.46	0.91	0.98	77.31	3.67

Scenario 3 - R2 Reservoir Overflowing

Design Flow : MH1 - MH2 = No Flow
: EMH - MH3 - MH4 - MH2 = 22,000 m3/day = .255 m3/s
: MH2 - Outfall = 22,000 m3/day = .255 m3/s
Manning N for RCC Hume Pipes : 0 .012

Segment No.	From MH	To MH	Length m	Flow m3/s	H/L	Dia m(")	d m	Full Cap. m3/s	Q max m3/s	% full	V m/s
1	MH1	MH2	40		0.025	.6 (24")					
2	EMH	MH3	6	0.255	0.038	.375 (15")	0.23	0.36	0.38	63.31	3.62
3	MH3	MH4	32	0.255	0.038	.375 (15")	0.23	0.36	0.38	63.31	3.62
4	MH4	MH2	32	0.255	0.038	.375 (15")	0.23	0.36	0.38	63.31	3.62
5	MH2	MH5	14	0.255	0.025	.6 (24")	0.20	1.05	1.13	33.54	3.07
6	MH5	MH6	31	0.255	0.025	.6 (24")	0.20	1.05	1.13	33.54	3.07
7	MH6	MH7	30	0.255	0.050	.6 (24")	0.17	1.49	1.60	27.74	3.91
8	MH7	MH8	23	0.255	0.050	.6 (24")	0.17	1.49	1.60	27.74	3.91
9	MH8	MH9	52	0.255	0.050	.6 (24")	0.17	1.49	1.60	27.74	3.91
10	MH9	MH10	52	0.255	0.050	.6 (24")	0.17	1.49	1.60	27.74	3.91
11	MH10	MH11	47	0.255	0.050	.6 (24")	0.17	1.49	1.60	27.74	3.91
12	MH11	Outfall	116	0.255	0.019	.75 (30")	0.20	1.65	1.78	26.29	2.70

Summary of Pipe Lengths .275 (15") = 70 m
.6 (24") = 289 m
.75 (30") = 116 m
Total =475 m

MALIGAKANDA RESERVOIR SITE – INLET / OUTLET SIZING

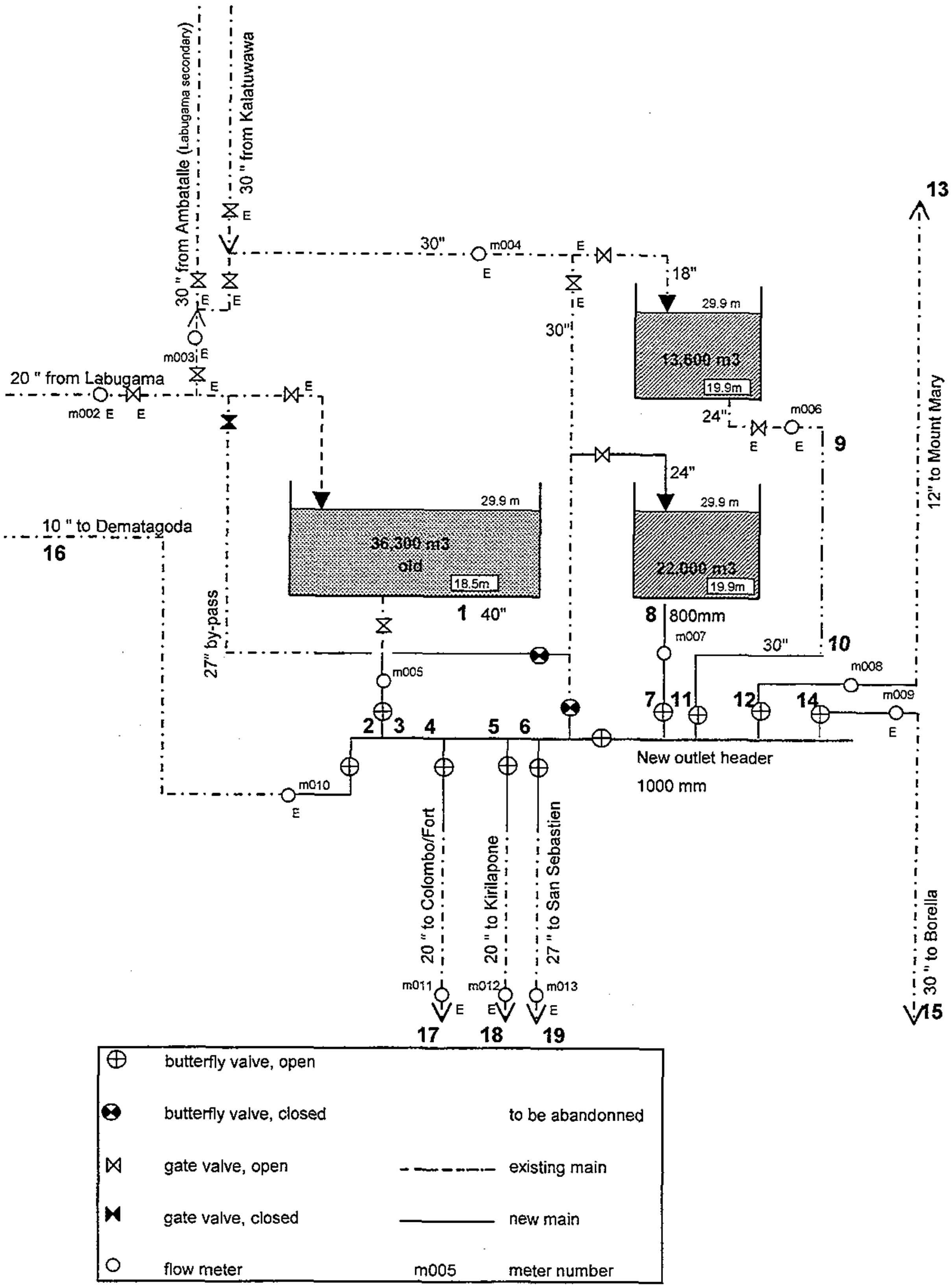


Figure 2-7 Maligakanda Reservoir - piping schematic for single tank option
overflow and washout drains not shown for clarity

note: two circular reservoirs in operation and old rectangular reservoir closed

NODE

NO	Type	Q	WL	GL	EH
		l/sec	m	m	m
3	0		29.37	17.00	12.37
4	0		29.37	17.00	12.37
5	0		29.37	17.00	12.37
6	0		29.38	17.00	12.38
7	0		29.38	17.00	12.38
8	1	-1571.891	29.90		29.90
9	1	-468.109	29.90		29.90
10	0		29.83	19.00	10.83
11	0		29.38	17.00	12.38
12	0		29.38	17.00	12.38
13	0	71.000	28.89	19.00	9.89
14	0		29.38	17.00	12.38
15	0	372.000	29.33	19.00	10.33
16	0	230.000	25.09	17.00	8.09
17	0	364.000	29.03	17.00	12.03
18	0	336.000	29.08	17.00	12.08
19	0	667.000	29.15	17.00	12.15

PIPE

NO(u)	NO(d)	Dia	Length	C	dH	Q	V	I
		mm	m		m	l/sec	m/sec	o/oo
3	4	1000	2	120		-230.00	-0.29	-0.10
4	5	1000	2	120		-594.00	-0.76	-0.58
5	6	1000	2	120		-930.00	-1.18	-1.33
6	7	1000	1	120		-1597.00	-2.03	-3.61
7	8	800	50	120		-1571.89	-3.13	-10.40
9	10	760	50	120		468.11	1.03	1.42
7	11	1000	2	120		-25.11	-0.03	0.00
10	11	600	100	120		468.11	1.66	4.49
11	12	1000	2	120		443.00	0.56	0.34
12	13	250	50	120		71.00	1.45	9.74
12	14	1000	2	120		372.00	0.47	0.24
14	15	760	50	120		372.00	0.82	0.93
3	16	250	50	120		230.00	4.69	85.65
4	17	500	50	120		364.00	1.85	6.85
5	18	500	50	120		336.00	1.71	5.91
6	19	685	50	120		667.00	1.81	4.53

End

			8	4,550	36,400	0.421	1.1	0.463

Note: 3 reservoirs in operation

NODE

NO	Type	Q	WL	GL	EH
		l/sec	m	m	m
1	1	-1232.423	29.90		29.90
2	0		29.81	17.00	12.81
3	0		29.81	17.00	12.81
4	0		29.81	17.00	12.81
5	0		29.80	17.00	12.80
6	0		29.80	17.00	12.80
7	0		29.81	17.00	12.81
8	1	-622.062	29.90		29.90
9	1	-185.515	29.90		29.90
10	0		29.89	19.00	10.89
11	0		29.81	17.00	12.81
12	0		29.81	17.00	12.81
13	0	71.000	29.32	19.00	10.32
14	0		29.81	17.00	12.81
15	0	372.000	29.76	19.00	10.76
16	0	230.000	25.53	17.00	8.53
17	0	364.000	29.46	17.00	12.46
18	0	336.000	29.51	17.00	12.51
19	0	667.000	29.58	17.00	12.58

PIPE

NO(u)	NO(d)	Dia	Length	C	dH	Q	V	I
		mm	m		m	l/sec	m/sec	o/oo
1	2	1000	40	120		1232.42	1.57	2.24
2	3	1000	1	120		1232.42	1.57	2.24
3	4	1000	2	120		1002.42	1.28	1.53
3	16	250	50	120		230.00	4.69	85.65
4	5	1000	2	120		638.42	0.81	0.66
4	17	500	50	120		364.00	1.85	6.85
5	6	1000	2	120		302.42	0.39	0.17
5	18	500	50	120		336.00	1.71	5.91
6	7	600	1	120		-364.58	-1.29	-2.83
6	19	685	50	120		667.00	1.81	4.53
7	8	800	50	120		-622.06	-1.24	-1.87
7	11	1000	2	120		257.49	0.33	0.12
9	10	760	50	120		185.51	0.41	0.26
10	11	600	100	120		185.51	0.66	0.81
11	12	1000	2	120		443.00	0.56	0.34
12	13	250	50	120		71.00	1.45	9.74
12	14	1000	2	120		372.00	0.47	0.24
14	15	760	50	120		372.00	0.82	0.93
End								
			8	4,550	36,400	0.421	1.1	0.463

Flows used in the hydraulic model for Maligakanda

A	maximum day supply (ultimate)	1275 l/s
B	maximum day demand (supply x 1.6)	2040 l/s

Node no.		**D** Measured Flow liter/s	**(B/C x D)** Estimated future flow liter/s
13	10" to mount mary	55	71
15	30" to Borella	289	372
16	10" to Dematagoda	179	230
17	20" to Fort	283	364
18	20" to Kirulapone	261	336
19	27" to San Sebastien	518	667
C	total	1585	2040

ELLIE HOUSE RESERVOIR SITE –
GRAVITY DRAIN FOR OVERFLOW / WASHOUT

Design of Overflow / washout pipe for Ellie House Reservoir

For overflowing Rate

A. From Manhole 1 to Manhole 2

Elevation at overflow vier = 27.85
Elevation at First manhole = 21.61
Distance = 42 m
Hydraulic Gradient = $\frac{27.85 - 21.61}{42} = \frac{6.24}{42} = 1.486$

Rate of flow = 2/3 x 110,000 m^3/d = 73,333 m3/d = 0.849 m^3/s

D= 500 mm n = 0.012

Solve for Actual Depth

D = 0.50 m S = 0.1486 n = 0.012 q = 0.849

D = 0.26 m Velocity = 8.18 m/s % Full = 52.38%
Full capacity = 1.58 cum/s QMax = 1.70 cum/s

B. From Manhole 2 to Existing washout

Elevation at overflow view = 27.85
Elevation at connection to existing overflow / washout = 21.00
Distance = 137 m

Hydraulic gradient = $\frac{27.85 - 21.00}{137} = 0.185$

Rate of flow = 110,000 m^3/d = 1.273 m^3/s

Valve for actual Depth

D= 0.60 S= 0.185 n = 0.012 Q = 1.273 m^3/s

d = 0.31 V = 9.76 m/s % full = 62. 96 %
Full capacity = 1.76 m^3/s Q max = 1.89 m^3/s

2. Washout Rates Through Overflow / Washout System

C. From Manhole 1 to Manhole 2

Elevation of pipe at MH 1 = 22.10
Elevation of pipe at MH 2 = 21.61
Drop = 0.49
Distance = 42 m
S = 0.01167

Solve for Full Flow capacity

d = 0.5 m S = .01167 N =.012 Q= 0.44 cum/s

O max = 0.48 cum/s = 41,472 m^3/d

D. From manhole 2 to Existing Washout

Elevation at MH 2	=	21.61
Elevation at MH 3	=	19.84
Drop	=	1.77
Distance	=	137
S	=	0.0129

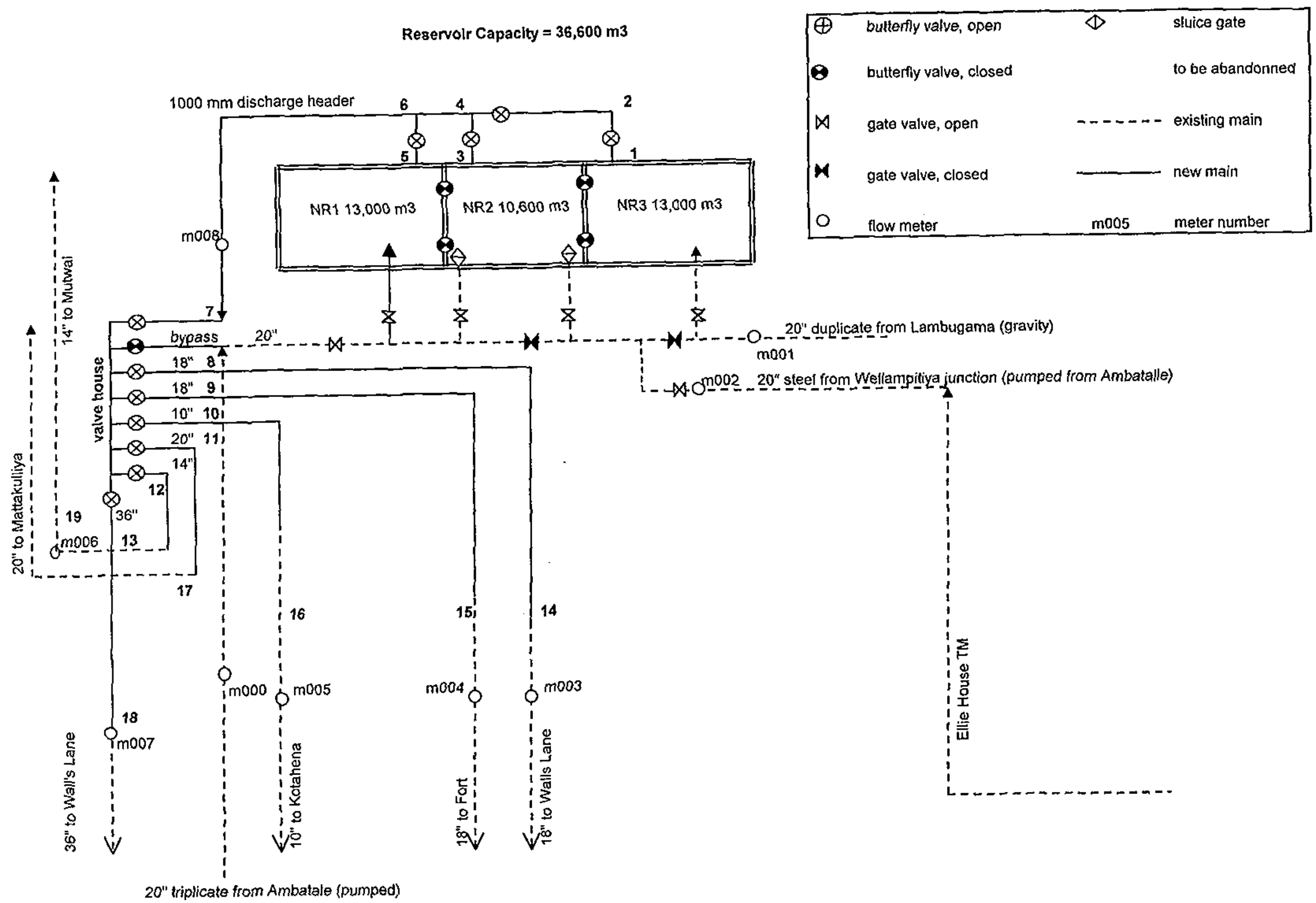
Solve for Full Flow capacity

D = 0.6 m S = .0129 N = 0.12 Q= 0.76 cum/s
Q Max = 0.81 cum/s = 69,984 m^3/d

Therefore the designed overflow/ washout system can safely discharge the maximum designed overflow rate of 110,000 m^3/d.

The system can also safely discharge a washout rate of 41,472 m^3/d.

ELLIE HOUSE RESERVOIR SITE –
INLET / OUTLET SIZING



New Ellie House Reservoir Schematic Diagram - Stage 8 inlet chanels restored
overflow and washout drains not shown for clarity

note: three cells in parallel operation

NODE

NO	Type	Q l/sec	WL m	GL m	EH m
1	1	-114.472	28.45	22.50	5.95
2	0		28.45	22.50	5.95
3	1	-187.847	28.45	22.50	5.95
4	0		28.45	22.50	5.95
5	1	-1737.681	28.45	22.50	5.95
6	0		28.44	22.50	5.94
7	0		28.07	22.50	5.57
8	0		28.05	22.50	5.55
9	0		28.04	22.50	5.54
10	0		28.03	22.50	5.53
11	0		28.02	22.50	5.52
12	0		28.02	22.50	5.52
13	0		28.02	22.50	5.52
14	0	330.000	27.49	20.00	7.49
15	0	330.000	27.48	20.00	7.48
16	0	180.000	24.83	20.00	4.83
17	0	400.000	27.54	20.00	7.54
18	0	600.000	27.96	20.00	7.96
19	0	200.000	26.42	20.00	6.42

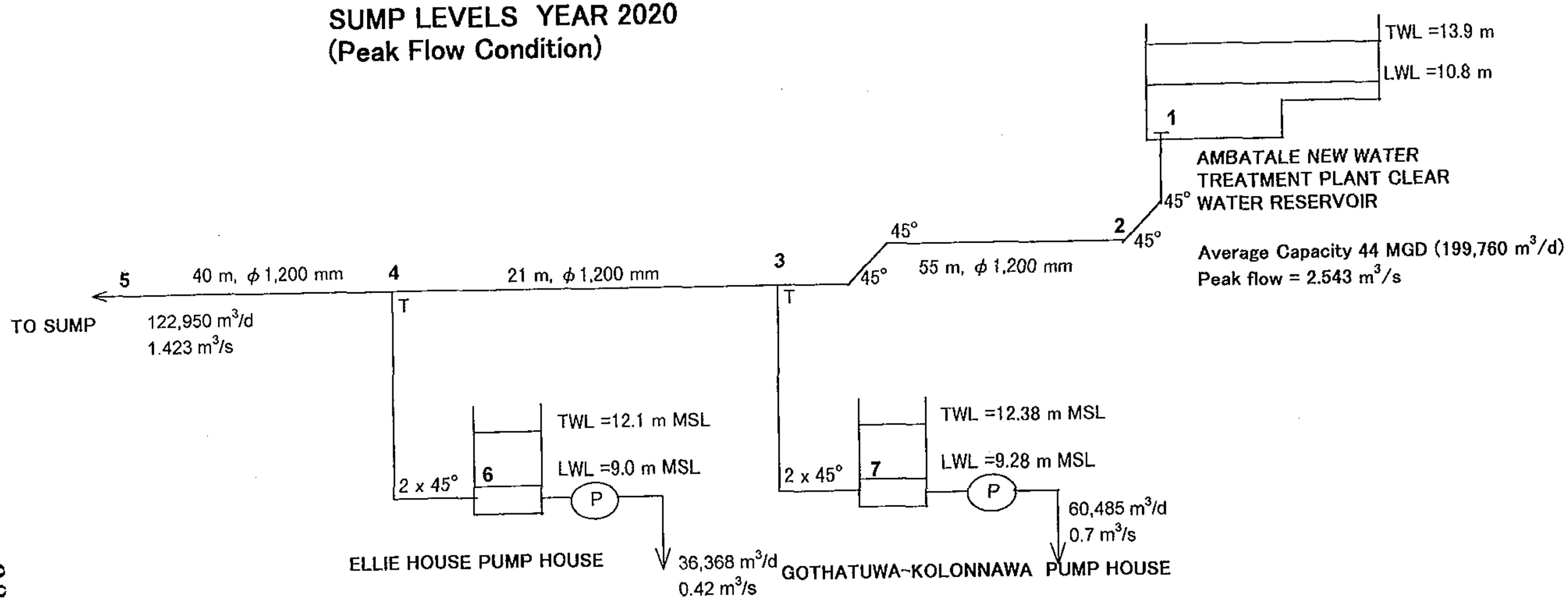
PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	1000	2	110		114.47	0.15	0.03
3	4	1000	2	110		187.85	0.24	0.08
5	6	1000	2	110		1737.68	2.21	4.96
2	4	1000	3	110		114.47	0.15	0.03
4	6	1000	50	110		302.32	0.38	0.20
6	7	1000	55	110		2040.00	2.60	6.67
7	8	1000	3	110		2040.00	2.60	6.67
8	9	1000	3	110		1710.00	2.18	4.81
9	10	1000	3	110		1380.00	1.76	3.24
10	11	1000	3	110		1200.00	1.53	2.50
11	12	1000	3	110		800.00	1.02	1.18
12	13	1000	3	110		600.00	0.76	0.69
8	14	450	50	110		330.00	2.07	11.21
9	15	450	50	110		330.00	2.07	11.21
10	16	250	50	110		180.00	3.67	63.93
11	17	500	50	110		400.00	2.04	9.58
12	19	300	50	110		200.00	2.83	31.97
13	18	900	50	110		600.00	0.94	1.16
End								
			8	4,550	36,400	0.421	1.1	0.463

Flows used in the hydraulic model for Ellie House						
A	maximum day supply (ultimate)				1275	l/s
B	maximum day demand (ultimate supply x 1.6)				2040	l/s
		D	(B/C x D)			
Node		Measured [	Estimated future flow			
no.		liter/s	liter/s			
15	18" to Fort	232	330			
16	18" to Walls lane	233	330			
17	10" to Kotahena	82	180			
18	20" to MattaKulliya	-	400			
19	36" to Walls lane	74	600			
20	12" to Mutawal	73	200			
C	total	694	2,040			

GOTHATUWA – KOLONNAWA PUMP HOUSE
- CLEAR WELL OPERATING LEVELS

SUMP LEVELS YEAR 2020
(Peak Flow Condition)



Pipe	Node (u)	Node (d)	Losses	Loss Coefficient k	Number	Flow m^3/s	Velocity m/s	Head Loss $kV^2/2g$
200	1	2	1000 mm ND	neglect				
			45° bend	0.4	2	2.54	3.24	0.428
300	2	3	1200 mm ND					0.260
			45° bend	0.4	2	2.54	2.25	0.206
700	3	7	1200 mm ND	neglect				
			T for Qa/Q = 0.7/3.43	1	1	0.7	2.25	0.26
			Butterfly valve	0.25	1	0.7	0.62	0.005
			45° bend	0.4	2	0.7	0.62	0.016

Total losses 1-3-7 = 1.173 m
Minimum operating water level = 10.8-1.203
= 9.627 m

Top water level is set as same level as the Clear Water Reservoir of Ambatale New Water Treatment Plant at 13.9 m MSL, to cater for the condition when clear water reservoir is full and the outflow is zero (stopping of all pumps).
An allowance of 350 mm is included to cater for changes in fittings etc. and the Low water level is set at 9.28 m MSL
Similarly, maximum operating level in year 2020 is 12.38 m MSL

NODE

NO	Type	Q l/sec	WL m	GL m	EH m
1	1	-2543.000	10.80	11.00	-0.20
2	0	0.000	10.76	11.00	-0.24
3	0	0.000	10.59	11.00	-0.41
4	0	0.000	10.55	11.00	-0.45
5	0	1423.000	10.51	11.00	-0.49
6	0	420.000	10.55	9.00	1.55
7	0	700.000	10.59	7.50	3.09
		1.000			

PIPE

	NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
200	1	2	1000	6	130	0.00	2543.00	3.24	7.36
300	2	3	1200	55	130		2543.00	2.25	3.03
	3	4	1200	21	130		1843.00	1.63	1.67
700	3	7	1200	10	130		700.00	0.62	0.28
	4	6	1200	10	130		420.00	0.37	0.11
	4	5	1200	40	130		1423.00	1.26	1.04

End

GOTHATUWA TRANSMISSION MAIN – HYDRAULIC ANALYSIS DURING NORMAL OPERATION

Pumping to Gothatuwa and Kolonnawa Ground Reservoirs

NODE Year 2020

NO	Type	Q l/sec	WL m	GL m	EH m
1	1	-700.100	9.28	7.00	2.28
2	0	0.000	50.49	11.00	39.49
3	0	0.000	43.54	18.00	25.54
4	0	357.800	29.35	26.25	3.10
5	0	342.300	25.20	25.20	0.00

R1 6.95 m Hospital Junction
R2 18.34 m Kolonnawa GR
R3 14.19 m Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	41.24	700.10	1.39	2.73
2	3	800	2541	110		700.10	1.39	2.73
3	4	500	1821	110		357.80	1.82	7.79
3	5	600	6207	110		342.30	1.21	2.95

End

NODE Year 2015

NO	Type	Q l/sec	WL m	GL m	EH m
1	1	-662.300	9.28	7.00	2.28
2	0	0.000	50.49	11.00	39.49
3	0	0.000	44.22	18.00	26.22
4	0	320.000	32.68	26.25	6.43
5	0	342.300	25.88	25.20	0.68

R1 6.27 m Hospital Junction
R2 18.34 m Kolonnawa GR
R3 11.54 m Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	41.24	662.30	1.32	2.47
2	3	800	2541	110		662.30	1.32	2.47
3	4	500	1821	110		320.00	1.63	6.34
3	5	600	6207	110		342.30	1.21	2.95

End

NODE Year 2010

NO	Type	Q l/sec	WL m	GL m	EH m
1	1	-501.500	9.28	7.00	2.28
2	0	0.000	39.34	11.00	28.34
3	0	0.000	35.60	18.00	17.60
4	0	285.500	26.25	26.25	0.00
5	0	216.000	27.77	25.20	2.57

R1 3.75 m Hospital Junction
R2 7.82 m Kolonnawa GR
R3 9.35 m Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	30.08	501.50	1.00	1.48
2	3	800	2541	110		501.50	1.00	1.48
3	4	500	1821	110		285.50	1.45	5.13
3	5	600	6207	110		216.00	0.76	1.26

End

NODE Year 2005

NO	Type	Q l/sec	WL m	GL m	EH m
1	1	-371.000	9.28	7.00	2.28
2	0	0.000	35.98	11.00	24.98
3	0	0.000	33.83	18.00	15.83
4	0	255.000	26.25	26.25	0.00
5	0	116.000	31.36	25.20	6.16

R1 2.15 m Hospital Junction
R2 2.48 m Kolonnawa GR
R3 7.58 m Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	26.71	371.00	0.74	0.84
2	3	800	2541	110		371.00	0.74	0.84
3	4	500	1821	110		255.00	1.30	4.16
3	5	600	6207	110		116.00	0.41	0.40

End

Note:

Q	Flowrate	EH	Effective Head
C	Hazen-William Coefficient	dH	Pumping Head
WL	Water Level	V	Velocity
GL	Ground Level	I	Friction Gradient

R1, R2 and R3 are friction losses in common main (800 mm), branch to Kolonnawa Ground Reservoir (600 mm) and branch to Gothatuwa Ground Reservoir (500 mm).

Pumping to Kolonnawa Ground Reservoir Only

NODE Year 2020 Kolonnawa Only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-342.300	9.28	7.00	2.28		
2	0	0.000	50.51	11.00	39.51		
3	0	0.000	48.66	18.00	30.66	R1	1.85 m Hospital Junction
4	0	342.300	30.32	25.20	5.12	R2	18.34 m Kolonnawa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	41.24	342.30	0.68	0.73
2	3	800	2541	110		342.30	0.68	0.73
3	4	600	6207	110		342.30	1.21	2.95

End

NODE Year 2015 Kolonnawa Only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-342.300	9.28	7.00	2.28		
2	0	0.000	50.51	11.00	39.51		
3	0	0.000	48.66	18.00	30.66	R1	1.85 Hospital Junction
4	0	342.300	30.32	25.20	5.12	R2	18.34 Kolonnawa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	41.24	342.30	0.68	0.73
2	3	800	2541	110		342.30	0.68	0.73
3	4	600	6207	110		342.30	1.21	2.95

End

NODE Year 2010 Kolonnawa Only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-216.000	9.28	7.00	2.28		
2	0	0.000	39.36	11.00	28.36		
3	0	0.000	38.57	18.00	20.57	R1	0.79 Hospital Junction
4	0	216.000	30.74	25.20	5.54	R2	7.82 Kolonnawa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	30.08	216.00	0.43	0.31
2	3	800	2541	110		216.00	0.43	0.31
3	4	600	6207	110		216.00	0.76	1.26

End

NODE Year 2005 Kolonnawa Only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-116.000	9.28	7.00	2.28		
2	0	0.000	39.36	11.00	28.36		
3	0	0.000	39.11	18.00	21.11	R1	0.25 Hospital Junction
4	0	116.000	36.63	25.20	11.43	R2	2.48 Kolonnawa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	30.08	116.00	0.23	0.10
2	3	800	2541	110		116.00	0.23	0.10
3	4	600	6207	110		116.00	0.41	0.40

End

Note:

Q	Flowrate	EH	Effective Head
C	Hazen-William Coefficient	dH	Pumping Head
WL	Water Level	V	Velocity
GL	Ground Level	I	Friction Gradient

R1, R2 and R3 are friction losses in common main (800 mm), branch to Kolonnawa Ground Reservoir (600 mm) and branch to Gothatuwa Ground Reservoir (500 mm).

Pumping to Gothatuwa Ground Reservoir Only

NODE Year 2020 Pumping to Gothatuwa only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-357.800	9.28	7.00	2.28		
2	0	0.000	50.51	11.00	39.51		
3	0	0.000	48.50	18.00	30.50	R1	2.01 Hospital Junction
4	0	357.800	34.31	26.25	8.06	R3	14.19 Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	41.24	357.80	0.71	0.79
2	3	800	2541	110		357.80	0.71	0.79
3	4	500	1821	110		357.80	1.82	7.79

End

NODE Year 2015 Pumping to Gothatuwa only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-320.000	9.28	7.00	2.28		
2	0	0.000	50.51	11.00	39.51		
3	0	0.000	48.88	18.00	30.88	R1	1.63 Hospital Junction
4	0	320.000	37.34	26.25	11.09	R3	11.54 Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	41.24	320.00	0.64	0.64
2	3	800	2541	110		320.00	0.64	0.64
3	4	500	1821	110		320.00	1.63	6.34

End

NODE Year 2010 Pumping to Gothatuwa only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-285.500	9.28	7.00	2.28		
2	0	0.000	39.35	11.00	28.35		
3	0	0.000	38.03	18.00	20.03	R1	1.32 Hospital Junction
4	0	285.500	28.69	26.25	2.44	R3	9.35 Gothatuwa GR

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	30.08	285.50	0.57	0.52
2	3	800	2541	110		285.50	0.57	0.52
3	4	500	1821	110		285.50	1.45	5.13

End

NODE Year 2005 Pumping to Gothatuwa only

NO	Type	Q l/sec	WL m	GL m	EH m		
1	1	-255.000	9.28	7.00	2.28		
2	0	0.000	39.36	11.00	28.36		
3	0	0.000	38.28	18.00	20.28	R1	1.07 Hospital Junction
4	0	255.000	30.70	26.25	4.45	R3	7.58 Gothatuwa GR

PIPE

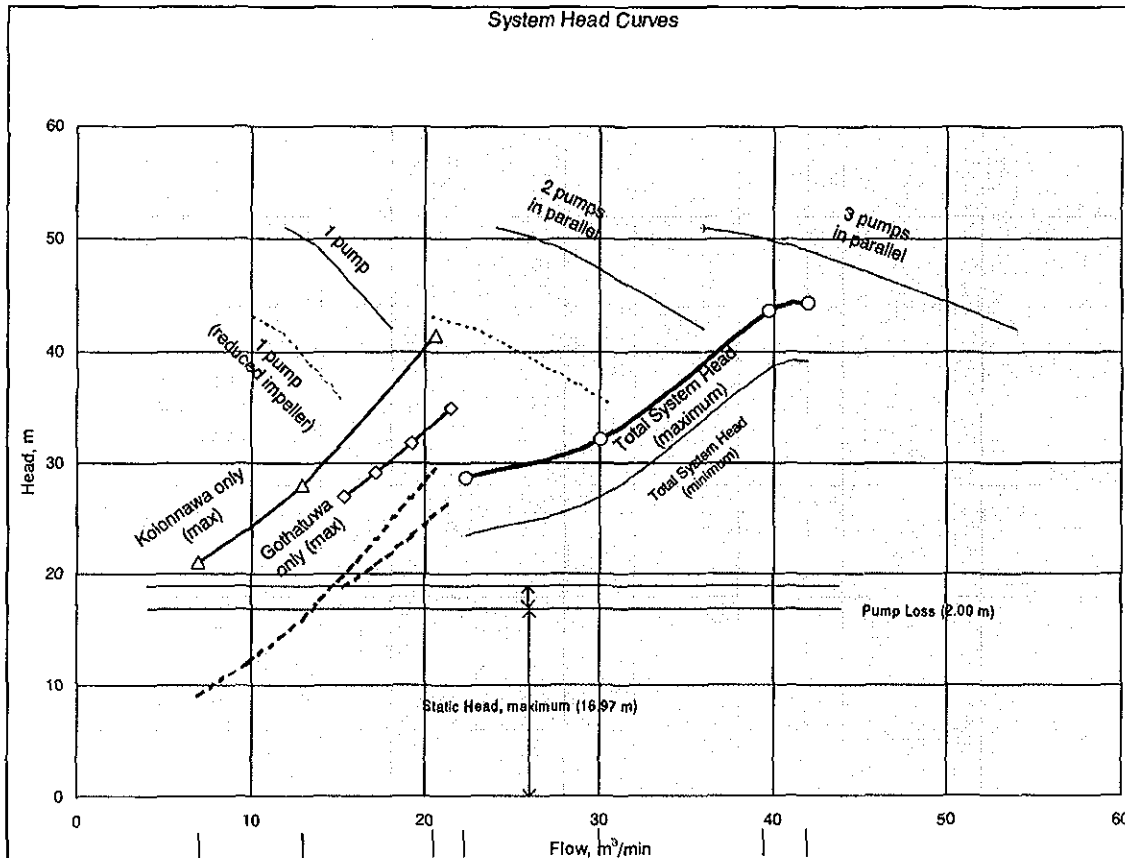
NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
1	2	800	11	110	30.08	255.00	0.51	0.42
2	3	800	2541	110		255.00	0.51	0.42
3	4	500	1821	110		255.00	1.30	4.16

End

Note:

Q	Flowrate	EH	Effective Head
C	Hazen-William Coefficient	dH	Pumping Head
WL	Water Level	V	Velocity
GL	Ground Level	I	Friction Gradient

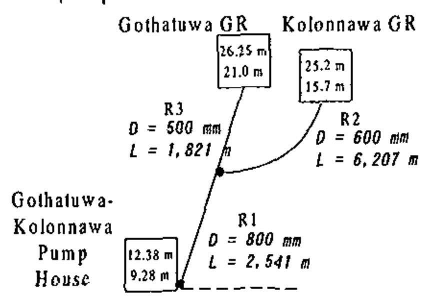
R1, R2 and R3 are friction losses in common main (800 mm), branch to Kolonnawa Ground Reservoir (600 mm) and branch to Gothatuwa Ground Reservoir (500 mm).



Kolonnawa	2005	2010	2015 and 2020
Day Max (m³/d)	10,100	18,655	29,575

Gothatuwa + Kolonnawa	2005	2010	2015	2020
Day Max (m³/d)	32,050	43,324	57,187	60,485

Gothatuwa	2005	2010	2015	2020
Day Max (m³/d)	22,040	24,669	27,612	30,910



Pumping to Gothatuwa and Kolonnawa

Item			Unit	Year 2005	2010	2015	2020
Quantity of water transmission							
Flow required at Gothatuwa	Q_{Kot}		L/s	255.0	285.5	320.0	357.8
Flow required at Kolonnawa	Q_{Kol}		L/s	116.0	216.0	342.3	342.3
Total flow required	Q_{tot}		L/s	371.0	501.5	662.3	700.1
Friction loss in pipeline							
Gothatuwa-Kolonnawa Pump House - Hospital Juncti	R1		m	2.15	3.75	6.27	6.95
Hospital Junction - Kolonnawa GR	R2		m	2.48	7.82	18.34	18.34
Hospital Junction - Gothatuwa GR	R3		m	7.58	9.35	11.54	14.19
Effective friction loss	If R2>R3, R1+R2		m			24.61	25.29
	If R2<R3, R1+R3		m	9.73	13.10		
Static Head							
Gothatuwa-Kolonnawa Pump House Sump		LWL	m	9.28	9.28	9.28	9.28
		HWL	m	12.38	12.38	12.38	12.38
Gothatuwa GR		HWL	m	26.25	26.25	26.25	26.25
		LWL	m	23.75	23.75	23.75	23.75
New Kolonnawa GR		HWL	m	25.20	25.20	25.20	25.20
		LWL	m	23.75	23.75	23.75	23.75
Maximum Static Head							
Gothatuwa-Kolonnawa Pump House Sump - Gothatuwa GR			m	16.97	16.97	16.97	16.97
Gothatuwa-Kolonnawa Pump House Sump - New Kolonnawa GR			m	15.92	15.92	15.92	15.92
Minimum Static Head							
Gothatuwa-Kolonnaw Pump House Sump - Gothatuwa GR			m	11.37	11.37	11.37	11.37
Gothatuwa-Kolonnawa Pump House Sump - New Kolonnawa GR			m	11.37	11.37	11.37	11.37
Effective static head	maximum		m	16.97	16.97	16.97	16.97
	minimum+ 0.5 m		m	11.87	11.87	11.87	11.87
Other Losses							
Around the pump			m	2.0	2.0	2.0	2.0
Effective friction loss			m	9.73	13.10	24.61	25.29
System Head Characteristics							
Total pumping head required	maximum		m	28.70	32.07	43.58	44.26
	minimum		m	23.60	26.97	38.48	39.16
Total flow			m³/min	22.26	30.09	39.74	42.01
Flow to Gothatuwa GR			m³/min	15.30	17.13	19.20	21.47
Total Head Loss from Ambatale to Gothatuwa GR			m	28.70	32.07	36.78	40.11
Flow to New Kolonnawa GR			m³/min	6.96	12.96	20.54	20.54
Total Head Loss from Ambatale to Kolonnawa GR			m	23.60	30.54	43.58	44.26

Pumping to Gothatuwa only

		Unit	2005	2010	2015	2020
System Head Characteristics						
Total pumping head required	maximum	m	27.62	29.64	32.14	35.17
	minimum	m	22.02	24.04	26.54	29.57
Total flow		m³/min	15.30	17.13	19.20	21.47

Pumping to Kolonnawa only

		Unit	2005	2010	2015	2020
System Head Characteristics						
Total pumping head required	maximum	m	20.65	26.54	38.11	38.11
	minimum	m	16.60	22.49	34.06	34.06
Total flow		m³/min	6.96	12.96	20.54	20.54

Note: Pumping head requirements are governed by Kolonnawa facilities which are at planning stage and are based on the data provided by NWSDB.

FIG. 3-10	System Head Curves for Pumping to Gothatuwa and Kolonnawa
SCALE	Not to scale

JICA STUDY TEAM
THE DETAILED DESIGN STUDY ON THE PROJECT FOR REDUCTION OF NON-REVENUE WATER IN THE GREATER COLOMBO AREA IN THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

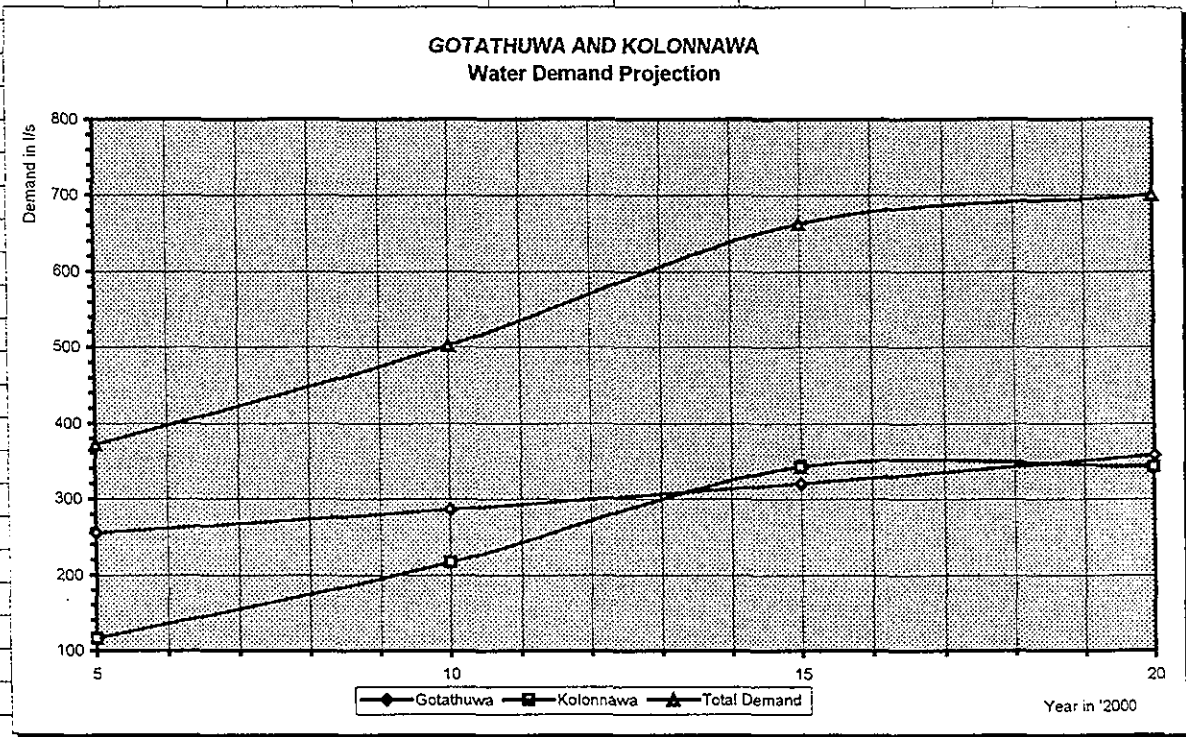
CEYWATER	PROJECT:- Gotathuwa Kolonnawa Water Supply		Job No	
			Des. By	AP
	COMPONENT:- Detailed Design of the Transmission System		Checked	
			Date	Sep-00

Design Flows

As per water demand projections for Gotathuwa and Kolonnawa, the required pumping rates in l/s are as follows:

	2005	*2010*	*2015*	*2020*
Gotathuwa	255.0	285.5	320.0	357.8
Kolannawa	116.0	216.0	342.3	342.3
Total	371.0	501.5	662.3	700.1

The increase of demand with time is graphically represented in the following chart.



As extrapolated from the above curves projected yearly design flows(l/s) are tabulated as follows:

	2005	2006	2007	2008	2009	**2010**	2011	2012	2013
Gotathuwa	**255**	260	265	275	280	**286**	295	300	305
Kolonnawa	**116**	135	155	175	195	**216**	240	275	300
Total	**371**	395	420	450	475	**502**	535	575	605

	2014	**2015**	2016	2017	2018	2019	**2020**
Gotathuwa	315	**320**	325	335	340	350	**358**
Kolonnawa	322	**342**	342	342	342	342	**342**
Total	637	**662**	667	677	682	692	**700**

Design Approach

An economic analysis, taking into account such factors as estimated pumping head, energy consumption capital and O & M costs for varying pipeline sizes were performed using "Present Worth" technique. The result of this analysis revealed the following sizing for the proposed transmission system:

From Ambatale WTP up to the hospital junction :-	800	mm dia DI with L=	2510
From the hospital junction up to Gotathuwa reservoir site :-	500	mm Dia DI with L=	1765
From the hospital junction up to Kolonnawa reservoir site :-	600	mm Dia DI with L=	6151

Based on this result, a transmission model was developed indicating the geometric and hydraulic properties of the system including node numbers, pipe numbers, node elevations, minor loss coefficient for each of the pipes and reservoir data. A basic data file was then set up to suit the KYPIPE computer program for hydraulic analysis of pipe networks developed by the Uneversity of Kentucky, USA. Flow control devices are introduced at inlets of both Gotathuwa and Kolonnawa reservoirs. Frictional head losses are calculated using Hazen William equation by adopting a C value of 110. The minor loss coefficient of specials in respect of each pipe is assumed to be included within the overall frictional head loss of the pipeline.

Because of the fact that Gotathuwa and Kolonnawa pipeline routes widely differ in length, it is rather difiicult to achieve perfect hydraulic balance. Hence, it is inevitable that flows to Gotathuwa and Kolonnawa need precise control in order to receive the correct quanity of water under all conditions.

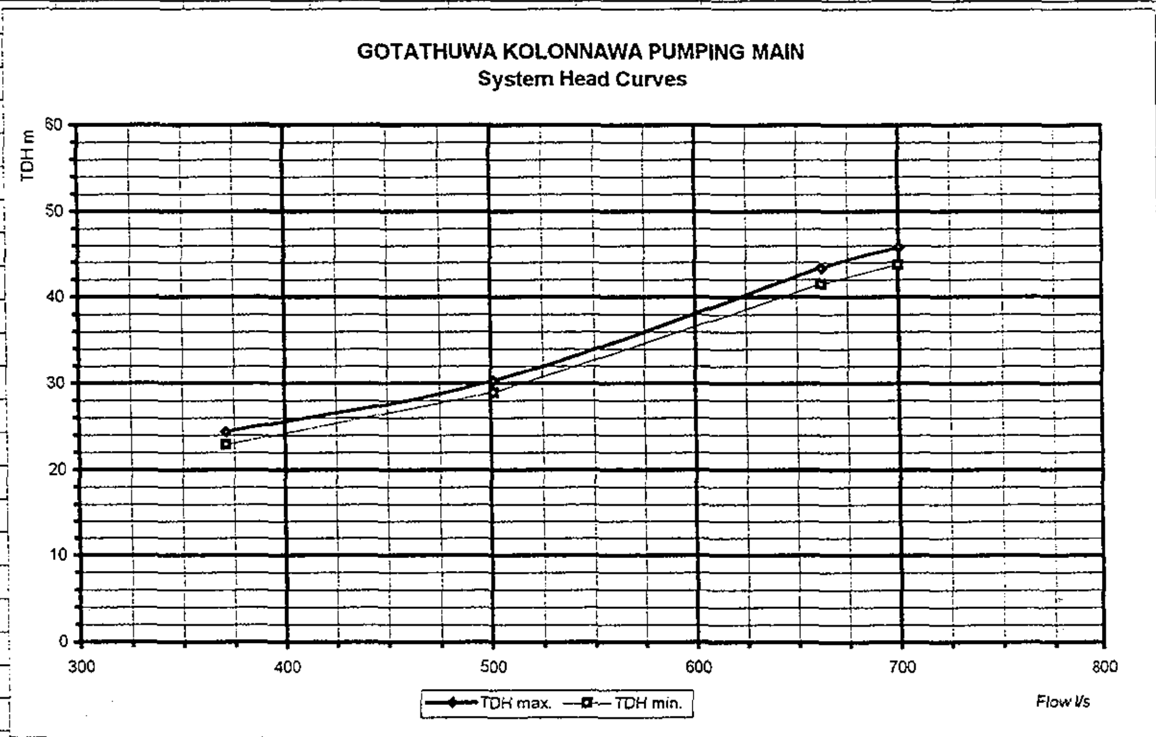
Based on this concept two system curves were developed using the KYPIPE program, one for the maximum static head and the other for the minimum static head. The results are summarised as follows:

Year	2005	2010	2015	2020	
Flow to G	255.0	285.5	320.0	357.8	l/s
Flow to K	116.0	216.0	342.3	342.3	l/s
Total flow	371.0	501.5	662.3	700.1	l/s
TDH(max)	24.35	30.3	43.35	45.71	m
TDH(min)	22.89	28.87	41.48	43.73	m

Eight (8) computer runs were executed in developing the sytem curves.

The system curves are garphically depicted below.

	A	B	C	D	E	F	G	H	I	J
1	CEYWATER			PROJECT:- Gotathuwa Kolonnawa					Job No	
2				Water Supply					Des. By	AP
3				COMPONENT:- Detailed Design of the					Checked	
4				Transmission System					Date	Sep-00



CASE 1 : 2010 to 2020

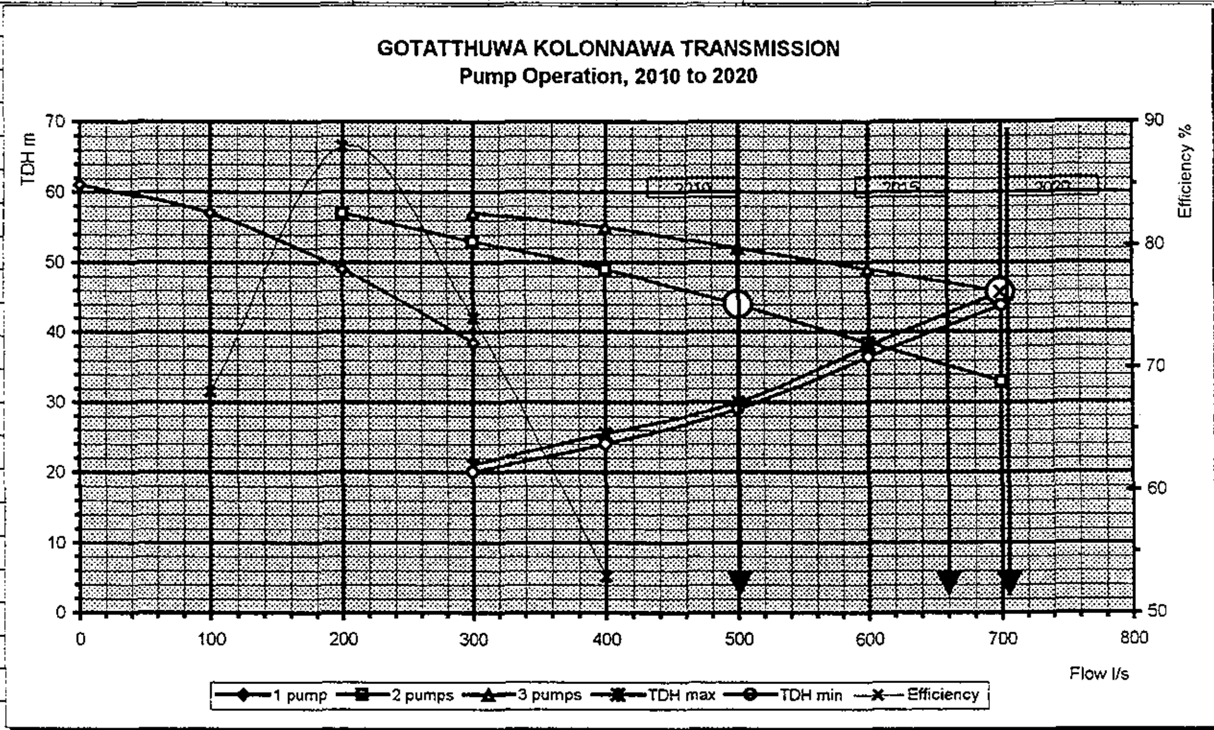
The details of the pump that would best fit into the above system curves are as given below:

Make	:	Weir
Type	:	Horizontal split casing
Model	:	SDB 250/300B
Speed	:	1480 rpm
Max WP	:	12 bar
Motor	:	165 kW

For the ultimate demand during the year 2020, 3 pumps (in parellel operation) will be required.
The pump characteristics (as extracted from manufacturerer's catalogue) superimposed with the system curves are indicated below:

Flow l/s	Pump Curves				TDH	
	1 pump	2 pump	3 pumps	Eff. %	max	min
0	61					
100	57			68		
200	49	57		88		
300	38.5	53	57	74	21	20
400		49	55	53	25.5	24
500		44	52		30	29
600		38.5	49		38	36.5
700		33	45.71		45.71	43.73
800						

CEYWATER	PROJECT:- Gotathuwa Kolonnawa Water Supply	Job No	
		Des. By	AP
	COMPONENT:- Detailed Design of the Transmission System	Checked	
		Date	Sep-00



It is seen from the above curves that the most desirable operating range of the pump lies between Q = 150 l/s and 250 l/s which corresponds with H values of 44 m and 54 m respectively.
This operating range corresponds with maximum efficiency varying between 75% and 88%.

Computer printout of the results output file relating to 2020 flow condition is annexed together with a schematic of the transmission model.

A number of computer runs were executed to determine the pump duty points when pumping water to any single location under 2020, 2015 and 2010 flow conditions. The results are summarised as follows:

Design Horizon	Point of Supply	Nr of duty Pumps	Q l/s per pump	H m	Q (Got)	Q (Kol)	Q (Total)	Hf (Got)	Hf (Kol)
2020	G & K	3	233.37	45.74	357.8	342.3	700.11	5.44	1.44
	G only	3	119.22	55.6	357.8	-	357.66	21.98	
	G only	2	178.9	50.89	357.8	-	357.8	17.15	
	K only	3	114.1	55.96		342.3	342.3		19.46
	K only	2	171.15	51.56		342.3	342.3		14.95
2015	G & K	3	220.77	47	320	342.3	662.31	10.25	4.53
	G only	3	106.67	56.46	320		320.01	25.96	
	G only	2	160	52.49	320		320	21.9	
	K only	3	114.1	55.96		342.3	342.3		19.46
	K only	2	171.51	51.56		342.3	343.02		14.95
2010	G & K	2	250.75	43.95	285.5		501.5	12.56	15.1
	G only	2	142.75	53.87	285.5		285.5	25.88	
	G only	1	285.5	40.16	285.5		285.5	11.76	
	K only	2	108	56.37		216	216		31.65
	K only	1	216	47.46		216	216		22.18

The highlighted rows represent the recommended operating modes. ***<u>It is important to maintain precise</u>*** **<u>flow control at both Gotathuwa and Kolonnawa.</u>** The estimated headloss at each flow control device is indicated in m water head.

As evident from the above results it is important to maintain a pump discharge head between 44 m and 54 m when operating the pumps under various flow conditions. This could be achieved either by using variable speed pumps or by changing the number of pumps working in parellel. For example, when three pumps are working in parellel, if suddenly the manometric head increases beyond 52 m, the operator should immediately switch off one pump in order to keep the pressure below 52 m limit.

Motor Horse Power:-

Required horse power of the motor is given by:

P = (Q x Hx g)/(n x 1000)

where P = Horse Power in kW
Q = Flow in l/s
H = Manometric Head in m
n1 = pump efficiency
n2 = motor excess

Considering the 2020 situation with 3 pumps in parellel, the required total power is computed as follows:

Q = 700.1
H = 45.71
g = 9.797
n1 = 0.8
n2 = 1.25

Therefore P = 489.874

Hence, required horse power of the motor = 163.2913 kW

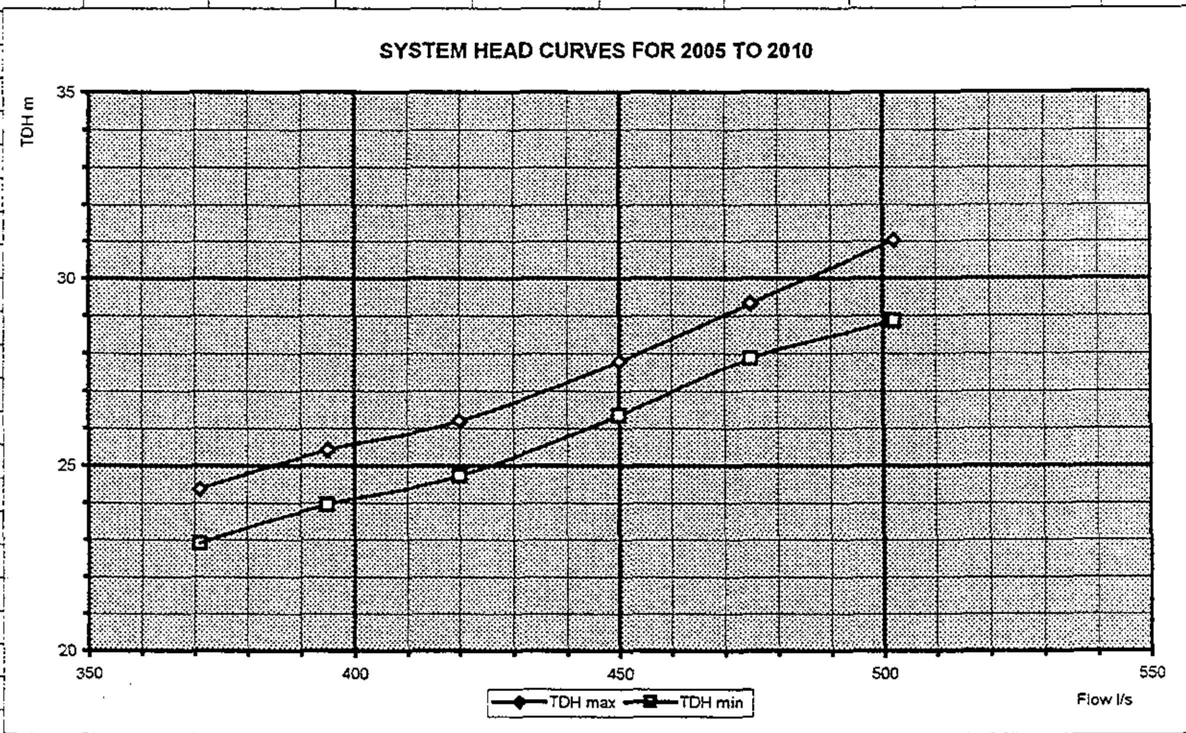
Provide a motor of capacity = 165 kW

<u>CASE 2</u> : 2010 to 2020

The results of the computer runs reveal the following system curves.

Year	2005	2006	2007	2008	2009	2010
Flow to G	255.0	260.0	265.0	275.0	280	**286**
Flow to K	116.0	135.0	155.0	175.0	195	**216**
Total flow	371.0	395.0	420.0	450.0	475	**502**
TDH(max)	24.35	25.41	26.18	27.79	29.33	**31.02**
TDH(min)	22.89	23.95	24.72	26.33	27.87	**28.87**

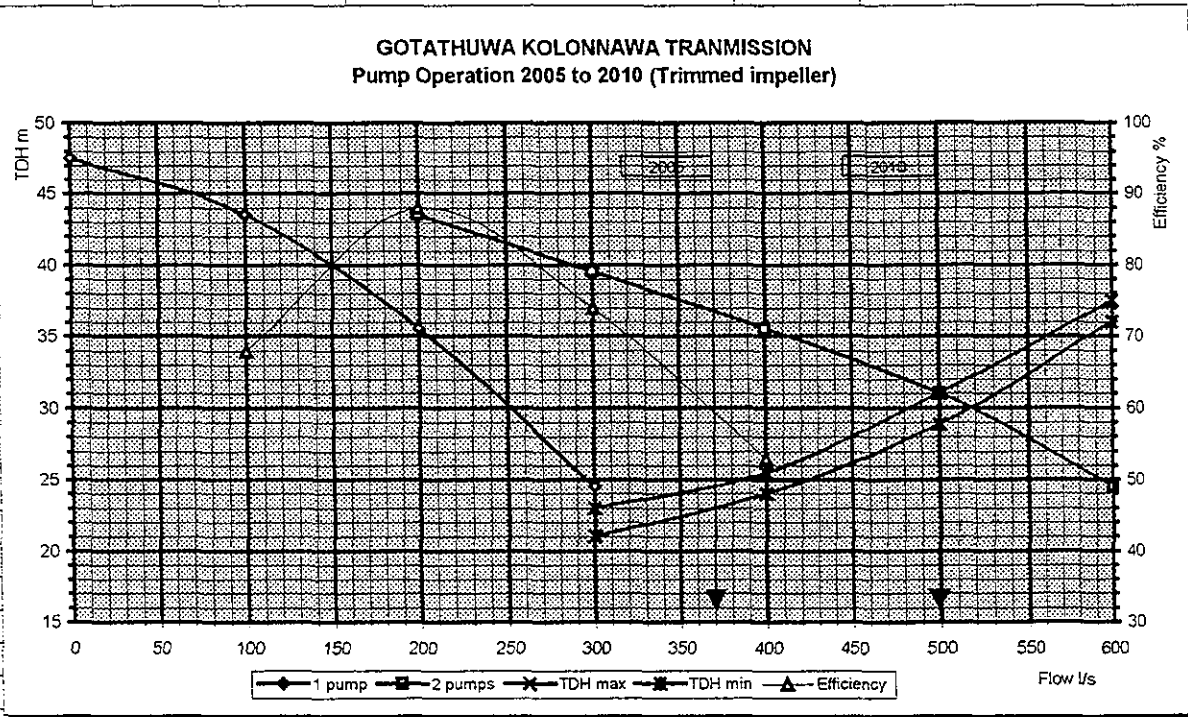
CEYWATER	PROJECT:- Gotathuwa Kolonnawa Water Supply	Job No	
		Des. By	AP
	COMPONENT:- Detailed Design of the Transmission System	Checked	
		Date	Sep-00



The same pump with a trimmed down impeller will be used during the period from 2005 to 2010.

For the ultimate demand during the year 2010, 2 pumps (in parellel operation) will be required.
The pump characteristics (as extracted from manufacturerer's catalogue) superimposed with the system curves are indicated below:

Flow l/s	Head m			TDH m	
	1 pump	2 pump	Eff. %	max	min
0	47.53				
100	43.53		68		
200	35.53	43.53	88		
300	24.53	39.53	74	23	21
400		35.53	53	25.5	24
500		31.02		31.02	28.87
600		24.53		37.5	36



344	**Motor Horse Power:-**
345	Required horse power of the motor is given by:
346	P = (Q x Hx g)/(n x 1000)
347	where P = Horse Power in kW
348	Q = Flow in l/s
349	H = Manometric Head in m
350	n1 = pump efficiency
351	n2 = motor excess
352	
353	*Considering the 2010 situation with 2 pumps in parellel, the required total power is computed as follows:*
354	
355	Q = 502.0
356	H = 30.5
357	g = 9.797
358	n1 = 0.88
359	n2 = 1.4
360	
361	Therefore P = 238.6393
362	
363	*Hence, required horse power of the motor =* 119.3197 kW
364	
365	**Although motor capacity required for the pump with trimmed impeller is only 120 kW, it is**
366	**recommended to provide a motor of 165 kW so that it could continue serving after upgrading**
367	**the pumps before the year 2010.**
368	

	A	B	C	D	E	F	G	H	I	J
1	CEYWATER			PROJECT:- Gotathuwa Kolonnawa Water Supply					Job No	
2									Des. By	AP
3				COMPONENT:- Detailed Design of the Transmission System					Checked	
4									Date	Sep-00
369										
370	**Net Positive Suction Head (NPSH) Computation:-**									
371										
372	The manufacturers have suggested to operate the pumps at flooded suction conditions. For solo									
373	operation the required NPSH is approximately					5	m			
374										
375	For "flooded suction" condition NPSH is given by:									
376										
377	NPSH = Pb + Lh - (Vp + hf)									
378	Where	Pb	=	Atmospheric Pressure in m of water						
379		Lh	=	Minimum Static Suction Head in m above the center line of the pump						
380		Vp	=	Vapor Pressure of Water (absolute)						
381		hf	=	Suction Piping Losses						
382	Minimum NPSHR required, at solo operation as recommended by suppliers							=	**5**	**m**
383							Pb	=	10.33	m
384							Vp	=	0.576	m
385	Suction Losses as extracted from KYPIPE output file						hf	=	1.68	m
386										
387										
388	In case of tapping from a pipeline under pressure, NPHS is given by,									
389										
390	NPSH = Pb+ p + H - (Vp + hf)									
391	Where	Pb	=	Atmospheric Pressure in m of water						
392		p		Gage Pressure in the main						
393		H	=	Height difference between pipe center line and pump center line						
394		Vp	=	Vapor Pressure of Water (absolute)						
395		hf	=	Suction Piping Losses						
396										
397	***Conclusion:-***									
398										
399	NPSHA (NPSH Available) Ref. Drawing Nr KMU/PSM/02									
400										
401			LWL of the well					=	9.28	m
402			Center line elevation of the pump					=	8.55	m
403							Lh	=	0.73	m
404										
405			**Therefore NPSHA is calculated as**					**=**	**8.80**	**m**
406			i.e. NPSHA is greater than NPSHR							
407			Hence, the proposed pump configuration is OK, provided water level in the							
408			intake well is abvove +9.28 m (LWL) elevation							

GOTATHUWA KOLONNAWA TRANSMISSION SYSTEM
Hydraulic Analysis
Year 2020 Situation – Three duty pumps in parallel and with flow control devices installed
At Gotathuwa and Kolonnawa Reservoirs

```
* * * * * * * * * *   K Y P I P E 2   * * * * * * * * * *
*   University of Kentucky Hydraulic Analysis Program   *
* Distribution of Pressure and Flows in Piping Networks *
*         1000 PIPE VERSION - 1.10    (08/25/92)         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

DATE: 10/17/2000
TIME: 9: 8:55

INPUT DATA FILENAME -------------- c:\anselm\kyp2\GKT_REV1.DAT
TABULATED OUTPUT FILENAME -------- c:\anselm\kyp2\GKT_REV1.OUT
POSTPROCESSOR RESULTS FILENAME --- c:\anselm\kyp2\GKT_REV1.RES

```
***********************************************
S U M M A R Y   O F   O R I G I N A L   D A T A
***********************************************
```

U N I T S   S P E C I F I E D

FLOWRATE .... = liters/second
HEAD (HGL) .... = meters
PRESSURE .... = kpa

R E G U L A T I N G   V A L V E   D A T A

VALVE TYPE	POSITION JUNCTION	CONTROLLED PIPE	VALVE SETTING (m or l/s)
FCV-1	12	15	357.80
FCV-1	18	22	342.30

P I P E L I N E   D A T A

STATUS CODE: XX -CLOSED PIPE   FG -FIXED GRADE NODE   PU -PUMP LINE
CV -CHECK VALVE   RV -REGULATING VALVE

PIPE NUMBER	NODE NOS. #1	#2	LENGTH (m)	DIAMETER (cm)	ROUGHNESS COEFF.	MINOR LOSS COEFF.	FGN-HGL (m)
1-FG	0	1	5.0	50.0	110.00	1.79	9.28
2-PU	1	2	6.0	50.0	110.00	4.64	
3-PU	1	2	6.0	50.0	110.00	4.64	
4-PU	1	2	6.0	50.0	110.00	4.64	
5	2	3	31.0	60.0	110.00	1.65	
6	3	4	225.0	80.0	110.00	.00	
7	4	5	100.0	80.0	110.00	.00	
8	5	6	725.0	80.0	110.00	.00	
9	6	7	275.0	80.0	110.00	.00	
10	7	8	850.0	80.0	110.00	.00	
11	8	9	335.0	80.0	110.00	.00	
12	9	10	40.0	50.0	110.00	.00	
13	10	11	925.0	50.0	110.00	.00	
14	11	12	800.0	50.0	110.00	.00	
15-RV	12	20	6.0	40.0	110.00	.00	
16	9	13	927.0	60.0	110.00	.00	
17	13	14	804.0	60.0	110.00	.00	
18	14	15	2572.0	60.0	110.00	.00	
19	15	16	558.0	60.0	110.00	.00	
20	16	17	1080.0	60.0	110.00	.00	
21	17	18	210.0	60.0	110.00	.00	
22-RV	18	19	6.0	50.0	110.00	.00	
23-FG	19	0	50.0	60.0	110.00	.00	25.20
24-FG	20	0	50.0	50.0	110.00	.00	26.25

GOTATHUWA KOLONNAWA TRANSMISSION SYSTEM
Hydraulic Analysis
Year 2020 Situation – Three duty pumps in parallel and with flow control devices installed At Gotathuwa and Kolonnawa Reservoirs

P U M P   D A T A

THERE IS A PUMP IN LINE 2 DESCRIBED BY THE FOLLOWING DATA:

HEAD (m)	FLOWRATE (l/s)
61.00	.00
45.74	233.70
38.50	300.00

THERE IS A PUMP IN LINE 3 DESCRIBED BY THE FOLLOWING DATA:

HEAD (m)	FLOWRATE (l/s)
61.00	.00
45.74	233.70
38.50	300.00

THERE IS A PUMP IN LINE 4 DESCRIBED BY THE FOLLOWING DATA:

HEAD (m)	FLOWRATE (l/s)
61.00	.00
45.74	233.70
38.50	300.00

J U N C T I O N   N O D E   D A T A

JUNCTION NUMBER	JUNCTION TITLE	EXTERNAL DEMAND (l/s)	JUNCTION ELEVATION (m)	CONNECTING PIPES			
1		.00	8.55	1	2	3	4
2		.00	8.55	2	3	4	5
3		.00	8.55	5	6		
4		.00	16.24	6	7		
5		.00	21.48	7	8		
6		.00	5.52	8	9		
7		.00	15.95	9	10		
8		.00	6.74	10	11		
9		.00	12.83	11	12	16	
10		.00	13.70	12	13		
11		.00	1.97	13	14		
12		.00	21.73	14	15		
13		.00	18.20	16	17		
14		.00	1.40	17	18		
15		.00	11.17	18	19		
16		.00	-.22	19	20		
17		.00	22.44	20	21		
18		.00	18.63	21	22		
19		.00	18.63	22	23		
20		.00	21.73	15	24		

O U T P U T   O P T I O N   D A T A

OUTPUT SELECTION: ALL RESULTS ARE INCLUDED IN THE TABULATED OUTPUT

S Y S T E M   C O N F I G U R A T I O N

NUMBER OF PIPES ....(p) = 24
NUMBER OF JUNCTION NODES ....(j) = 20
NUMBER OF PRIMARY LOOPS ....(l) = 2
NUMBER OF FIXED GRADE NODES ....(f) = 3
NUMBER OF SUPPLY ZONES ....(z) = 1

Hydraulic Analysis
Year 2020 Situation – Three duty pumps in parallel and with flow control devices installed At Gotathuwa and Kolonnawa Reservoirs

```
*************************************
S I M U L A T I O N   R E S U L T S
*************************************
```

THE RESULTS ARE OBTAINED AFTER 2 TRIALS WITH AN ACCURACY = .00000

P I P E L I N E   R E S U L T S

STATUS CODE: XX -CLOSED PIPE FG -FIXED GRADE NODE PU -PUMP LINE
CV -CHECK VALVE RV -REGULATING VALVE TK -STORAGE TANK

PIPE NUMBER	NODE NOS. #1	#2	FLOWRATE (l/s)	HEAD LOSS (m)	PUMP HEAD (m)	MINOR LOSS (m)	LINE VELO. (m/s)	HL/ 1000 (m/m)
1-FG	0	1	700.10	.13	.00	1.16	3.57	26.77
2-PU	1	2	233.37	.02	45.77	.33	1.19	3.50
3-PU	1	2	233.37	.02	45.77	.33	1.19	3.50
4-PU	1	2	233.37	.02	45.77	.33	1.19	3.50
5	2	3	700.10	.34	.00	.52	2.48	11.01
6	3	4	700.10	.61	.00	.00	1.39	2.71
7	4	5	700.10	.27	.00	.00	1.39	2.71
8	5	6	700.10	1.97	.00	.00	1.39	2.71
9	6	7	700.10	.75	.00	.00	1.39	2.71
10	7	8	700.10	2.31	.00	.00	1.39	2.71
11	8	9	700.10	.91	.00	.00	1.39	2.71
12	9	10	357.80	.31	.00	.00	1.82	7.72
13	10	11	357.80	7.14	.00	.00	1.82	7.72
14	11	12	357.80	6.18	.00	.00	1.82	7.72
15-RV	12	20						
16	9	13	342.30	2.71	.00	.00	1.21	2.93
17	13	14	342.30	2.35	.00	.00	1.21	2.93
18	14	15	342.30	7.53	.00	.00	1.21	2.93
19	15	16	342.30	1.63	.00	.00	1.21	2.93
20	16	17	342.30	3.16	.00	.00	1.21	2.93
21	17	18	342.30	.61	.00	.00	1.21	2.93
22-RV	18	19						
23-FG	19	0	342.30	.15	.00	.00	1.21	2.93
24-FG	20	0	357.80	.39	.00	.00	1.82	7.72

J U N C T I O N   N O D E   R E S U L T S

JUNCTION NUMBER	JUNCTION TITLE	EXTERNAL DEMAND (l/s)	HYDRAULIC GRADE (m)	JUNCTION ELEVATION (m)	PRESSURE HEAD (m)	JUNCTION PRESSURE (kpa)
1		.00	7.99	8.55	-.56	-5.53
2		.00	53.40	8.55	44.85	439.88
3		.00	52.55	8.55	44.00	431.47
4		.00	51.94	16.24	35.70	350.07
5		.00	51.67	21.48	30.19	296.02
6		.00	49.70	5.52	44.18	433.24
7		.00	48.95	15.95	33.00	323.64
8		.00	46.65	6.74	39.91	391.35
9		.00	45.74	12.83	32.91	322.71
10		.00	45.43	13.70	31.73	311.15
11		.00	38.29	1.97	36.32	356.14
12		.00	32.11	21.73	10.38	101.79
13		.00	43.02	18.20	24.82	243.44
14		.00	40.67	1.40	39.27	385.11
15		.00	33.14	11.17	21.97	215.47
16		.00	31.51	-.22	31.73	311.15
17		.00	28.35	22.44	5.91	57.93
18		.00	27.73	18.63	9.10	89.26
19		.00	25.35	18.63	6.72	65.87
20		.00	26.64	21.73	4.91	48.11

Hydraulic Analysis

Year 2020 Situation – Three duty pumps in parallel and with flow control devices installed At Gotathuwa and Kolonnawa Reservoirs

R E G U L A T I N G   V A L V E   R E P O R T

VALVE TYPE	POSITION NODE	CONTROLLED PIPE	VALVE SETTING (m or l/s)	VALVE STATUS	UPSTREAM GRADE (m)	DOWNSTREAM GRADE (m)	THROUGH FLOW (l/s)
FCV-1	12	15	357.80	THROTTLED	32.11	26.64	357.80
FCV-1	18	22	342.30	THROTTLED	27.73	25.35	342.30

S U M M A R Y   O F   I N F L O W S   A N D   O U T F L O W S

(+) INFLOWS INTO THE SYSTEM FROM FIXED GRADE NODES
(-) OUTFLOWS FROM THE SYSTEM INTO FIXED GRADE NODES

PIPE NUMBER	FLOWRATE (l/s)
1	700.10
23	-342.30
24	-357.80

NET SYSTEM INFLOW = 700.10
NET SYSTEM OUTFLOW = -700.10
NET SYSTEM DEMAND = .00

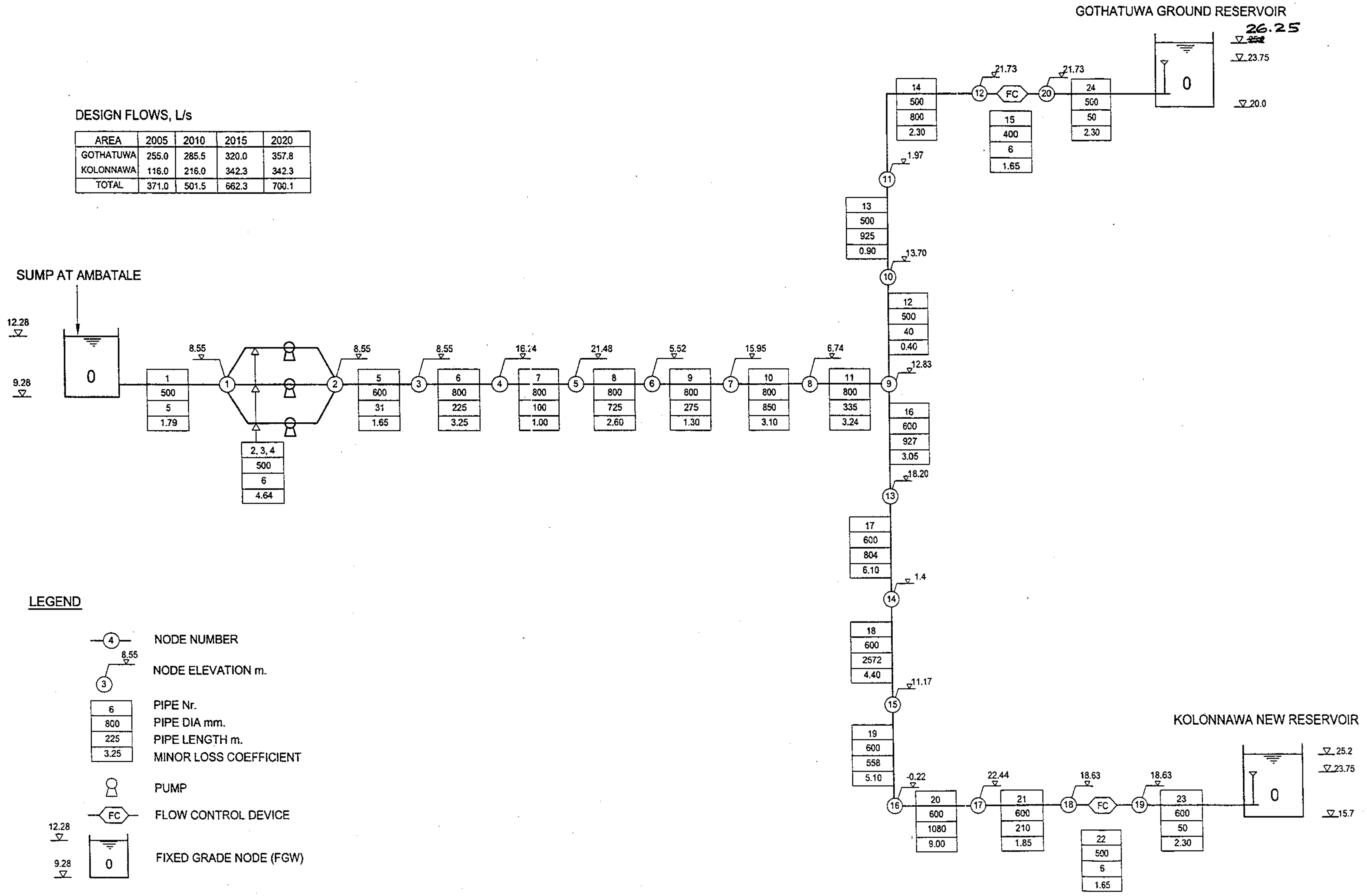
**** KYPIPE SIMULATION COMPLETED ****

DATE: 10/17/2000
TIME: 9: 8:55

GOTHATUWA - KOLONNAWA TRANSMISSION MODEL

DESIGN FLOWS, L/s

AREA	2005	2010	2015	2020
GOTHATUWA	255.0	285.5	320.0	357.8
KOLONNAWA	116.0	216.0	342.3	342.3
TOTAL	371.0	501.5	662.3	700.1



GOTHATUWA TRANSMISSION MAIN
– SURGE ANALYSIS

	A	B	C	D	E	F	G	H	I	J
1	water CEYWATER			PROJECT:- Greater Colombo NRW Reduction					Job No	
2									Des. By	AP
3				COMPONENT:- G'thuwa K'nawa Pumping Main					Checked	
4					Surge Analysis				Date	25-7-00

5

6 **1. Design Flow Condition**

7 *The surge control system is designed to cater for the year 2020 flow condition ie* 700.1 l/s

8

9 **2. Design of Surge Control System**

10

11 ***Introduction***

12

13 In the event of power failure or a rapid pump shutdown, the pump rapidly decelerates from steady
14 speed to zero speed, causing abrupt decrease of discharge into the pumping main, while the water
15 body in the pipeline still moves forward. At this time a negative pressure wave is created just upstream
16 of the pump and this wave rapidly travels from pump station end of the force main to its discharge end.
17 This negative pressure wave decelerates the flow in the pumping main and when it reaches the discharge
18 end it is reflected back in the direction of pumping station as a positive wave which further reduces the
19 flow in the pumping main. When this positive wave reaches the pump station the cycle of wave travel is
20 completed. When the pump comes to a stand still the check valve closes and isolates the pump from
21 the force main.
22 However, pressure wave cycle is repeated until all the energy has been dissipated by friction in the pipe.
23 The round trip travel time of the pressure wave is termed the critical period. The magnitude of the pressure
24 build up at the pump is dependent on whether the flow is stopped in a time interval equal to or less than
25 or greater than the critical period.

26

27 ***Surge Analysis***

28

29 The critical period T (in secs) is given by
30 T = 2*L/a
31 where L = Length of the pumping main between pump station and point of discharge in m

32

33	From Ambatale WTP up to the hospital junction :-	800 mm dia DI with L=	2510
34	From the hospital junction up to Gotathuwa reservoir site :-	500 mm Dia DI with L=	1818
35	From the hospital junction up to Kolonnawa reservoir site :-	600 mm Dia DI with L=	6151
36		Maximum L =	8661

37

38 Hs = Static Head = 15.92 m
39 a = Velocity of pressure wave in m/s

40

41 Pressure wave velocity in m/s is given by
42 a = 1440/(1+C1*(K*d/E*e))^.5
43 where C1 = 1, for pipe with expansion joints throughout
44 1-u^2, for pipes anchored against axial movement throughout (ex. buried pipes)
45 5/4-u, for pipes without expansion joints and anchored at the upstream end
46 u = Poisson's Ratio
47 K = Bulk Modulus of Water taken as 2.2E+09 N/sq m
48 d = Pipe diameter , m
49 E = Modulus of elasticity of pipe material in MN/sq m
50 e = Pipe wall thickness in m

51

		B	C	D	
52	For	0.5	0.60	0.80	m dia. *Class K9 DI* pipe,
53	u =	0.28			
54	E =	1.7E+11			
55	e =	0.0140	0.0150	0.0175	
56	C1 =	0.92	for buried pipeline		
57	a =	**1200**	**1179**	**1152**	**Average a = 1177.28 m/s**

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CEYWATER	PROJECT:- Greater Colombo NRW Reduction	Job No	
		Des. By	AP
	COMPONENT:- G'thuwa K'nawa Pumping Main	Checked	
	Surge Analysis	Date	25-7-00

Therefore critical period T	=	**13.87431**	secs	for Kolonnawa branch
	=	**4.260303**	secs	for Gotathuwa branch

The magnitude of the maximum water hammer pressure Ps (in m) at pump discharge is given by

Ps = a*v/g

where	a =	Pressure wave velocity in m/s			
	v =	Steady flow velocity in m/s	=	1.47	average
	g =	Gravity constant in m/s^2			

In the case of a pump trip this pressure is negative. For this to happen, pump speed must reach zero within a time period less than the critical time.

When pressure in the pipeline reaches sub atmospheric conditions, vapor bubbles start developing and gives rise to sudden implosion into the inter space between water and pipe. This phenomenon is called "cavitation" and it can cause damage to pipes and equipment. Hence, it is very important that pipeline and equipment is adequately protected against cavitaion.

When pressure wave approaches the pump after reflecting back at the reservoir end, the reverse velocity causes a positive surge and the cycle repeats until all energy has been dissipated.

Analysis of Pressure/Flow Transients

<u>Introduction</u>

The computer program "SURGE 4" which is a separate module of KYPIPE2 has been used to analyze and determine the type and magnitude of surge control equipment required for this application.

This program provides for analyzing the hydraulics of the system at a number of time intervals measured from the time of pump stoppage. Time period for the analysis is predetermined, which in this case we have used 100 seconds and 200 seconds.

The steps of analysis is briefly described as follows:

1. Develop a geometric layout of the basic system (without provision for surge control devices) indicating all parameters viz. pipe lengths, diameters, nodal elevations pump curves etc. Refer Figure 1
2. Create a data (DAT) file using KYPIPE2.
3. Execute a snap shot run for steady state analysis.
4. Convert KYPIPE DAT file into Steady state Initial Condition (SIC) using C-SIC data conversion program.
5. Run C-SIC program and create the Initial Condition File (ICF) required for the Surge Analysis.
6. Open the already created ICF file within SURGE4 Program and, edit and modify data as required by the SURGE4 program to simulate pump trip.
7. Run the program and compile results of flows and pressures from Pump Station end of the pipeline up to the delivery end at the reservoir.
8. Modify the geometric model to include side discharge orifices (SDOs) for modeling surge control facilities such as surge tanks and air valves (Refer Figure 2).
9. Input additional data for surge tank and air valves.
10. Repeat steps 1 to 7 and compile results including variation of gas volume within the surge tank.
11. Execute number of trial runs and determine the most economical size for the surge tank
12. Design layout, piping and air compressor for the surge tank.

Computer Runs

The following computer runs were executed for the simulation of "pump trip" under different operational scenarios:

Run 1 The system with no surge control device and with one pump in operation delivering the ultimate design output of 700.1 l/s to Gotathuwa and Kolonnawa

Run 2 The system with no surge control device and with one pump in operation delivering the ultimate design output to Gotathuwa only

Run 3 The system with no surge control device and with one pump in operation delivering the ultimate design output to Kolonnawa only

Run 4 The system with surge control device in place and with one pump in operation delivering the ultimate design output to Gotathuwa and Kolonnawa.

Program assumptions:-

- Within the program, each of the pipelines is divided into line segments as indicated in network diagrams. Each line segment is defined by the program by assigning two numbers one at the starting point and the other at the end point.
- The basic parameters calculated by the program for each of the line segment are:
  - Number of wave travel increments in terms of time increment provided, which in this case .01 *seconds was allocated.*
  - Factor c/gA which is (wave speed)/(gravity constant*cross sectional area of pipe) Initial flowrate
  - Segment Resistance
  - *Pump Curves are defined by quadratic curves with A, B and C as constants*
- The wave speed is assumed to remain constant in all pipe branches
- Simulation time is taken as 100 seconds for the runs 1, 2 and 3 and 200 secs for the run 4.
- Multiple pumps have been simplified, to be represented by one equivalent pump
- Duration of 1 second is allowed for the pump to come to a complete stop from the time of sudden stoppage
- The gas volume within the surge tank is assumed to follow adiabatic compression and expansion with gas constant = 1.1

Presentation of Results:-

Computer printouts of SIC and Surge Analysis programs for each of the Runs mentioned above are enclosed in the Appendix. The results are summarized as follows:

Run 1

Computer File Organization:-

Steady State Initial Condition Input Data File : gk__ic1.SIC

Steady State Initial Condition Output Data File : gk__ic1.TIC

Surge Analysis

Input Data File : gk_ic1.DAT

Results Interpretation:-

Maximum Pressure occurs at the position 3 and is equal to 318.3 m.

During the surge sub atmospheric pressure will develop along the pipeline. Along the pipeline sub-atmospheric pressure will reach cavitation range I e -10.1 m.

The maximum pressure of 318.3 m as well as the sub atmospheric pressure condition is not acceptable since this phenomenon would result in cavitation and possible damage to the pipeline. to the system.

The results are graphically represented in the attached Charts 1 and 2.

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CEYWATER	PROJECT:- Greater Colombo NRW Reduction	Job No	
		Des. By	AP
	COMPONENT:- G'thuwa K'nawa Pumping Main	Checked	
	Surge Analysis	Date	25-7-00

Run 2

Computer File Organization:-

Steady State Initial Condition Input Data File	:	gk__ic2.SIC
Steady State Initial Condition Output Data File	:	gk__ic2.TIC
Surge Analysis		
Input Data File	:	gk_ic2.DAT
Output File	:	gk_ic2.OUT

Results Interpretation:-

The positive surge is not so severe as in the case of Run 1 and the maximum pressure of 115.1 m occurs at position 4. However, negative surge will reach cavitation pressure soon after the pump.

The results are graphically represented in the attached Charts 2 and 3.

Run 3

Computer File Organization:-

Steady State Initial Condition Input Data File	:	gk__ic3.SIC
Steady State Initial Condition Output Data File	:	gk__ic3.TIC
Surge Analysis		
Input Data File	:	gk_ic3.DAT
Output File	:	gk_ic3.OUT

Results Interpretation:-

The positive surge is not so severe as in the case of Runs 1 & 2 and the max. pressure of 108.6 m occurs at position 5. However, negative surge will reach cavitation pressure along the pipeline.

The results are graphically represented in the attached Charts 5 and 6.

Run 4

Run 4 simulates "pump trip" with the surge tank in place and for the operational scenario defined under Run 1.

Computer File Organization:-

Steady State Initial Condition Input Data File	:	gk__ic4.SIC
Steady State Initial Condition Output Data File	:	gk__ic4.TIC
Surge Analysis		
Input Data File	:	gk_ic4.DAT
Output File	:	gk_ic4.OUT

With the surge tank in place, a maximum pressure of 83.3 m occurs at position 3. The pipeline will not be subjected to sub atmospheric pressure up to -10.1 m. Hence the system is not at risk.
The sub-atmospheric pressure indicated for positions 1, 2 and 3 can be disregarded since water in the clear water tank will flow into the negative pressure region and nullifies the vacuum.
Pressure wave energy is absorbed by the volume of gas in the surge tank. The gas volume increases from 7 cum to a maximum of 19.6 cum and gradually decreases to 17.6 cum at the end of 200 secs.

The initial gas head is estimated at 41.6 m

The surge tank must be so sized that adequate water level is maintained within the tank at all times without allowing the tank to go empty. Sizing of the tank is indicated later in this calculation.

CEYWATER	PROJECT:- Greater Colombo NRW Reduction	Job No	
		Des. By	AP
	COMPONENT:- G'thuwa K'nawa Pumping Main	Checked	
	Surge Analysis	Date	25-7-00

The results are graphically represented in the attached Charts 7, 8 and 9 representing:

Variation of Head and Flow Vs. Time at Position 22

Gas Volume Vs. Time

Sizing of the surge vessel:-

The proposed surge vessel is designed to cater for the ultimate operating condition of 700.1 l/s and should be able to withstand a pressure of 10 bar.

As per above analysis, maximum gas volume	=	19.6	cu m
To avoid gas escaping into the pipeline, a 50.00 % buffer capacity is usually allowed.			
Hence the required capacity of the vessel	=	29.4	cu m
	Say	**30**	**cu m**

Replaceable bladder type hydropneumatic tank (2 in number) is selected with the following dimensions:

Diameter of the vessel	**=**	**2**	**m**
Overall Height of the vessel	**=**	**5.97**	**m**

Design of Air Compressor:-

Initial gas volume	=	7	cu m
Initial gas head (gage)	=	41.6	m
Atmospheric Pressure	=	10.34	m
Therefore, Initial gas head (absolute)	=	51.94	m
Applying Boyle's Law PV = constant, equivalent volume of free air	=	35.1625	cu m
	=	35162.5	liters

Provide a compressor conforming to following:

Capacity in terms of Free Air Delivery (FAD)	=	26.66	l/s
Operating Pressure	=	10	bar
	=	101.97	m
Absolute Operating Pressure	=	112.31	m
Time taken to pressurize the vessel	=	1318.92	secs
	=	21.982	mins
		OK	

Theoretical Air Power for the compressor in kW is given by:-

((P1*FAD)/10)*ln(P2/P1)

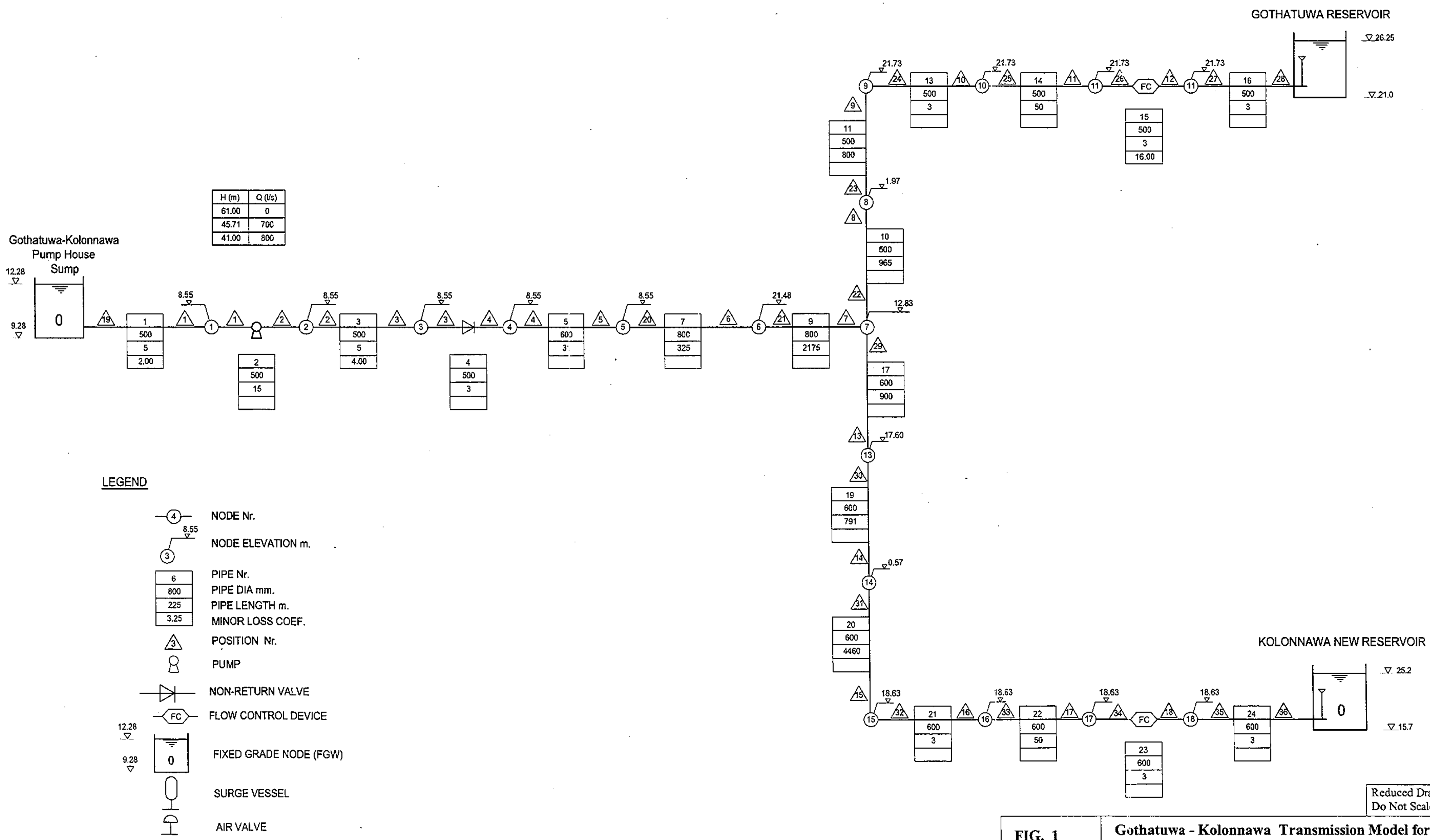
Where P is the absolute pressure in bar at initial and final conditions

Therefore, theoretical air power	**=**	**6.44824**	**kW**
Required Horse Power of the motor is generally 2 times the theoritical horse power.			
Therefore, required motor horse power	=	**12.8965**	**kW**
Provide a motor of capacity	=	**15**	**kW**

	A	B	C	D	E	F	G	H	I	J
1	CEYWATER			PROJECT:- Greater Colombo NRW Reduction					Job No	
2									Des. By	AP
3				COMPONENT:- G'thuwa K'nawa Pumping Main					Checked	
4					Surge Analysis				Date	25-7-00
274										
275	Computation of size of the air receiver:-									
276										
277	Required volume of the receiver is given by:									
278										
279	Vr =	60*C*B/P	for constant demand							
280	Vr =	180*C*B/P	for variable demand							
281	Where	C =	Output of the compressor in FAD l/s							
282		B =	Atmospheric Pressure in bar absolute							
283		P =	Working Pressure in bar absolute							
284							B	=	1.01	bar
285							P	=	10	bar
286					Vr for constant demand			=	161.56	liters
287					Vr for variable demand			=	484.679	liters
288										
289	**Therefore, provide a air receiver with volume not less than**							**480**	**liters**	

FIGURE 1

GOTATHUWA - KOLONNAWA TRANSMISSION SYSTEM
MODEL FOR SURGE ANALYSIS
(WITHOUT SURGE CONTROL FACILITIES)



NOTE;
'C' VALUE IS GLOBALLY TAKEN AS 110

Reduced Drawing
Do Not Scale

FIG. 1	**Gothatuwa - Kolonnawa Transmission Model for Surge Analysis**
SCALE	**DRG. No.**

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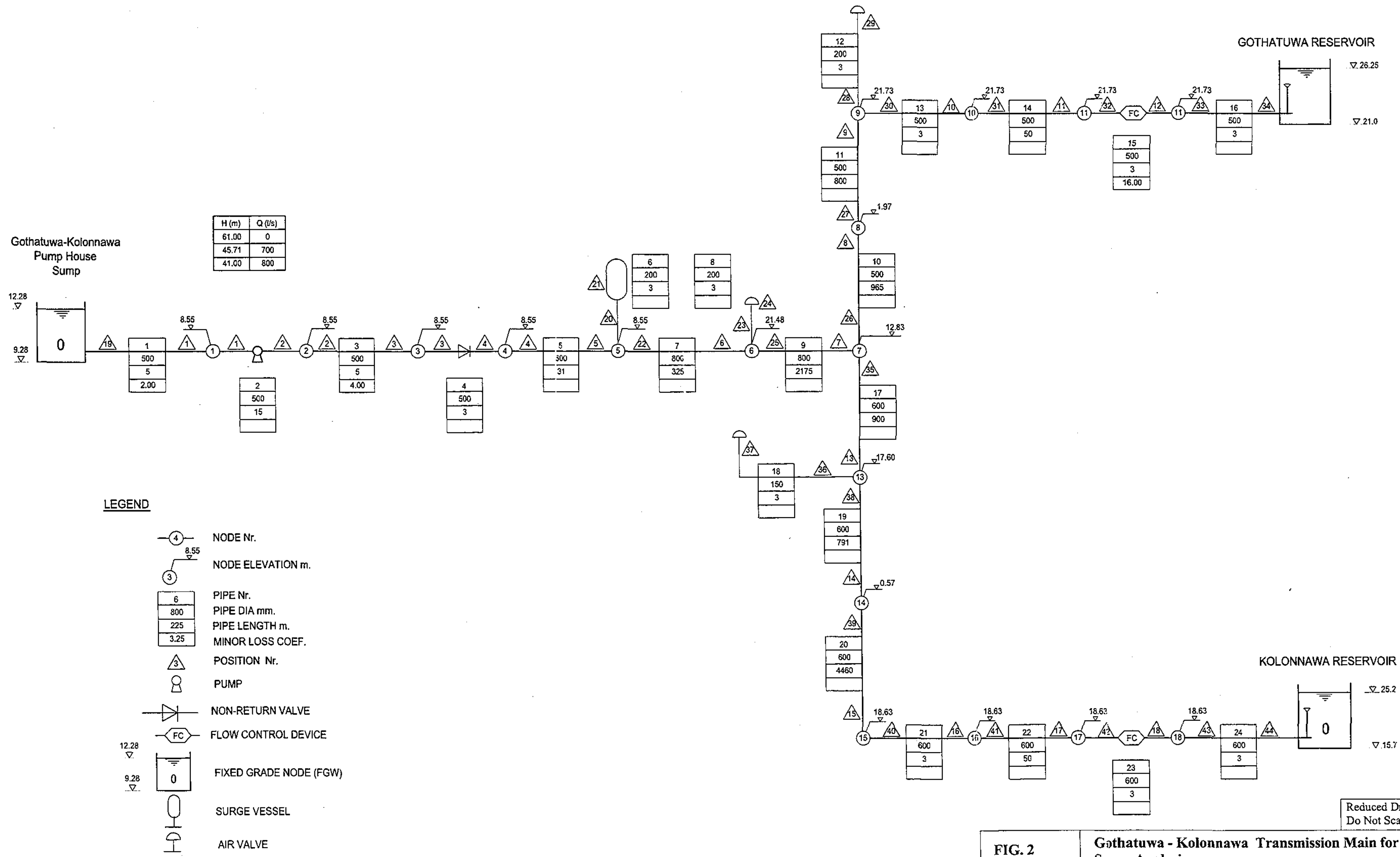
FIGURE 2

GOTATHUWA - KOLONNAWA TRANSMISSION SYSTEM
MODEL FOR SURGE ANALYSIS
(WITH SURGE TANK AND AIR VALVES IN PLACE)



NOTE;
'C' VALUE IS GLOBALLY TAKEN AS 110

Reduced Drawing
Do Not Scale

FIG. 2	Gothatuwa - Kolonnawa Transmission Main for Surge Analysis (with surge control facilities)		
SCALE		DRG. No.	

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