$$0.0011h_2+0.0013h_3-0.0024h_4= \ 0.0045$$

$\therefore h_2=38.705,\ h_3=38.453,\ h_4=36.694$

$|38.705-38.708|=0.003>0.001$ .... NO

$|38.453-38.446|=0.007>0.001$ .... NO

$|36.694-36.691|=0.003>0.001$ .... NO

(f) The sixth trial

$k_{12}=k_{21}=0.0032,\ k_{13}=k_{31}=0.0012,\ k_{23}=k'_{32}=0.0037$

$k_{24}=k_{42}=0.0011,\ k_{34}=k_{43}=0.0013$

$$\therefore \begin{cases} -0.0080h_2+0.0037h_3+0.0011h_4=-0.1270 \\ 0.0037h_2-0.0062h_3+0.0013h_4=-0.0475 \\ 0.0011h_2+0.0013h_3-0.0024h_4= \ 0.0045 \end{cases}$$

$\therefore h_2=38.705,\ h_3=38.453,\ h_4=36.694$

$|38.705-38.705|=0<0.001$ .... OK

$|38.453-38.453|=0<0.001$ .... OK

$|36.694-36.694|=0<0.001$ .... OK

The dynamic hydraulic pressures are,

$h_1= 40.000^m$

$h_2= 38.705^m$

$h_3= 38.453^m$

$h_4= 36.694^m$

The quanities of flow in every pipelines are as follows

$$q_{12}=0.27853\,C\cdot D_{12}^{2.63}\ \left(\frac{h_1-h_2}{L_{12}}\right)^{0.54}$$

$$=0.27853\times140\times0.100^{2.63}\times\left(\frac{40.000-38.705}{400}\right)^{0.54}$$

$$=0.00414\ m^3/sec=4.14\ l/sec$$

by the same way

$$q_{13}=0.27853\times140\times0.075^{2.63}\times\left(\frac{40.000-38.453}{500}\right)^{0.54}$$

$$=0.00189\ m^3/sec=1.89\ m^3/sec=1.89\ l/sec$$

$$q_{23}=0.27853\times140\times0.075^{2.63}\times\left(\frac{38.705-38.453}{300}\right)^{0.54}$$

$$=0.00094\ m^3/sec=0.94\ l/sec$$

$$q_{24}=0.27853\times140\times0.075^{2.63}\times\left(\frac{38.705-36.694}{500}\right)^{0.54}$$

$$=0.00218\ m^3/sec=2.18\ l/sec$$

$$q_{34}=0.27853\times140\times0.075^{2.63}\times\left(\frac{38.453-36.694}{400}\right)^{0.54}$$

$$=0.00229\ m^3/sec=2.29\ l/sec$$

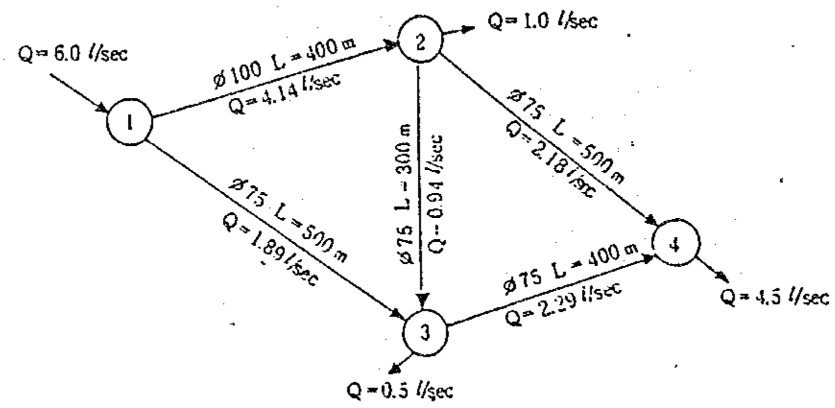


Fig. S6 -2 Results of calculation.

A P P E N D I X

Appendix A. Method of Population Project

(1) Arithmetical progression method

This method is based on the annual average population growth.

$$Pn = Po + n \cdot q$$

$$q = \left(\frac{Po - Pt}{t}\right)$$

Where, Pn : Population n years after the base year

Po : Present population

n : Years counted from the base year

q : Increasing ratio of population per year

Pt : Population t years before the base year

This method can be applied only to slow-developing or developed cities.

(2) Geometric progression method

This method is based on average yearly increase ratio in population.

$$Pn = Po\ (1 + r)^n \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$r = \left(\frac{Po}{Pt}\right)^{1/t} - 1$$

Where, r : Average yearly increase ratio in population

This method is applied to developing cities with a uniform rate of population growth for a certain period of time. When cities have a tendency to decrease in the rate of population growth after the maximum population, this method is not applicable.

Hence we can obtain the future population by substituting the values of n in Table A-2 into the equation (2).

Table A-2. Estimated Population of City B

Year	n	Estimation Population y
1981	1	121,000
1982	2	127,100
1983	3	133,500
1984	4	140,300
1985	5	147,400

(3) Power functional method

This method is based on exponential curve

$$Pn = Po + An^{a}$$

Where, Pn : Population n years after the base year

Po : Population of the base year

n : Years counted from the base year

A and a: Constants

A and a can be obtained in the following equation:

$$\log (pn - Po) = \log A + a \operatorname{Log} n$$

$$Y = ax + b$$

Where, $\log (Pr - Pb) = Y$

$\log n = x$

$\log A = b$

This method is applied to most cities.

(4) Logistic curve method

$$Y = \frac{K}{1 + e^{a-bx}}$$

Where, Y : Population x years after the base year

x : Years counted from the base year

e : Base of natural logarithm

K : Saturation population

a and b : Constants

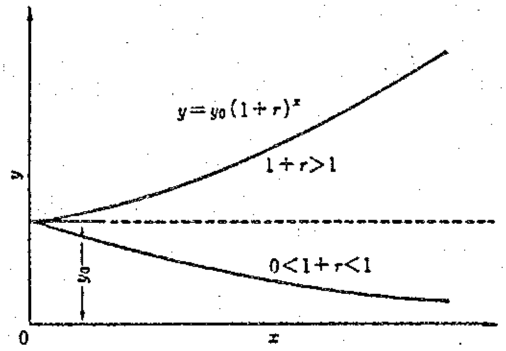


Fig. A-1. Curve based on average yearly increase (ratio) in population

(Example A-1)

From the recorded population of city B in Table A-1, the future population is estimated.

Table A-1. Recorded Population of City B

Year	Population
1971	73,905
1972	76,634
1973	82,381
1974	86,939
1975	92,139
1976	95,122
1977	101,317
1978	104,986
1979	108,747
1980	115,191

(Solution) from Table A-1, we have:

$$q = \left(\frac{Po}{Pt}\right)^{\frac{1}{t}} - 1 = \left(\frac{115,191}{73,905}\right)^{\frac{1}{t}} - 1 = 0.05055$$

Thus, the equation (1) becomes,

$$P_n = Po\ (1 + r)^n = 115,191 \times (1 + 0.05055)^n \ \ldots . \ (2)$$

Appendix B. Typical Water Consumption

Table B-1. Domestic Water Consumption (Ref. Book No.1)

Type of Water Supply	Typical Water Consumption (liters/capita/day)	Range (liters/capita/day)
Communal stand pipe walking distance 250m	30	20 - 50
Yard connection tap placed in house yard	40	20 - 80
House connection		
- single tap	50	30 - 60
- multiple tap	150	70 - 250

Table B-2. Various Water Consumption (Ref. Book No.1)

Category	Typical Water Use
- Schools	
Day Schools	150-30 l/day per pupil
Boarding Schools	90-140 "
- Hospitals (with laundry facilities)	220-300 l/day per bed
- Hotels	80-120 l/day per resident
- Restaurants	65-90 l/day per seat
- Mosques (Temples)	25-40 l/day per visitor
- Cinema Houses	10-15 l/day per seat
- Offices	25-40 l/day per person
- Railway and Bus Stations	15-20 l/day per user
- Livestock	
Cattle	25-35 l/day per head
Horse and Mules	20-25 "
Sheep	15-25 "
Pigs	10-15 "
- Poultry	
Chicken	15-25 l/day per 100

Table B-3. Average Daily Supply Per Capita in Major Cities of the World (1)

Country	City	Population Served (x 1,000)	Average Daily Supply in liters/Head
Belgium	Antwerp	640	456
	Brussels	1,311	178
Denmark	Copenhagen	537	311
	Odense	129	386
Finland	Espoo	177	283
	Helsinki	490	394
France	Marseilles	965	486
	Paris	3,960	249
Germany (West)	Berlin	2,000	268
	Frankfurt	901	312
Ireland	Cork	135	354
	Dublin	998	251
Israel	Jerusalem	380	291
	Tel Aviv	343	281
Italy	Naples	1,600	394
	Rome	2,792	651
Netherlands	Amsterdam	758	241 (2)
	Rotterdam	672	338 (2)
Poland	Lodz	804	365
	Wroclaw	585	325
South Africa	Cape Town	750	225 (2)
	Johannesburg	1,394	355
Spain	Barcelona	3,147	267
	Selvilla	742	317
Sweden	Gothenburg	427	439
	Stockholm	930	328
UK	Liverpool	860	349
	London	5,710	314
USA	Atlanta	675	562
	Hamilton	800	887
	Philadelphia	1,900	741
	San Francisco	665	608
JAPAN (3)	TOKYO	10,636	455
	Osaka	2,677	602
	Nagasaki	410	363
Thailand (4)	Chonburi	173.9	409
	Songkhla	209.6	252
	Khonkean	119.0	182
	Chiengmai	188.7	301

(1) E.C. Reed "Report on Water Losses" AQUA, No. 8, 1980
(2) Excludes unaccounted-for water
(3) 1978 JWWA
(4) 1985 PWA

Appendix C. Data Sheet for Geoelectric Prospecting

Geoelectric Prospecting

Location________ Point No.__________ Location__________ Point No.__________
Date________ Method______________ Date________ Method______________

a	V	I	R	2πa	ρ	a	V	I	R	2πa	ρ
0.5				3.14		0.5				3.14	
1				6.28		1				6.28	
2				12.56		2				12.56	
3				18.84		3				18.84	
4				25.1		4				25.1	
5				31.4		5				31.4	
6				37.7		6				37.7	
7				44.0		7				44.0	
8				50.3		8				50.3	
9				56.5		9				56.5	
10				62.8		10				62.8	
12				75.4		12				75.4	
14				88.0		14				88.0	
16				100.5		16				100.5	
18				113.0		18				113.0	
20				125.6		20				125.6	
24				150.9		24				150.9	
28				175.9		28				175.9	
32				201.0		32				201.0	
36				225.0		36				226.0	
40				251.0		40				251.0	
45				282.7		45				282.7	
50				314.2		50				314.2	
60				376.5		60				376.3	
70				439.8		70				439.8	
80				502.5		80				502.5	
90				565.5		90				565.5	
100				628.3		100				628.3	

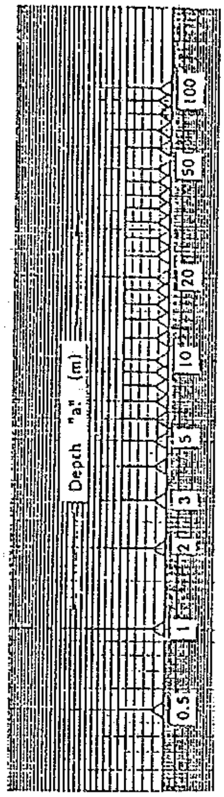
Remarks

$\rho = 2\pi a \times R$ (Wenner Arrangement)

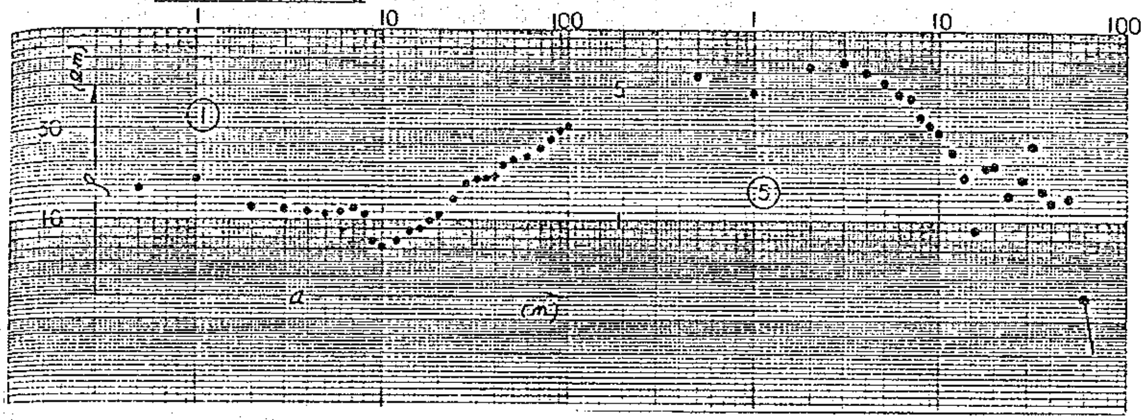
$R = \frac{V}{I}$

Remarks

S.C.L. Japan



Kham Sakae Sang (1)   Sample ρ-a curve



Appendix D. Water Quality Standard (Ref. Book No. 4)

(1) Physical condition

Item	WHO Highest desirable	WHO Maximum permissible	Japan
Colour	15	50	5
Taste	not offensive	not offensive	not offensive
Odour	"	"	"
Turbidity	5	25	2
PH	6.5 to 8.5	6.5 to 9.2	5.8 to 8.6

(2) Chemical condition

Item \ PPM	WHO Highest disirable	WHO Maximum permissible	Japan
Total solids	500	1,500	-
Fe	0.1	1.0	0.3
Mn	0.05	0.5	0.3
Fe + Mn	-	-	-
Cu	0.05	1.5	1.0
Ca	75	200	-
Mg	30	150	-
SO_4	200	400	-
Cl	200	600	200
F	0.6	-	0.8
NO_3	10	-	10
Alkylbenzyl Sulfohates, ABS	0.5	-	0.5
Phenolic-substance as phenol	0.001	-	0.005
Hardness	100	500	300

(3) Toxin

Item	WHO	Japan
Hg	0.001	None
Pb	0.1	0.1
As	0.05	0.05
Se	0.01	0.01
Cr^{6+}	0.05	0.05
CN	0.1	None
Cd	0.005	0.01
Ba	1.0	-

(4) Bacteriological condition

Item	WHO	Japan
Standard Plate count (Coloines/cm^3)	-	100
MPN (Coliform Organism/$100m^3$)	1	None
F. Coli	-	-

Appendix E. Diagram of Hazen-William's Formula
(Ref. Book No. 11)

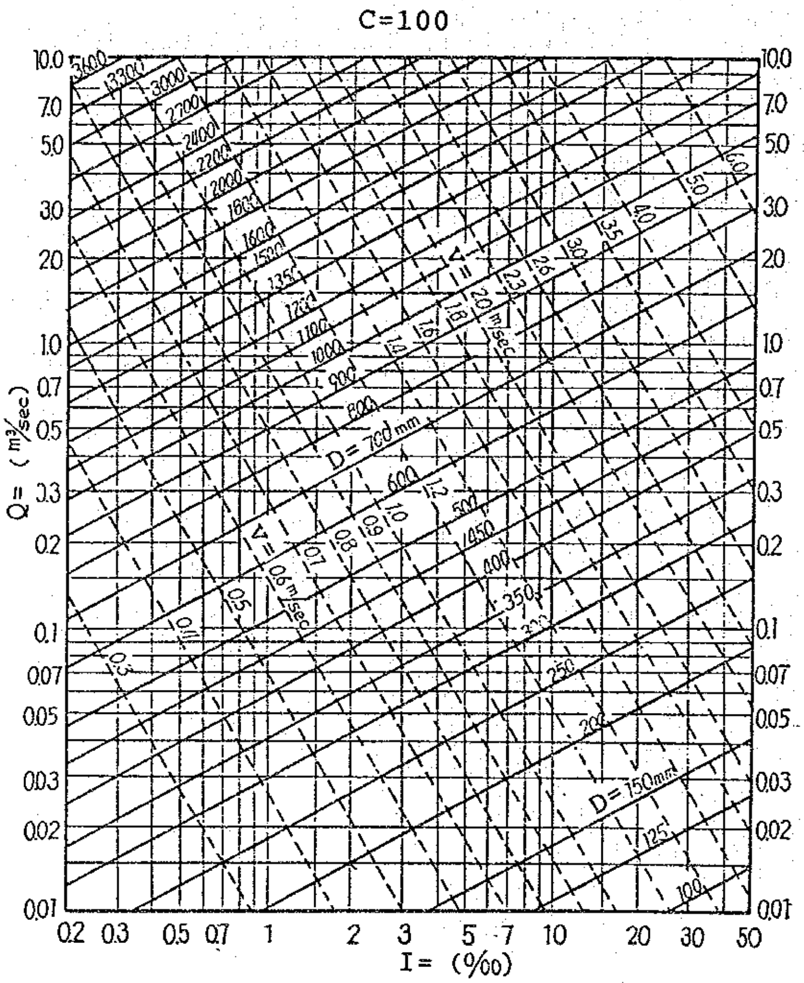


Fig. E-1. Friction Head Loss C = 100

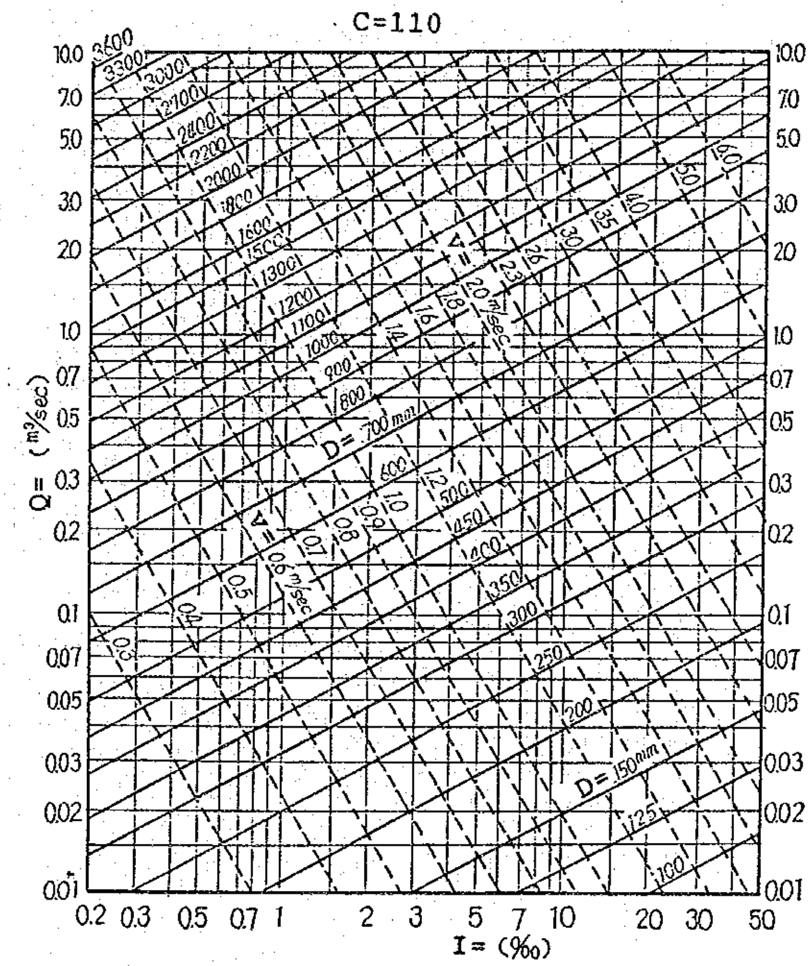


Fig. E-2. Friction Head Loss C = 110

C=120

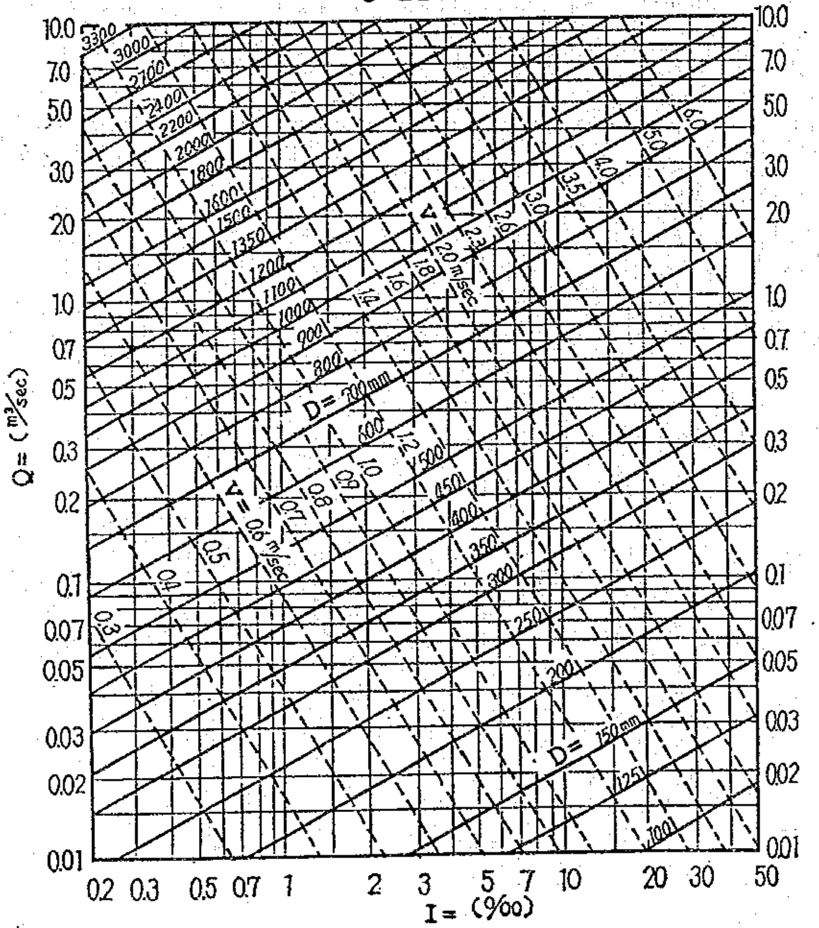


Fig. E-3. Friction Head Loss C = 120

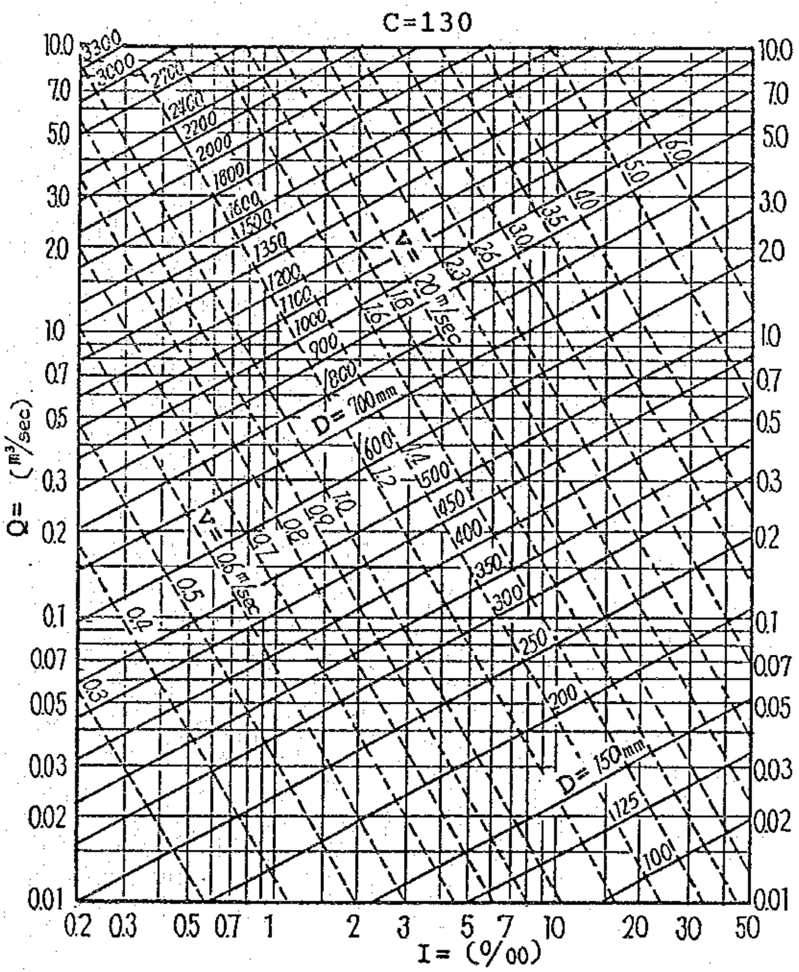


Fig. E-4. Friction Head Loss C = 130

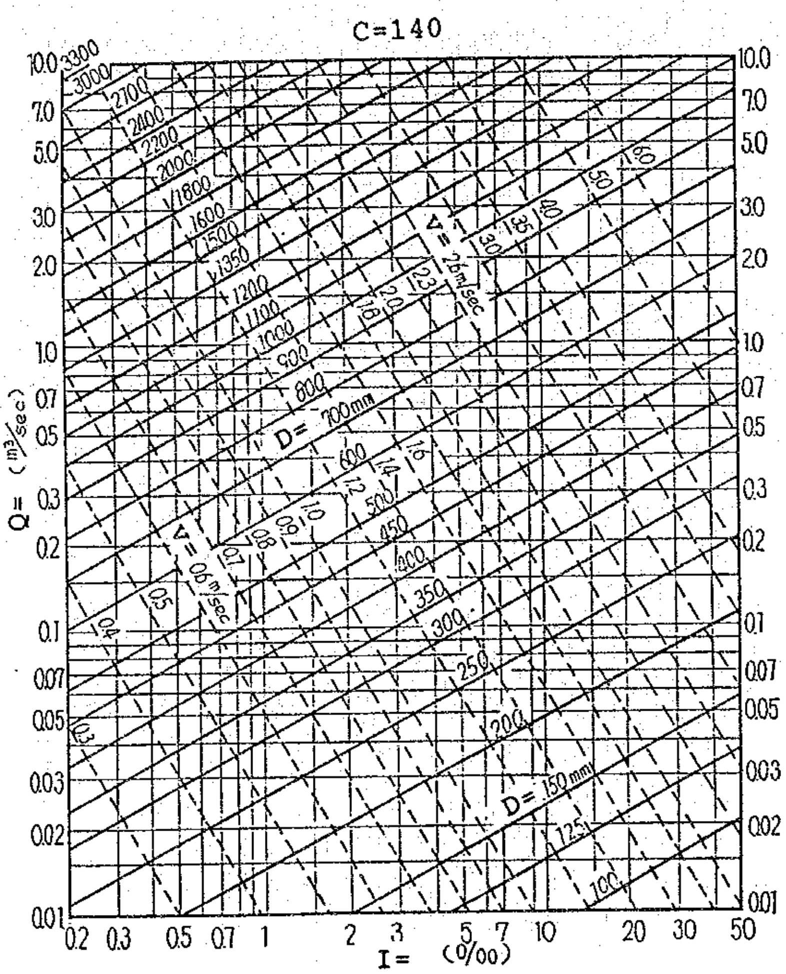


Fig. E-5. Friction Head Loss C = 140

Source: Discharge Table of Pipe and Weir 1980.JWWA

Figure F-1. Discharge of Weirs

A. Triangular Weir

by stlicland's formula

$$Q=60\ (1.334+\frac{0.0205}{\sqrt{H}})\ H^{\frac{5}{2}}$$

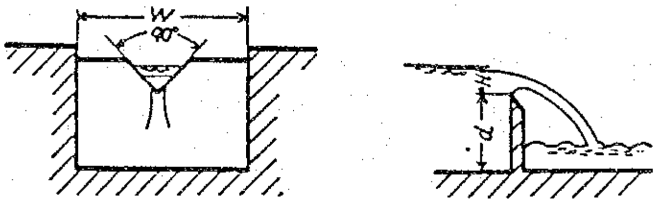
$\theta=90°$ $H>50mm$ $W>7H$ $d>3H$

Q = Discharge .... m^3/min

H = Depth over the weir..... m

W = Width of Channel .... m

d = Height of the weir ...m



Discharge Table of Triangular Weir m^3/min

H(mm)	0	1	2	3	4	5	6	7	8	9
50	0.0478	0.0503	0.0527	0.0553	0.0579	0.0605	0.0633	0.0662	0.0690	0.0720
60	0.0751	0.0782	0.0814	0.0847	0.0881	0.0914	0.0950	0.0986	0.1022	0.1060
70	0.1099	0.1137	0.1178	0.1219	0.1261	0.1302	0.1346	0.1390	0.1434	0.1481
80	0.1528	0.1575	0.1625	0.1675	0.1724	0.1775	0.1828	0.1882	0.1935	0.1989
90	0.2046	0.2103	0.2161	0.2219	0.2278	0.2339	0.2401	0.2462	0.2524	0.2590
100	0.2656	0.2722	0.2788	0.2857	0.2927	0.2997	0.3067	0.3139	0.3214	0.3288
110	0.3362	0.3437	0.3516	0.3595	0.3674	0.3754	0.3834	0.3918	0.4002	0.4086
120	0.4170	0.4258	0.4347	0.4436	0.4525	0.4614	0.4707	0.4892	0.4896	0.4990
130	0.5085	0.5184	0.5284	0.5383	0.5482	0.5585	0.5689	0.5794	0.5898	0.6004
140	0.6113	0.6222	0.6332	0.6441	0.6555	0.6670	0.6784	0.6899	0.7014	0.7135
150	0.7255	0.7375	0.7495	0.7618	0.7744	0.7869	0.7995	0.8121	0.8251	0.8383
160	0.8514	0.8645	0.8778	0.8915	0.9053	0.9190	0.9328	0.9465	0.9608	0.9752
170	0.9897	1.0040	1.0184	1.0303	1.0480	1.0530	1.0780	1.0940	1.1080	1.124
180	1.1390	1.1550	1.1720	1.1880	1.2040	1.2210	1.2370	1.2540	1.2700	1.287
190	1.3040	1.3210	1.3390	1.3560	1.3730	1.3910	1.4090	1.4280	1.4460	1.464
200	1.4810	1.500	1.519	1.537	1.556	1.575	1.594	1.613	1.633	1.652
210	1.672	1.692	1.712	1.732	1.752	1.772	1.783	1.814	1.835	1.856
220	1.877	1.898	1.920	1.941	1.963	1.984	2.007	2.029	2.051	2.073
230	2.096	2.119	2.142	2.165	2.188	2.211	2.234	2.253	2.281	2.304

Source: Discharge Table of Pipe and Weir, 1980, JWWA.

H(mm)	0	1	2	3	4	5	6	7	8	9
240	2.329	2.354	2.379	2.402	2.427	2.452	2.477	2.502	2.528	2.553
250	2.578	2.604	2.630	2.656	2.682	2.708	2.735	2.762	2.789	2.815
260	2.842	2.870	2.897	2.926	2.953	2.980	3.008	3.037	3.065	3.093
270	3.122	3.151	3.180	3.209	3.238	3.267	3.297	3.327	3.357	3.387
280	3.417	3.448	3.473	3.504	3.535	3.571	3.602	3.634	3.665	3.697
290	3.728	3.761	3.793	3.825	3.858	3.890	3.923	3.957	3.990	4.023
300	4.056	4.090	4.124	4.159	4.192	4.226	4.261	4.296	4.331	4.366
310	4.401	4.446	4.465	4.487	4.528	4.562	4.597	4.635	4.678	4.713

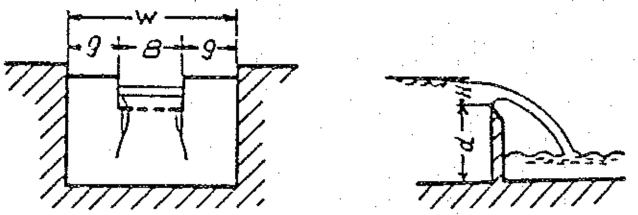
B. Rectaugular Weir (Reducer Type)

by Francis' formula

$$Q = 1.838\ (B - 0.2H)\ H^{\frac{3}{2}} \cdots\cdots\cdots\ m^3/sec$$

$300mm > H > 150mm \quad B > 3H$

$g > 2H \quad d > 3H$



Discharge Table of Rectangular Weir (Reducer Type)

H(mm) \ B(mm)	750	1,000	1,500	2,000	3,000	4,000
150	4.606	6.215	9.418	12.62	19.03	25.43
155	4.840	6.519	9.886	13.26	19.98	26.71
160	5.068	6.832	10.360	13.89	20.95	28.01
165	5.301	7.149	10.850	14.54	21.93	29.33
170	5.535	7.467	11.33	15.20	22.93	30.66
175	5.772	7.791	11.86	15.86	23.94	32.01
180	6.013	8.119	12.33	16.54	24.96	33.38
185	6.057	8.451	12.84	17.23	26.00	34.78
190	6.503	8.786	13.35	17.92	27.05	36.19
195	6.752	9.126	13.87	18.62	28.12	37.61
200	7.003	9.469	14.40	19.33	29.20	39.06
205	7.257	9.816	14.93	20.05	30.29	40.52

B/(mm) H(mm)	750	1,000	1,500	2,000	3,000	4,000
210	7.512	10.160	15.47	20.78	31.39	42.00
215	7.765	10.51	15.99	21.48	32.48	43.46
220	8.034	10.88	16.57	22.25	33.64	45.02
225	8.299	11.24	17.13	23.01	34.78	46.56
230	8.563	11.60	17.69	23.77	35.93	48.10
235	8.832	11.97	18.25	24.54	37.10	49.66
240	9.071	12.30	18.83	25.31	38.27	51.24
245	9.375	12.72	19.45	26.09	39.47	52.84
250	9.650	13.10	19.99	26.88	40.67	54.45
255		13.48	20.58	27.68	41.88	56.08
260		13.86	21.17	28.48	43.10	57.72
265		14.25	21.77	29.29	44.35	59.38
270		14.64	22.37	30.11	45.58	61.05
275		15.03	22.98	30.93	46.84	62.74
280		15.42	23.59	31.77	48.10	64.44
285		15.82	24.21	32.60	49.38	66.16
290		16.22	24.83	33.45	50.67	67.89
295		16.61	25.46	34.30	51.97	69.64
300		17.03	26.09	35.15	53.28	71.40

C. Rectangular Weir (Flat type)

by Francis' formula

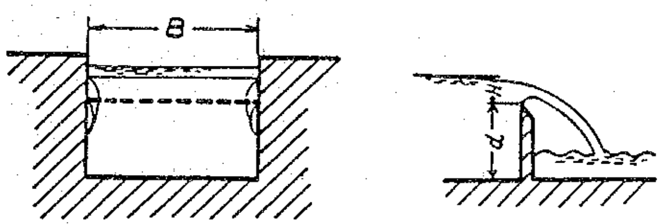
with approach velocity

$$Q = 1.838\,B\left\{\left(H + \frac{V^2}{2g}\right)^{\frac{3}{2}} - \left(\frac{V^2}{2g}\right)^{\frac{3}{2}}\right\} \cdots m^3/sec$$

without approach velocity

$$Q = 1.838\,BH^{\frac{3}{2}} \cdots\cdots\cdots\cdots m^3/sec$$

d>3H H>150mm

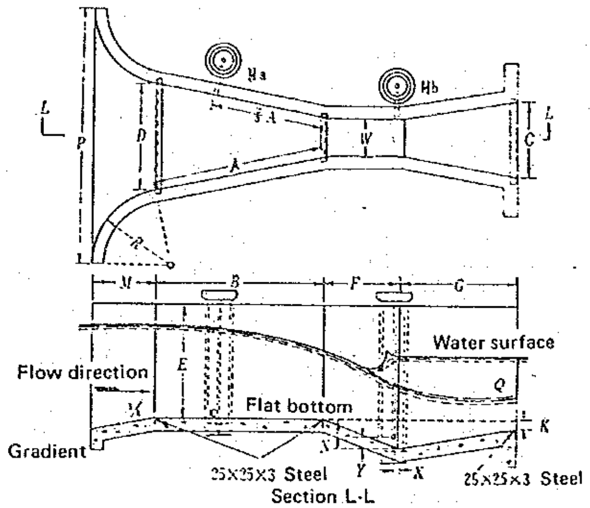


Discharge Table of Rectangular Weir (Flat Type)

H(mm) \ B(mm)	1,000	2,000	3,000	4,000	5,000	6,000
150	6.465	12.81	19.22	25.63	32.03	38.44
155	6.729	13.46	20.19	26.92	33.65	40.38
160	7.058	14.12	21.17	28.23	35.29	42.35
165	7.393	14.79	22.18	29.57	36.97	44.36
170	7.730	15.46	23.19	30.92	38.65	46.38
175	8.073	16.15	24.22	32.29	40.37	48.44
180	8.422	16.84	25.24	33.69	42.11	50.53
185	8.775	17.55	26.33	35.10	43.88	52.65
190	9.133	18.27	27.40	36.53	45.67	54.80
195	9.495	18.99	28.49	37.99	47.48	56.98
200	9.863	19.73	29.59	39.45	49.32	59.18
205	10.23	20.47	30.71	40.94	51.18	61.42
210	10.61	21.22	31.83	42.44	53.05	63.66
215	10.98	21.97	32.95	43.93	54.91	65.90
220	11.38	22.76	34.14	45.52	56.90	68.28
225	11.77	23.54	35.31	47.08	58.86	70.63
230	12.16	24.32	36.49	48.77	60.82	72.99
235	12.56	25.13	37.69	50.25	62.82	75.38
240	12.96	25.93	38.90	51.86	64.83	77.79
245	13.38	26.75	40.12	53.49	66.87	80.24
250	13.79	27.57	41.36	55.14	68.93	82.71
255	14.20	28.40	42.60	56.80	71.00	85.20
260	14.62	29.24	43.86	58.48	73.09	87.72
265	15.05	30.09	45.13	60.18	75.22	90.19
270	15.47	30.94	46.42	61.89	77.36	92.83
275	15.90	31.81	47.71	63.61	79.52	95.42
280	16.34	32.68	49.02	65.36	81.70	98.04
285	16.78	33.56	50.34	67.12	83.89	100.67
290	17.23	34.45	51.67	68.89	86.11	103.33
295	17.67	35.34	53.01	70.68	88.35	106.02
300	18.12	36.24	54.36	72.48	90.60	108.72

Fig. F-2. Discharge of Parshall Flume

Source: Hydraulic Formula Handbook JSCE. 1971



W	A	$\frac{2}{3}A$	B	C	D	E	F	G	K	N	R	M	P	X	Y	Capacity (m^3/sec) min.	Capacity (m^3/sec) max.
7.62 (3 in)	46.7	31.1	45.7	17.8	25.9	61.0	15.2	30.5	2.5	5.7	40.6	30.5	76.8	2.5	3.8	0.000 85	0.053 8
15.24 (6 in)	62.1	41.4	61.0	39.4	39.7	61.0	30.5	61.0	7.6	11.4	40.6	30.5	90.2	5.1	7.7	0.001 42	0.110
22.86 (9 in)	88.0	58.7	86.4	38.1	57.5	76.2	30.5	45.7	7.6	11.4	40.6	30.5	108.0	5.1	7.6	0.002 55	0.252
30.48 (1 ft)	137.2	91.4	134.3	61.0	84.5	91.4	61.0	91.4	7.6	22.9	50.8	38.1	149.2	5.1	7.6	0.003 11	0.456
45.72 (1 ft 6 in)	144.8	96.5	141.9	76.2	102.6	91.4	61.0	91.4	7.6	22.9	50.8	38.1	167.6	5.1	7.6	0.004 25	0.697
60.96 (2 ft)	152.4	101.6	149.5	91.4	120.7	91.4	61.0	91.4	7.6	22.9	50.8	38.1	185.4	5.1	7.6	0.011 9	0.937
91.44 (3 ft)	167.6	111.8	164.5	121.9	157.2	91.4	61.0	91.4	7.6	22.9	50.8	38.1	222.3	5.1	7.6	0.017 3	1.43
121.92 (4 ft)	182.9	121.9	179.4	152.4	193.7	91.4	61.0	91.4	7.6	22.9	61.0	45.7	271.2	5.1	7.6	0.036 8	1.92
152.40 (5 ft)	198.1	132.1	194.3	182.9	230.2	91.4	61.0	91.4	7.6	22.9	61.0	45.7	308.0	5.1	7.6	0.045 3	2.42
182.88 (6 ft)	213.4	142.2	209.2	213.4	266.7	91.4	61.0	91.4	7.6	22.9	61.0	45.7	344.2	5.1	7.6	0.073 6	2.93
213.36 (7 ft)	228.6	152.4	224.2	243.8	303.2	91.4	61.0	91.4	7.6	22.9	61.0	45.7	381.0	5.1	7.6	0.085 0	3.44
243.84 (8 ft)	243.8	162.6	239.1	274.3	339.7	91.4	61.0	91.4	7.6	22.9	61.0	45.7	417.2	5.1	7.6	0.099 1	3.95

Discharge formula of Parshall flume

W-value	ft-sec unit	*l*-sec unit
1 in	$q=0.338\,H_a^{1.55}$	$q=0.048\,H_a^{1.55}$
2	$q=0.676\,H_a^{1.55}$	$q=0.096\,H_a^{1.55}$
3	$q=0.992\,H_a^{1.55}$	$q=0.141\,H_a^{1.55}$
6	$q=2.060\,H_a^{1.58}$	$q=0.264\,H_a^{1.58}$
9	$q=3.070\,H_a^{1.53}$	$q=0.466\,H_a^{1.53}$
1~8 ft	$q=4\cdot W\cdot H_a\,1.522\,W^{0.026}$	$q=\frac{3.711}{115.66\,W^{0.026}}\,W\cdot H_a\,1.39\,W^{0.026}$
Remarks	q=ft³/sec H_a=ft W=ft	q=*l*/sec H_a=cm W=cm

Source: Hydraulic Formula Handbook, JSCE, 1971

Appendix G

Table G-1. Standard of Coagulants (Ref. Book No. 5 and PWD)

Classification of coagulants	Aluminum sulfate for water works (1977.8.1)			Aluminum Sulfate for TIS			
Standards	JIS K 1450—1977			Type 1		Type 2	
Classification	Solidity No. 1	Solidity No. 2	Liquid	Powder	Granu-lar	Powder	Granu-lar
Appearance			pellucid liquid of colorless or yellowish light brown				
Specific gravity (20°C)							
Aluminum oxide (Al_2O_3) (%)	more than 15.0	more than 14.0	8.0～8.2	16.0	8.0	15.0	7.5
pH	more than 3.0	more than 2.5	more than 3.0	2.8	2.8	2.5	2.5
Ammonia nitrogen (N) (%)	less than 0.03	less than 0.03	less than 0.01	0.03	0.015	0.030	0.015
Arsenic (As) (ppm)	〃 20	〃 20	〃 10	5.0	2.5	20.0	10.0
Iron (Fe) (%)	〃 0.06	〃 1.5	〃 0.02	0.10	0.05	2.00	1.00
Manganese (Mn) (ppm)	〃 50	〃 150	〃 25	50	25	50	25
Cadmium (Cd) (ppm)	〃 4	〃 4	〃 2	4	2	4	2
Lead (Pb) (ppm)	〃 20	〃 20	〃 10	20	10	20	10
Mercury (Hg) (ppm)	〃 0.4	〃 0.4	〃 0.2	0.4	0.2	0.4	0.2
Chrome (Cr) (ppm)	〃 20	〃 20	〃 10	20	10	20	10
Heavy metal (as Pb) (%)				20	10	20	10
Insoluble matter (%)	less than 0.1	less than 0.3		0.3	0.015	0.3	0.015
Sulphate ion (%)							
Basicity (%)							
Sodium oxide (Na_2O) (%)							

Table G-2. Slaked lime for water works (JWWA K 107 - 1978)

Item	Standard value
Calciun oxide (CaO) (%)	more than 72
Sieve remnants (%)	less than 5
Arsenic (As) (ppm)	less than 5
Chrome (Cr) (ppm)	less than 50
Cadmium (Cd) (ppm)	less than 5
Lead (Pb) (ppm)	less than 20
Mercury (Hg) (ppm)	less than 0.2

Table G-3. Soda ash for water works (JWWA K 108 - 1976)

Item	Standard value
Total alkali (Na_2CO_3) (%)	more than 99
Heating loss (%)	less than 5
Arsenic (As) (ppm)	less than 2
Chrome (Cr) (ppm)	less than 5
Cadmium (Cd) (ppm)	less than 2
Lead (Pb) (ppm)	less than 20
Mercury (Hg) (ppm)	less than 0.2

Appendix H. Capacity of Distribution Reservoir and Elevated Tank

Their capacities are determined on the basis of the findings obtained from the field survey in Chonnabot sanitary district.

Variation of hourly water consumption in the district is shown in Figure H-1.

The following matters are observed in the future.

- Maximum hourly water demand .... 78 m^3/h
- Maximum daily water demand .... 52 m^3/h
- Total water demand .... 945 m^3
- Total amount consumed during night from 10 PM to 5 AM .... 105 m^3

(1) Capacity of Elevated Tank

$105 \div 52 \fallingdotseq 2$ hours

Therefore, the capacity is to be two hours' volume of the maximum daily water demand.

(2) Capacity of Distribution Reservoir

The capacity is determined by considering the inflow amount, operation time of pump, capacity of elevated tank and water consumption.

The required capacity is 276 cu.m as described in Table H-1 and Figure H-2.

By adding the amount of water for fire-fighting to the said required capacity:

$$(276 + 30)/52 = 5.9 \quad 6.0 \text{ hours}$$

Therefore, the capacity is to be six hours' volume of the maximum daily water demand.

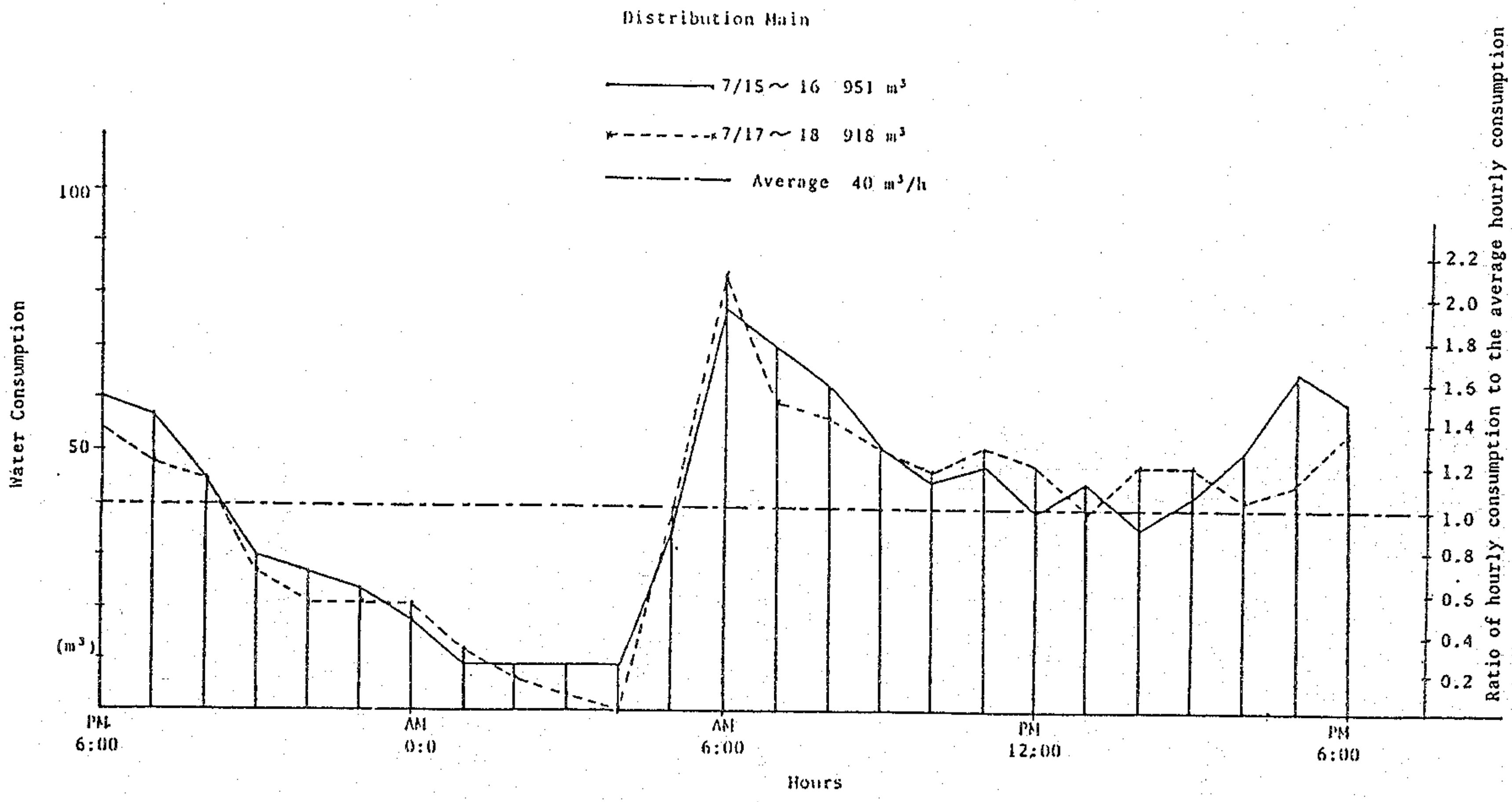


Fig. H-1. Variation of Hourly Water Consumption in Chonnabot SD.

Table H-1. Water Balance Computation

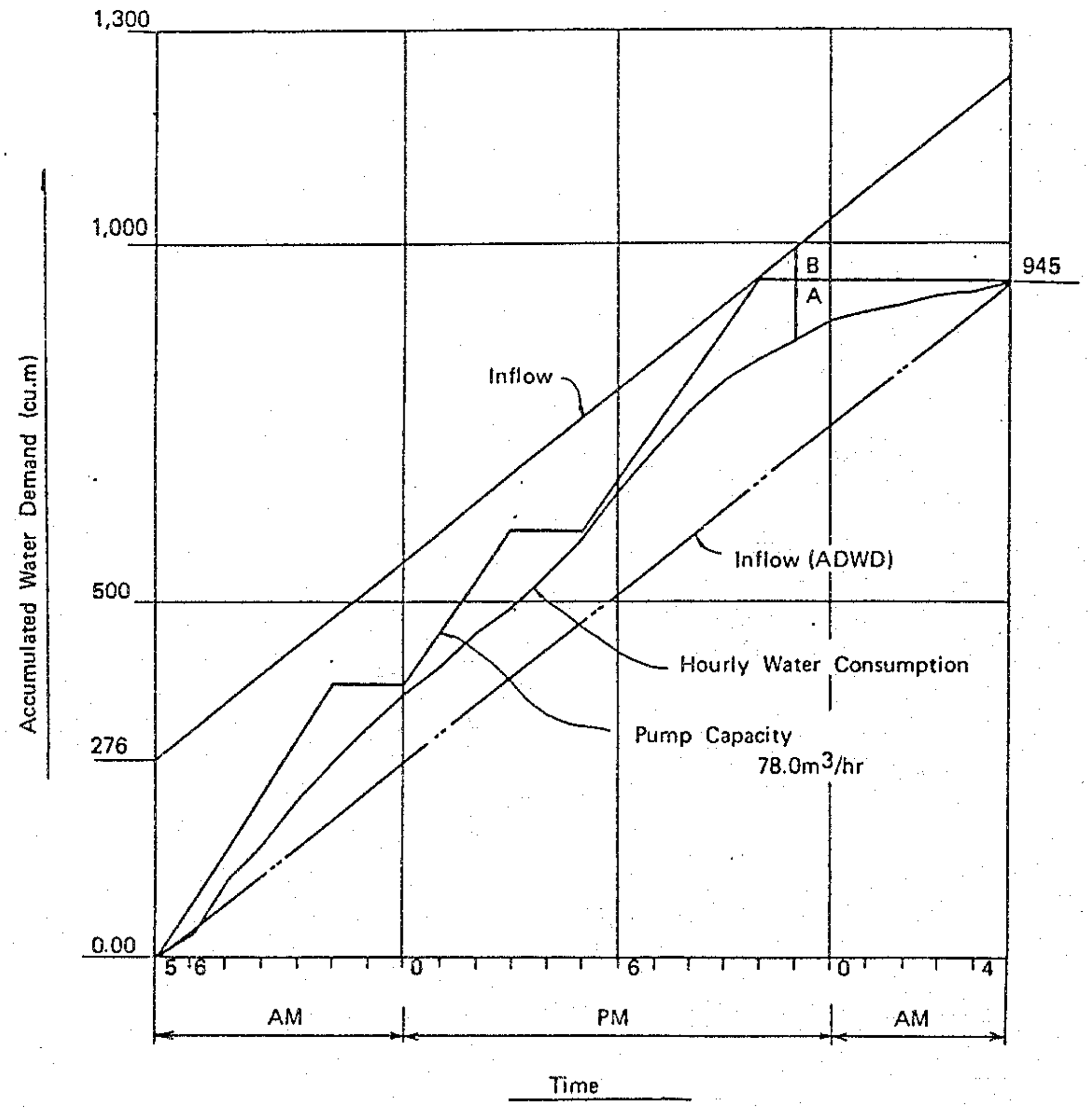
Time	Inflow	Pump Up	Consumption	Storage Volume (m^3) Total (276)	Elevated Tank	Reservoir (276)	Remarks
5~6 PM	39.4	78	36	279	42	237	
7	39.4	78	78	241	42	199	
8	39.4	78	48	238	72	160	
9	39.4	78	63	209	87	122	
10	39.4	(78)	51	197	104	93	
11	39.4	-	45	191	59	132	
12	39.4	-	48	183	11	172	
1	39.4	78	39	183	50	133	
2	39.4	78	45	178	83	95	
3	39.4	(78)	36	181	104	77	
4	39.4	-	42	178	62	116	
5	39.4	-	51	167	1	166	
6	39.4	78	66	140	23	117	
7	39.4	78	60	119	41	78	
8	39.4	78	57	102	62	40	
9	39.4	78	45	96	95	1	
10	39.4	(78)	30	105	105	0	
11	39.4	-	27	118	78	40	
12	39.4	-	24	133	54	79	
1 AM	39.4	-	18	155	36	79	
2	39.4	-	9	185	27	119	
3	39.4	-	9	215	18	158	
4	39.4	-	9	246	9	197	
5	39.4	-	9	276	0	276	

(276) ----- Initial storage volume

(78) ----- Not full operating in one hour

Total operating hours is 6 hrs.

Figure H-2. Capacity of Distribution Reservoir and Elevated Tank



A; Strage Volume of the Elevated Tank
Amax = 105m^3 (2.0 hrs)

B; Strage Volume of the Distribution Reservoir
Bmax = 276m^3 (5.3 hrs)
(Initial straged Volume)

MHWD ---- 78m^3/hr
MDWD ---- 52m^3/hr
ADWD ---- 39.4m^3/hr

Hourly Water Consumption
Data Source ---- Chonnabot SD

APPENDIX I

List of Networks Analysis Program by a micro-computer

```
10 ' Buffered Successive Over Relaxation by H. Aya
20 '
30 DEFINT I-N
40 '
50 'Read Data
60 READ N,M      'N=Number of Nodes, M=Number of Pipes.
70 '
80 DIM S%(N,2),S1(N,3),P%(M,3),P1(M,3)
90 DIM S2%(N,3),SP%(2*M),P2%(M,2),DH(N)
100 '
110 FOR I=1 TO N
120      READ S%(I,1),S%(I,2)
130      READ S1(I,1),S1(I,2),S1(I,3)
140 NEXT I
150 FOR I=1 TO M
160     READ P%(I,1),P%(I,2),P%(I,3)
170     READ P1(I,1),P1(I,2),P1(I,3)
180 NEXT I
190 '
200 'Preparations, list structure
210 NSP=1
220 WL=0
230 NS=0
240 FOR I=1 TO N
250     NPIPE=0
260     S2%(I,2)=NSP
270     S%=S%(I,1)
280     FOR J=1 TO M
290     IF P%(J,2)=S% THEN P2%(J,1)=I:NPIPE=NPIPE+1:SP%(NSP)=J:NSP=NSP+1
300     IF P%(J,3)=S% THEN P2%(J,2)=I:NPIPE=NPIPE+1:SP%(NSP)=J:NSP=NSP+1
310     NEXT J
320     S2%(I,1)=NPIPE
330     IF S%(I,2)=1 THEN WL=WL+S1(I,1):NS=NS+1
340 NEXT I
350 WL=WL/NS              'average level of water source
360 FOR I=1 TO N
370     S1(I,1)=S1(I,1)-WL
380 NEXT I
390 '
400 E=.00001              'allowable error (m^3/sec)
410 NCOUNT=0              'number of iterations
420 FLAG%=0               'if converged then 0 else 1
430 A=1.3                 'accelerator
440 B=.5                  'decelerator
```

```
450 '
460 'Scratch
470 FOR I=1 TO N
480     F=S1(I,3)
490     IF S%(I,2)<>0 THEN F=0
500     DF=0
510     FOR J=S2%(I,2) TO S2%(I,2)+S2%(I,1)-1
520             P%=SP%(J)
530             NFROM=P2%(P%,1)
540             NTO=P2%(P%,2)
550             H=S1(NFROM,1)-S1(NTO,1)
560             IF H=0 THEN H=.00001
570             XC=P1(P%,1)
580             XD=P1(P%,2)/1000
590             XL=P1(P%,3)
600 '
610 '   ** Hazen-Williams **
620             R=.27853*XC*XD^2.63*XL^(-.54)
630             Q=SGN(H)*R*ABS(H)^.54
640             DQ=.54*R*ABS(H)^(-.46)
650 '   ** for Manning Formula, **
660 '           R=.31169*XC*XD^(8/3)*XL^(-.5)
670 '           Q=SGN(H)*R*ABS(H)^.5
680 '           DQ=.5*R*ABS(H)^(-.5)
690 '
700             IF NTO=I THEN Q=-Q
710             F=F+Q
720             DF=DF+DQ
730     NEXT J
740 '   water source
750     IF S%(I,2)<>0 THEN S1(I,3)=-F:PRINT "(";S%(I,1);")Q=";-F:GOTO 880
760 '   error check
770     IF ABS(F)<E THEN 880                'no need of correction
780 '   error
790     FLAG%=1
800 '
810     DH=-F/DQ
820     IF DH*DH(I)>=0 THEN DH=A*DH          'accelerate
830     IF DH*DH(I)<0 THEN DH=B*DH           'decelerate
840     DH(I)=DH                             'store dh
850     PRINT "(";S%(I,1);")";F,"DH";DH;
860 '   correction
870     S1(I,1)=S1(I,1)+DH:PRINT "H";S1(I,1)+WL
880 NEXT I
890 '
900 IF FLAG%=0 THEN 970             'go to sollution
910 FLAG%=0
920 NCOUNT=NCOUNT+1
930 PRINT " N=";NCOUNT:PRINT
940 GOTO 470                        'go back to scratch
```

```
950 '
960 '** sollution **
970 FOR I=1 TO N
980     S1(I,1)=S1(I,1)+WL:PRINT S$(I,1);"=";S1(I,1),
990 NEXT
1000 'insert print out program here
1010 '
1020 '** data **
1030 '
1040 DATA 20                          'number of nodes
1050 '
1060 DATA 32                          'number of pipes
1070 '
1080 'data of nodes;
1090 'node number, node class(unkown=0,fixed=1), head(m), ground level(m)
1100 'flow rate of supply(m^3/sec)
1110 '
1120 DATA 1,1,150,120,0.12
1130 DATA 2,0,130,100,0.1
1140 '    continue
1150 '
1160 'data of pipes;
1170 'pipe number, connected node number beginning, connected node number
1180 'coefficient, diameter(mm), length(m)
1190 '
1200 DATA 1,1,2,100,450,500
1210 DATA 2,1,3,110,350,1000
1220 DATA 3,2,4,100,250,600
1230 '    continue
1240 '
```

SOURCE:

APPROPRIATE METHOD OF DISTRIBUTION NETWORKS ANALYSIS
FOR DEVELOPING COUNTRIES

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1985

OPERATION AND MAINTENANCE MANUAL

FOR

THE SANITARY DISTRICT WATERWORKS

OPERATION AND MAINTENANCE MANUAL

FOR THE WATERWORKS

CONTENTS

PART I. PRACTICE OF OPERATION AND MAINTENANCE

PART II. QUESTION AND ANSWER

PART I. PRACTICES OF OPERATION AND MAINTENANCE

CHAPTER I. INTRODUCTION

1.1. Purposes and Contents to Provide Operation and Maintenance Manual

The Operation and Maintenance Manual for Sanitary District (hereinafter referred to as the Manual) has been prepared to secure stable supply of hygienically safe and low-cost water with the local beneficiaries by effective and efficient operation and management of the regional waterworks, generally at the Sanitary District (hereinafter abbreviated as SD) level, in Thailand in accordance with the instruction given herein as various standards, methodologies, countermeasures to be taken against emergencies, etc. The Manual has been edited with two parts: one covers the general items on operation and maintenance of the waterworks facilities, and the other covers "Questions and Answers" on the necessary operation and maintenance practices.

1.2. Scope of Application of the Manual

The Manual has been prepared in consultation of the Study Team with those technical officials of PWD and PWA according to the study and investigation on the existing waterworks systems of the SDs in the Northeast of Thailand.

The scope to apply the Manual is defined as follows:

- The Manual shall be applied to the operation and maintenance (hereinafter abbreviated as O & M) services mainly for the SD's waterworks in the scale with population served in a range from 2,000 to 20,000, or maximum daily water consumption from 300 to 3,000 m^3/day.

- Those who can utilize the Manual shall be mainly the operators of the SD waterworks facilities.

- The Manual shall exclude the comments on the theoretical and technical discussions except for those cases specifically required for practical operation of the facilities. Therefore, when further detailed studies of the O & M works and/or the improvement of the facilities are required, reference can be made to "Design Manual" prepared in the same series for the Project or any other reference materials.

- Safer operation and careful studies and improvement on O & M techniques will allow operators to ensure more effective and efficient O & M works of the facilities. Consequently, the Manual shall be revised to meet the local requirements of each SD waterworks.

CHAPTER II. OUTLINE OF OPERATION AND MAINTENANCE

2.1. General

The operation and maintenance services of the waterworks aim to provide effective and efficient supply of safe drinking water with the local beneficiaries. The water supplied through waterworks is directly and deeply concerned with the daily life of the beneficiaries, and the troubles and accidents to be caused from the O & M services of the related facilities may result in the limited water supply control or restriction sometimes. If there should be the water pollution arisen by harmful virus and bacteria, the case would become a serious social problem. The basic rule of the O & M services for the waterworks systems can be summarized as follows.

In brief, 1) the water is sufficiently supplied, 2) the water is in good quality as living water, and 3) the water keeps the constant pressure throughout the delivery system.

2.2. Frameworks of Operation and Maintenance Services

2.2.1. Water Quantity Control

The water quantity control should be carried out in paying careful attention to the following matters:

- The records shall be regularly taken on the amount of water at intake point, treatment plant and delivery system for confirmation.

- The water shall be supplied in the constant amount and water pressure to meet the beneficiaries requirements.

- The water leakage from transmission pipes and delivery pipes shall be reduced as much as possible.

2.2.2. Water Quality Control

Following are the general items on water quality control, and the details can be referred to the item No. Q-7 of the Questions and Answers.

- The hygienically safe drinking water shall be supplied with careful checking water quality at those points of filtration plants for raw water and service connection points for treated water respectively.

- The major items of the regular inspection are as follows:

  * Turbidity, color, taste and odour.
  * Residual chlorine and Ph .

- Every possible effort shall be made to conserve favourable environmental conditions for those facilities of water sources, intakes, transmission, water treatment and distribution.

- Medical checks shall be conducted for the operators engaged in O & M of the facilities so as to prevent the water from pollution by infectious diseases.

2.2.3. Countermeasures of Emergency

The following matters should be pre-studied for taking the proper countermeasures for emergency of the waterworks system.

- An organization shall be established for taking proper countermeasures against troubles and emergencies and an appropriate action plan for the cases shall be prepared, and at the same time those persons who should be in charge of the respective works shall be assigned to discharge duties successfully according to each action planned with clear aims.

- If the water-borne disease should take place by water of waterworks, the water supply should be halted immediately and the authorities concerned, mainly the health centers, shall have consultative meetings for taking proper countermeasures. Prior to resuming the water supply, adequate measures such as increasing chlorine dosing, etc. shall be taken into consideration.

- For fire, the hydrants shall be fully released and the water pressure and sufficient amount of water shall be kept necessarily for positive support to the fire fighting team.

2.3. Duty and Responsibility of the Staff of Operation and Maintenance

2.3.1. Qualification of the Staff Concerned

The technical staffs of waterworks shall be those persons who are well-qualified with keeping the standard level in O & M technology of the facilities through regular training and study, and shall be fully responsible for the O & M services of the waterworks facilities. The aforesaid technical staff shall positively help those workers who are engaged in reading indicators of the water meters, collecting the water charges, etc. to be carried out by O & M offices.

2.3.2. Duty and Responsibility of the Technical Administrator

The duty to be discharged by technical administrator can be summarized as follows:

- The technical administrator shall assist the General Administrator of the Water Supply Office in carrying out smooth and effective O & M services for the facilities.

- The technical administrator shall be technically responsible for O & M services of the facilities as a whole from water sources and intakes to water treatment, distribution, service connection, etc.

- The technical administrator shall be fully responsible for giving orders/instructions and direction in taking adequate countermeasures as well as for pursuing to check the reasons of the troubles/accidents, when emergencies take place.

2.3.3. Duty and Responsibility of Operators

The operators shall be fully responsible for carrying out the following matters under the control and supervision of the technical administrator concerned.

- The operators shall have a full knowledge of the mechanism, functions and capacity of water the treating facilities together with providing the following reference books.

  a) Layout and profile drawings of transmission pipelines and distribution pipelines.

  b) Structural drawings and construction drawings of the facilities.

  c) Reference materials on the topography and geology of the related areas.

  d) Other reference books and materials on O & M for waterworks facilities.

- The operators shall keep the records on the O & M services for the facilities on the daily basis on the following items:

  a) Intake amount of water, treated amount, and delivered amount.

  b) Raw water, water in the process of treatment in flocculation basin (Ph value), sedimentation basin (Ph, turbidity), filtration basin (turbidity, color) and on-the-spot tests of water quality at service connection points.

  c) Reports on water leakage and troubles/ breakages of facilities.

  d) Records on operation of major valves as follows:

     * Valves for chlorine dosing control.
     * Valves for chemical solution control.
     * Valves for washing of basins.
     * Valves for distribution works.

  e) Any other items specified in the forms.

- The operators shall make regular checking and repair, if necessary, the facilities.

  a) Regular checking and repair shall be made for the facilities. The operators should make reports and consultation to the technical administrator, if the repair works would have to be requested to be made by outsiders. In particular, the service water meters shall be regularly checked.

b) In the case that any troubles/accidents would be caused from natural calamities such as floodings, droughts, etc., special checking shall be made for pumps, motors and other equipment and devices as well as measurement of residual chlorine shall be increased in frequency.

c) Stand-by equipment and spare devices shall always be kept in operative conditions.

CHAPTER III. MANAGEMENT OF WATER SOURCE FACILITIES

3.1. General Description

A careful attention should be paid to the management for the water sources and the related facilities so as to take quick countermeasures for preventing the water from pollution and decrease in quantity. Following are the items to be paid careful attention:

- To secure the amount of intake water

  The water level in the water source shall be regularly measured. For extraordinary water level to the designed maximum or minimum water level, consultation shall be made with the officers in charge of management of the water source so as to take appropriate countermeasures.

  For constant drawdown of the water table of the groundwater as sources, pumping-up control shall be made, and at the same time, cleaning of well strainers or overhauling of the pump unit shall be taken into due consideration to be carried out.

- Quality control in the water sources

  The water sources, when located near the service areas, shall be protected from pollution by sewage water or waste water disposed from factories. And furthermore, a special attention should be paid to prevent the water sources from inflow of harmful materials like agri-chemicals, etc.

- Countermeasures for emergencies

  Since the water quality is prone to be defected in floodings or droughts, the necessary countermeasures shall be established in advance for effective treatment. In those cases, there are often algae growing extraordinarily or turbidity increase in the water.

CHAPTER IV. MANAGEMENT OF FACILITIES FOR WATER INTAKE AND TRANSMISSIODN

4.1. Intake Facilities

4.1.1. Surface Water

a) Rivers

Confirmation of the water level is most important for water intake from rivers. The river water level varies with runoff discharge depending upon rainfall in the relevant catchment area. A careful attention should be paid to the fact that the inflow sand and silt, which will cause the turbidity of the water to be increased, will be deposited around the intake works, and also the water lilies and trushes may clog the entrance of the intake works. The facilities such as intake gates, discharge meters, etc. should be always kept in good conditions through constant maintenance services and repair works, if necessary.

b) Reservoirs

Since the quality of the water stored in reservoirs may sometimes changes by water depth, it is necessary to make proper water quality check in the large-scale reservoir for successful and effective intake from the appropriate water level. The careful maintenance and inspection shall be made from time to time on the intake gates, discharge meters, etc., and in particular, effective coordination works should be conducted for smoothening water intake in relation to the other water use. Besides, the daily records should be kept on the fluctuation of the water level in the reservoir.

4.1.2. Groundwater

a) Shallow Wells

The shallow well water, which is easily polluted by inflow of rainwater, various kinds of waste water shall be protected from inflow of such water and various foreign materials with casings and covers provided.

b) Deep Wells

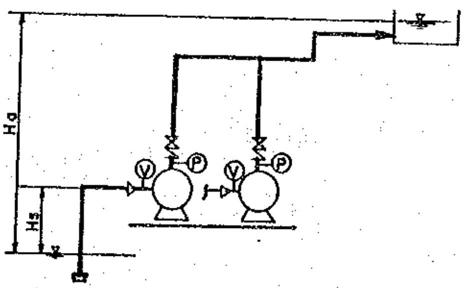
The well strainers, which are sometimes clogged by foreign materials to result in gradual decrease in amount of pumping-up water, shall be cleaned and repaired, if necessary, as well as checked always carefully throughout the operation.

4.2. Intake Pumps

The intake pumps are installed for transmitting the raw water from intake point to the treatment plant by pressure. The centrifugal pumps are commonly used for surface water transmission, while the submersible pumps for groundwater transmission. And this section discuss those notes on maintenance and checking of the intake pumps and Chapter VI shall cover those of other equipment and devices.

4.2.1. Suction Head and Cavitation

Fig. 4-1 is the typical installation drawing of centrifugal pump.



ha: Actual head
hs: Suction head
P : Pressure gauge
V : Vacuum gauge

Fig. 4-1. Installation Standard of Pump

- It is carefully noted that cavitation phenomenon takes place resulting in vibration and breakage of pumps and abrasion of suction pipes, when, in general, suction head (hs) exceeds approximately 6.0 m. If the suction pipes are longer than the standard length, the friction water head loss becomes larger, and it should be therefore noted that cavitation may sometimes occur even when hs is less than 6.0 m.

- A careful study/review shall be made on the installation spot of the pumps as well as the intake method in the case that the cavitation takes place in a spell of drought.

4.2.2. Water Hammer

For water hammer, a careful check shall be made on the valves of the pressurizing pipeline system to confirm that these devices are always ready to work.

4.2.3. Management of Stand-by Equipment

The diesel engine shall be driven once a month against blackout.

4.3. Transmission Pipelines and Open Canals

4.3.1. Transmission Pipelines

Management of transmission pipelines shall be made in paying careful attention to the following points:

- Commonly for the waterworks in the scale of SD projects, the single pipeline route shall be employed for transmission of water. Therefore, a trouble on a pipeline system causes suspension of water supply for the whole service area. And the spare pipes and other spare parts shall be provided always to be ready for use.

- The operators shall always try to inspect and watch carefully the conditions of the road surface of the pipeline course so as to find earliest possible breakage of the pipes and leakage, and shall keep records of the results of watch.

- The operators shall always try to check control valves, delivery valves, air valves, etc. to keep the records of the results.

- Although it is desirable to check the discharge at the terminal point of the transmission pipelines with the discharge meters provided, the discharge check can be made on the basis of the specific curve of the pumps if the discharge meters are not installed.

4.3.2. Open Canals

There are two types of the open canals, those for exclusive use for waterworks and those for dual purpose use for waterworks and irrigation. And the canals can transmit the necessary amount of raw water from the water source to the treatment plant or to the reservoirs.

The most important point of O & M services for open canals is to ensure the water transmission in protecting the water from pollution to be caused by environmental contamination.

A careful watch is required to maintain the canals so that the water can flow smoothly without any blockades which are prone to take place by sand and silt sediment, trushes, thick growth of algae, etc.

Appropriate maintenance and repair works are required for breakage of lining and corruption of embankment lest the water leakage should take place.

CHAPTER V. MANAGEMENT OF WATER TREATMENT FACILITIES

5.1. General Description

The water treatment plant, which provides sedimentation basin, filter, disinfection devices, etc., is installed to supply the treated safe drinking water. Therefore, first of all, the environmental conditions shall be kept hygienically favourable around the treatment plant, and the O & M services for the plant shall be rendered according to the following indications.

- No persons can enter the water treatment plant site without permission and fences shall be installed around the plant site so that any animals cannot trespass into the plant site.

- Locks shall be put on the gate of the entrance of the treated water reservoir and covers of manholes in the plant.

- Notice boards shall be put at the entrances of every plant and any other dangerous places for warning.

- Drainage control in the plant site shall be made to prevent the rainwater and other drained water from pouring into the treated water reservoir.

- No residences can be permitted within the plant site.

5.2. Rapid Sand Filtration

5.2.1. General

The rapid sand filtration, which is most widely used at present, is the method that chemicals shall be dosed into raw water to form flocs which are sedimented, and then water shall be filtrated.

The rapid sand filtration system consists mainly of the following major equipment and facilities:

- Measuring facility
- Rapid mixing equipment
- Flocculation facility
- Sedimentation facility
- Sand filter facility
- Chemicals dosing equipment

This method will not require a large space of the facility site because of its high sedimentation efficiency and considerably high filtration speed. The method, however, requires high operation cost due to chemical dosing, although countermeasures for wide range of water quality available. Consequently, the treatment works by this method will require the innovated technology. (Refer to Fig. 5-1.)

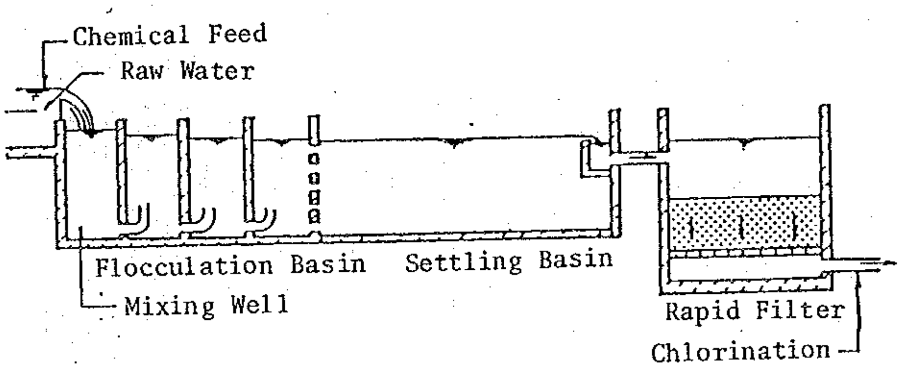


Fig. 5-1. Flow Diagram of Rapid Sand Filtration System (Ref. Book No.1.)

5.2.2. Measuring Facility

The purpose of measuring of water amount at the receiving point of the treatment plant is to control the daily treatment amount and to decide the amount of chemicals to be dosed on the basis of the treated water discharge and the water quality. Measuring shall be made along with the instructions of the devices to be used, and the graph should be prepared for quick conversion of the data obtained on the water depth, pressure, etc. The measuring methods employed most widely are the weir type, parshall flume, venturi meter, orifice meter, etc. Fig. 5-2 illustrates the rectangular measuring facilities as an example. The daily discharge control shall be made by both the operation hour control of pumps and control valves.

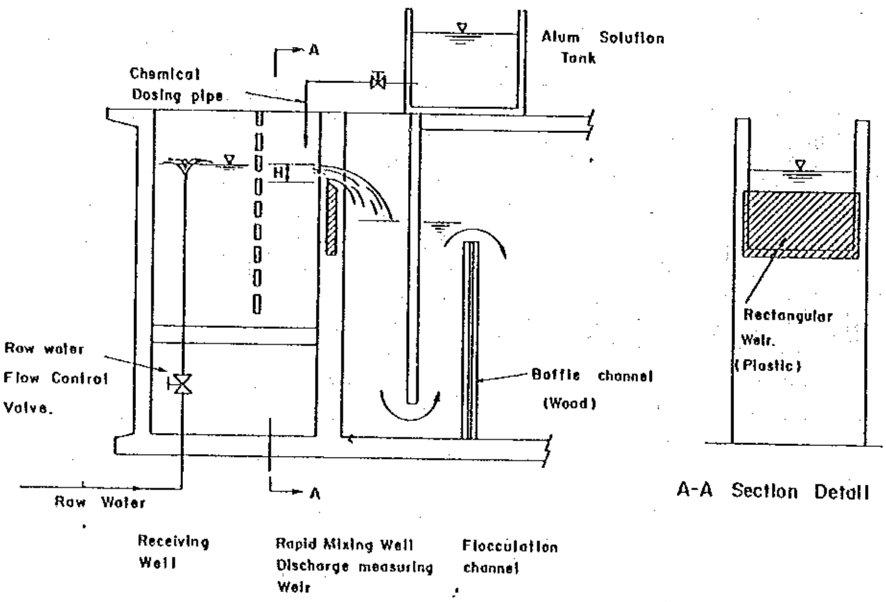


Fig. 5-2. Measuring Facility

5.2.3. Rapid Mixing Equipment

The rapid mixing equipment is provided to bring raw water and chemicals dosed into mixture rapidly and evenly. A careful attention should be paid to the following items for successful mixing.

- Chemicals shall be dosed into water so as to be evenly dispursed immediately before the measuring weir.

- The dosing rate of chemicals can be determined by the Jar Test, and the dosing rate of coagulant shall be estimated by discharge and chemicals solution rate so as to give adequate dosing.

- When the alkaline dosing is required, dosing shall be made before dosing of sulphate alum.

- In case of weir type, mixing tank provided, the effective drop of the weir shall be more than 0.30 m.

5.2.4. Chemical Dosing Equipment

1) Chemical Dosing Equipment

The most common facility of dosing the chemicals are as follows:

a) Storage capacity of alum solution (dosed usually by 3% to 7%; average by 5%) and coagulant feeding shall be at least 10 hours or more. (See Fig. 5-3.)

b) Two tanks shall be provided, one for operation and the other is for preparing solution.

c) For alum, the pH zone for coagulation is under the optimum value of 6.0. If the necessary alkalinity in raw water for coagulant is insufficient, the alkaline should be added so that residual alkalinity can be at least 20 degrees after coagulation.

d) It is recommended that sodium ash is used as alkalinity (usually for 1 to 0.5% solution).

2) Operation and Maintenance

The dosing amount, in principle, shall be decided by Jar Test. Example 5-1 shows a model case.

[Example 5-1]

For successful coagulation, the dose of optimal coagulant is essential.

<u>Operation Data</u>

1) Raw water quality

Turbidity .... 20 NTU
Alkalinity ... 20 mg/l
pH 6.8

2) Design capacity: 50 m^3/hr

<u>Operation Process</u>

1) Solution in water

a) Aluminum sulfate

Approximately 50 kg of alum solid shall be put into the solution tank with content of 1.0 m^3 and stirred up in the water sufficiently more than 10 hours to bring it into 5.0 percent solution of alum. For the solution tank with content of 0.5 m^3, about 25 kg of alum solid shall be put into, to make about 5.0 percent solution.

There shall be two solution tanks provided; one is for solving alum solid in the water and the other for dosing solution into treatment basin.

b) Soda Ash

(Total alkali, Na_2CO_3 more than 99%)

It is desirable to use soda ash instead of slaked lime because the latter is unsoluble in the water. The soda ash solution shall be below the solution degree of one percent. One solution tank will be available because soda ash solution, different from alum solution, will not be required for constant dosing. (Necessity should be judged by Jar Test.)

2) Feeding Rate

a) The feeding rate of the chemical shall be decided according to the results of the Jar Test.

b) As shown in Fig. 5-4, it is desirable to prepare a graph illustrating the correlationship between raw water turbidity and feeding rate and to try to obtain the ideal values for effective feeding.

c) As for the water taken up as the example, the quality was checked by Jar Test, and according to the feeding rate graph, the optimum feeding rate was obtained as follows:

Alum feeding rate: 20 mg/l
Soda ash: 4 mg/l

i) Alum feeding amounts

Solid, 50 m^3/hr x 20 kg/m^3 x 10^{-3}

= 1.0 kg/hr

5% solution, 50 m^3/hr x 20 kg x

10^{-3}/50 kg/m^3 = 20 l/hr

ii) Soda ash feeding amounts

Powder, 50 m^3/hr x 4 kg/m^3 x 10^{-3}

= 0.2 kg/hr

1% solution, 50 m^3/hr x 4 kg/m^3 x

10^{-3}/10 kg/m^3

= 20 l/hr

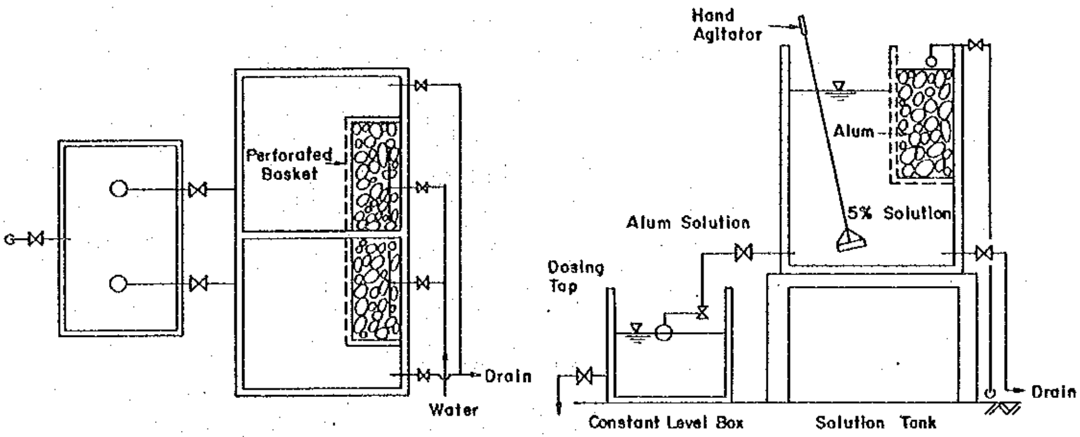


Fig. 5-3. Alum Dosing Facility

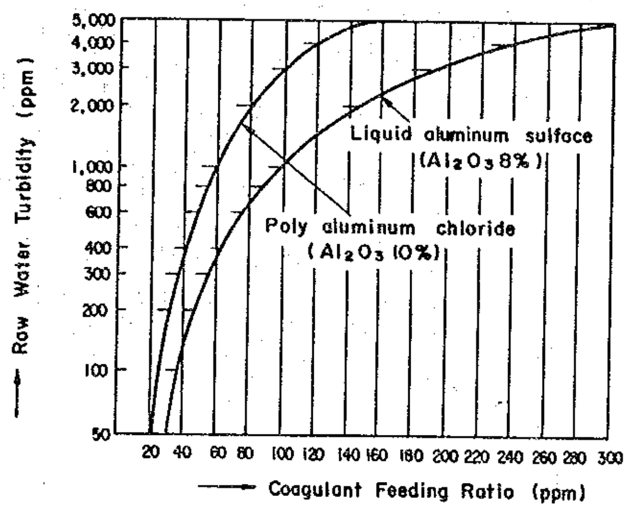


Fig. 5-4. Raw Water Turbidity and Coagulant Feeding Ratio. [An example is KAWASAKI NAGASAWA Water Works Purification Plant.] (Ref. Book No. 5)

d) Notes on O & M

1) The discharge of raw water should always be checked and the chemicals should be dosed in corresponding to the amount of discharge.

2) The feeding rate for raw water quantity shall be decided by Jar Test or in reference to the aforesaid correlation curve of raw water turbidity and feeding rate.

3) The chemicals shall be dosed after discharge of solution has been controlled along designed rate.

4) Solid alum shall be dosed and solved at least once for two days.

5) Solid alum shall be stocked in the amount by 30 days consumptions.

6) When alum, which is strong acid (Ph 3.0 - 2.0), is handled by hand, rubber gloves shall be used. Furthermore, floor surface and concrete surface of the tanks might be corroded by strong acid, it is necessary to pay attention to protection of leakage of water and prevention of structures from corrosion.

5.2.5. Flocculation Facilities

1) Process of flocculation

The raw water mixed with the chemicals shall be gently stirred up so that foreign particles can form flocs which are large and heavy enough to easily be sedimented in the basin.

2) Flocculation type

There are two types in flocculation, the horizontal flocculation type and the vertical type. The vertical type is desirable because the variable baffle channel can be provided to allow the stirring speed to be variable. (Refer to Fig. 5-5.)

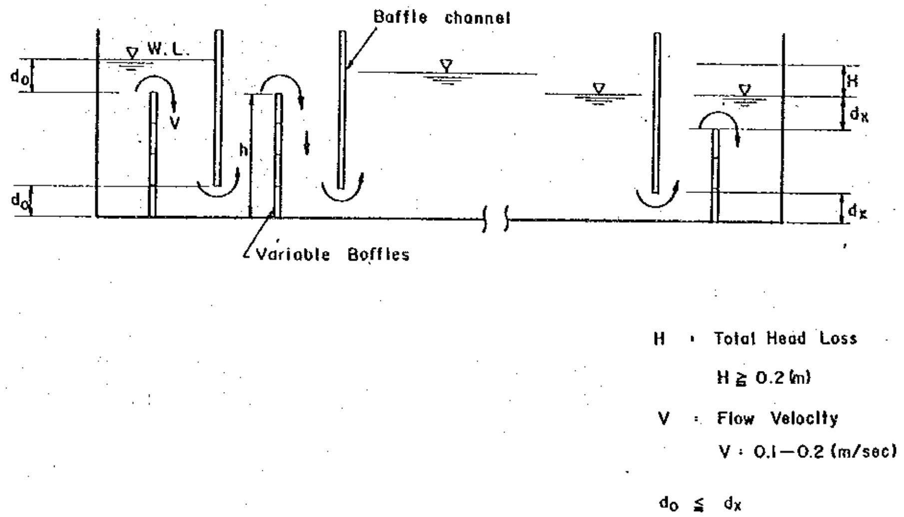


Fig. 5-5. Flocculation Facilities

3) Floc formation

The floc formation stage is most important in a series of sedimentation tank operation. Slow stir-up of the raw water mixed with chemicals for a considerable long time will make flocs grow larger; however, the flocs will tend to be easily broken by themselves as they grow larger and larger. Therefore, stirring should speed down gradually. Baffle channels shall be controlled in number and height so as for flocs to be formed most suitably to sedimentation.

4) Cleaning

Cleaning of the bottom and side walls of the flocculator shall be practised at least once a month for removing deposited or adhered flocs (sludge) thereabout.

5.2.6. Sedimentation Basin

1) Function

The sedimentation basin, consisting of the inlet zone, settling zone, outlet zone and sludge zone, serves for settling and separating the comparatively large size suspended particles by gravity. (Refer to Fig. 5-6.)

2) Operation and maintenance

Operation of the facilities shall be carried out in paying attention to the following matters:

a) Influent zone

- Careful checking shall be made on whether or not the water is flowing in steady flow from flocculator to sedimentation basin.

- Careful attention shall be paid to whether or not the unsteady flow causes due to clogging at the effluent of the facility by trapping flocs at influent trough.

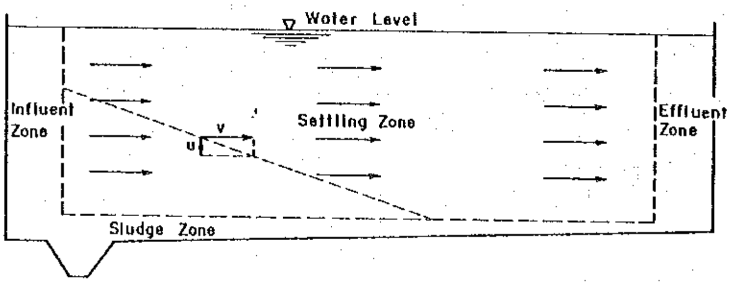


Fig. 5-6. Typical Rectangular Sedimentation Basin (Ref. Book No. 3)

b) Settling zone

- The flocs, growing sufficiently large, will mostly settle down after flowing one-third length of the zone at the longest. (Refer to Fig. 5-7.)

- Since density current and differences in water temperature in the basin will not always allow to keep the horizontal flow, it is desirable that the perforated baffles wall is provided in the basin.

c) Effluent zone

- The surface clean water shall be collected and conveyed to the filtration basin.

- In the course to the filtration basin, it is desirable that any objectional structures like trough, etc. are not provided so as to keep smooth flow of the water.

- There should be difference in water level reserved between those at the sedimentation basin and after effluent trough.

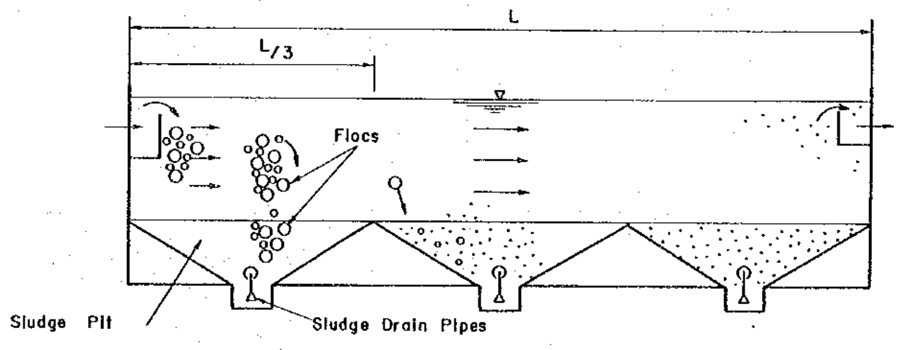


Fig. 5-7. Sludge Drain in a Rectangular Sedimentation Basin

d) Sludge zone

- The operators should pay the closest attention to the hydraulic removal of sludge as one of the most important operations in all the processes.

- The sludge valves shall be opened to drain sludge everyday for highly intensive filtration and once a week for considerably extensive filtration.

- For valve operation, it is recommended that the handle should be turned quickly for releasing a few minutes and then turned quickly for closing, such operation shall be repeated for smooth drain of dense sludge by making the better use of suction at valves.

- When sludge removal is neglected, sludge will be thickly deposited in the basin not only to decrease the amount of water available but to cause algae and other aquatic weeds grow.

- Pre-chlorination by 1 - 2 ppm shall be practised, when algae are found growing.

- The filtration basin should be emptied for cleaning once or twice a year.

5.2.7. Rapid Sand Filter

1) Mechanism

The rapid sand filter consists of two types of mechanism; one for filtration and the other for washing.

a) Filtration

The water passed through the sedimentation basin will filtrate by sand layer, which will catch the suspended particles to clean the water for meeting the requirements of the drinking water.

The sand layers shall commonly have the thickness of 0.6 m and 0.4 m in minimum. Grain size of the sand particles shall have the average effective sizes ranging from 0.4 mm to 1.2 mm and the uniformity coefficient commonly applied ranges from 1.3 to 1.7.

b) Washing

Continuous filtration for a considerable time will result in dirty sand by adsorption of foreign materials and increase in resistivity of sand. Finally, the water will reach the design highest water level. At this stage, backwash shall be carried out for cleaning the sand.

The backwashing shall be practised by both ways that the sand shall be backwashed from the lower layer of the filter bed and shall be washed from the surface of the layer by pressure water.

2) Operation and maintenance

a) The operation of the filter system for filtration and backwash can be made by operating five or six valves, except for influent valves. (Refer to Fig. 5-8.)

Manual operation will be commonly applied to those valves for the small-scaled waterworks.

b) The valve operation shall be made according to the procedures illustrated in Fig. 5-9.

These valves shall be operated carefully and prudently so as not to make too tightly.

c) The effective and efficient operation of the filter required to meet the following requirements:

- Filtration rate: 120 - 140 (m/day)
- Maximum loss head: 1.5 - 1.6 (m)
- Backwash velocity: 0.5 - 0.7 (m/min.)
- Surface wash velocity: 0.15 (m/min) at 1.5 (kg/cm^2) on surface nozzle.

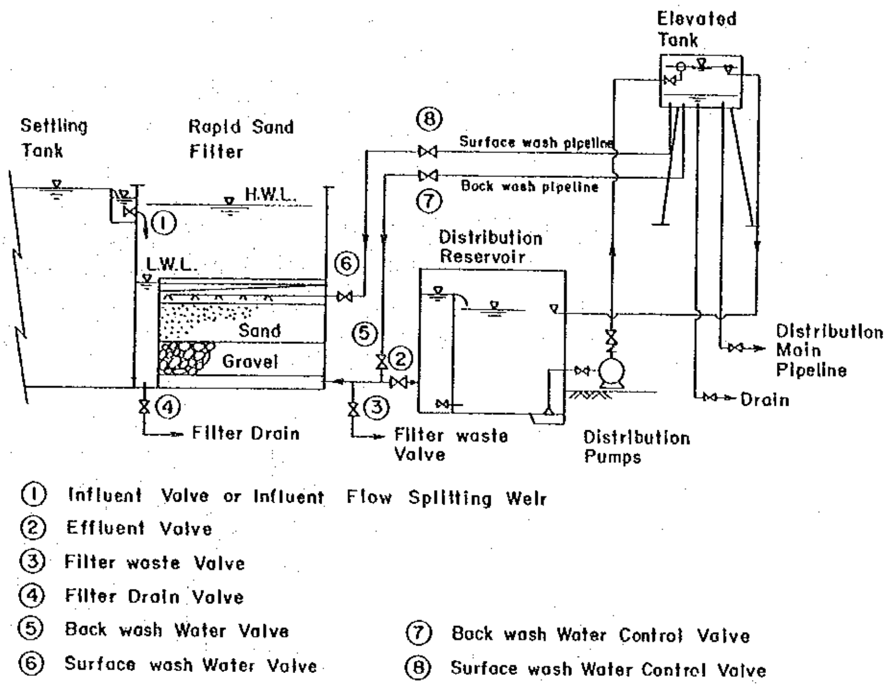


Fig. 5-8. Rapid Sand Filter Flow Diagram

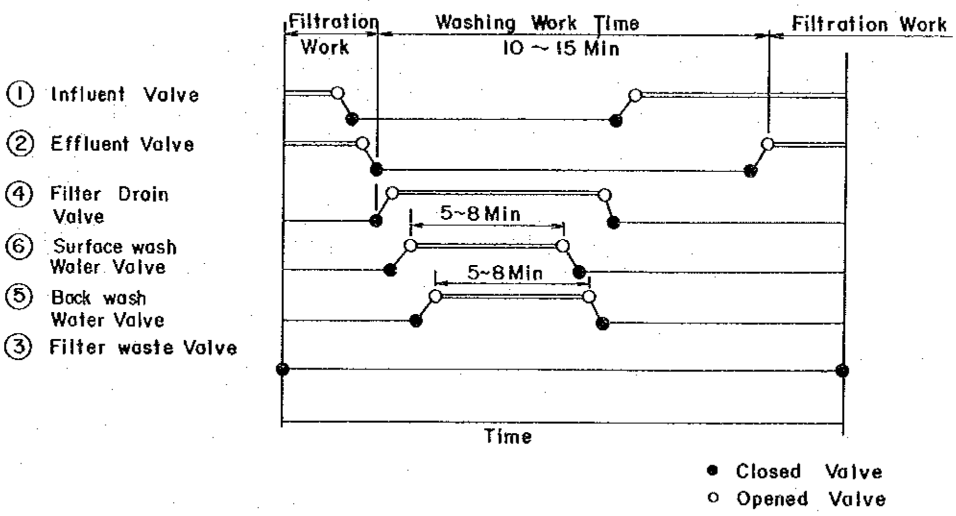


Fig. 5-9. Washing Process in Rapid Sand Filter

5.3. Slow Sand Filtration

5.3.1. General

Slow sand filtration is a method of removing suspended solid and pathogenic organisms from raw water through sand layer which consists of selected sand materials in an effective grain size of 0.2 mm and with a coefficient of uniformity less than 3.

In slow sand filters, the most important theory is that on biochemical and microbiological actions in the top layer of the filter bed.

The filter skin or layer of deposited materials will form on the top of a slow sand filter.

Generally, the slow sand filter is most suitable water treatment process for surface water resources. (Refer to Table 5-1.) In Thailand forty-four slow sand filters have been constructed up to 1981. (Refer to Figs. 5-10 and 5-11.)

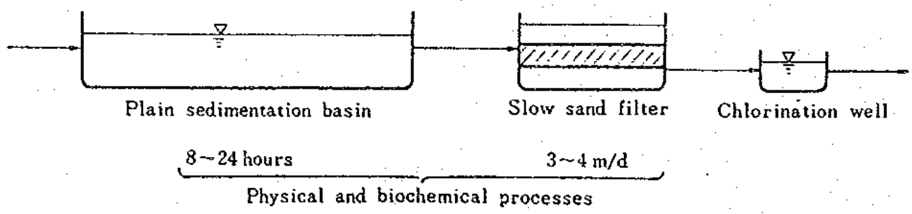


Fig. 5-10. Slow Sand Filtration Process
(Ref. Book No. 4)

' Nong Ko Slow Sand Filter

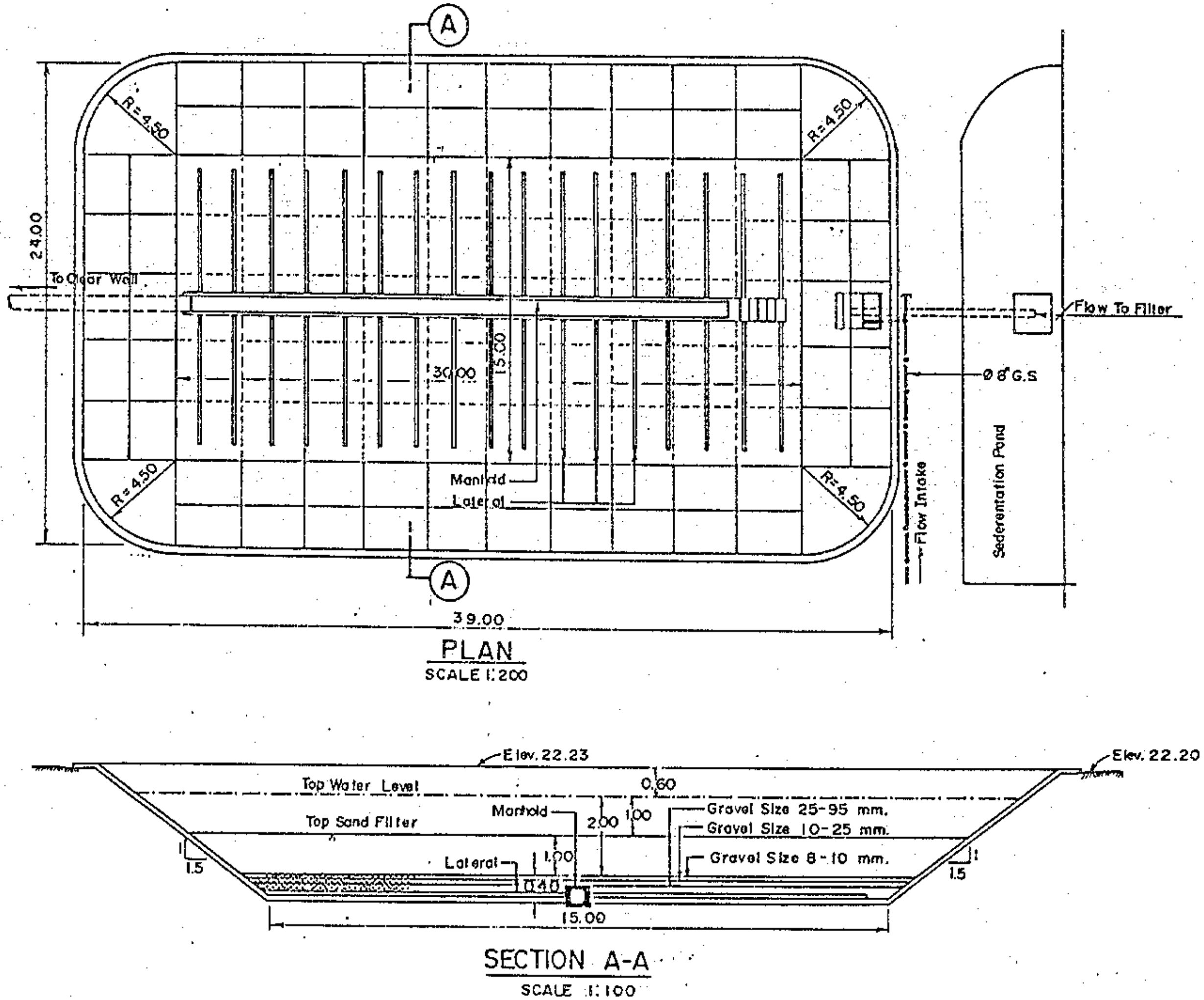


Fig. 5-11. Existing Slow Sand Filter

Source: Experience with Slow Sand Filters in Thailand, AIT, Bangkok, 1983

Table 5-1. List of Existing Slow Sand Filter Plants in Thailand (as of 1982)

Plant Capacity	Plant Name	District	Province
2 m^3/h	B. Jedee-Thong	Samkoke	Patumtani
10 m^3/h	B. Thadindum	Chaibadan	Lopburi
	B. Banglao	Muang	Singburi
	Po-sri*	Bangplama	Supanburi
	S. Ban-amnaj	Amnaj-charoen	Ubolrajthani
	B. Phanok-kao	Phukradueng	Loei
	B. Puan-pu	Phukradueng	Loei
	Nong-bua	Phurua	Loei
	B. Tha-ko*	Muang	Nakorn-phanom
	B. Harngeo	Bangdong	Chiengmai
	B. Donmoon	Sungmen	Phrae
	B. Shong-kho-kard	Tapla	Uttaradit
	Suesasongkroh	Muang	Tak
	B. Mqegidluang	Maesod	Tak
	B. Nam-ron	Nakorn-thai	Pitsanulok
	B. Wang-barn	Lomgao	Petchaboon
	B. Kokemoh	Taptan	Uthaithani
	S. Kanom	Kanom	Nakornsrithamarat
	S. Bannanstar	Bannanstar	Yala
20 m^3/h	S. Thaleung	Thaleung	Lopburi
	B. Pak-warn	Nangrong	Burirum
	S. Kokphra	Kantrwichai	Mahasarakram
	S. Jaehom	Jaehom	Lampang
	S. Tapla*	Tapla	Uttaradit
	B. Muang-bang	Lomgao	Petchaboon
	S. Kroakpra	Kroakpra	Nakorn-sawan
	B. Rajkrud	Muang	Ranong
	S. Thepkrasattree	Talang	Phuket
	S. Yarang	Yarang	Pattani
	S. Yuwa	Sunpatong	Chiengmai
	B. Jedee-koh	Maesod	Tak
	Jedee-koh (expansion)	Maesod	Tak
30 m^3/h	S. Dansai*	Dansai	Loei
	S. Pua	Pua	Nan
	S. Ronpiboon	Ronpiboon	Nakornsrithamarat
40 m^3/h	S. Sritart	Sritart	Udornthani
50 m^3/h	S. Nongko	Kranuan	Khonkaen
	S. Ubolrat	Ubolrat	Khonkaen
	B. Maegu-not	Maesod	Tak

Note : * Not Functioning.

Data Source : Experience with Slow Sand Filters in Thailand
Asian Institute of Technology
Bangkok, Thailand , 1983

5.3.2. Operation and Maintenance of Slow Sand Filters

1) When the maximum head loss reaches the design water level, the following works should be practised by operator. (Refer to Fig. 5-12.)

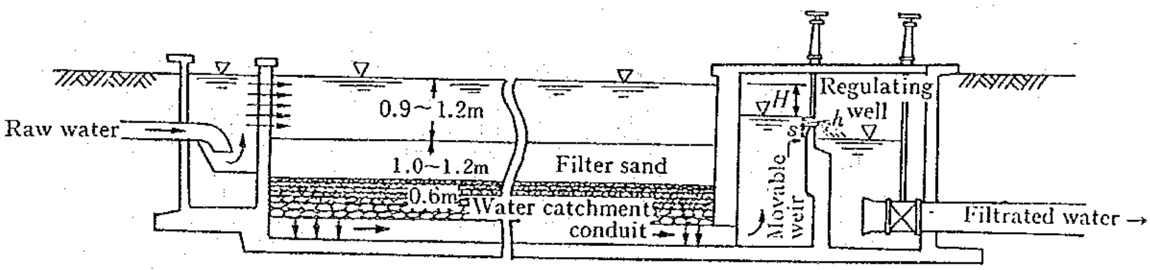
a) Drain the water in the sand layer gradually so as not to disturb the layer.

b) Remove the top layer of dirty sand by 1.5 to 2.0 cm from the surface by scraping off with hand shovel. (Refer to Fig. 5-13.)

c) Discard the dirty sand or clean it by washing. (The discarded sand can be used for land fill.) (Refer to Fig. 5-14.)

d) Supply water to raise the water level by 10-20 cm above the surface of the filter in keeping the filtration velocity less than 2.0 m/day.

e) Use the cleaned filter again at least three days after cleaning.



H: Head Loss

Fig. 5-12. Slow Sand Filter (Ref. Book No. 5)

2) Successful operation requires the following works:

a) Cleaning sand bed should be practised every two months, in principle, but if algae are found to grow, cleaning is required every month.

b) The amount of water filtered should be controlled by sluice valves or float valves according to the depth over the weir. (Refer to Fig. 5-12.)

c) New sand should be supplemented when the thickness of the old sand layer becomes about 40 cm.

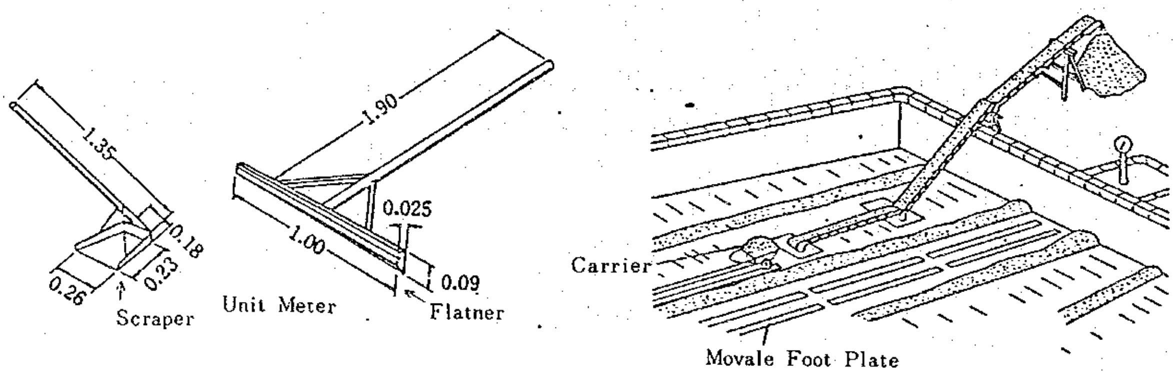


Fig. 5-13. Remove the Top Sand Layer (Ref. Book No. 6)

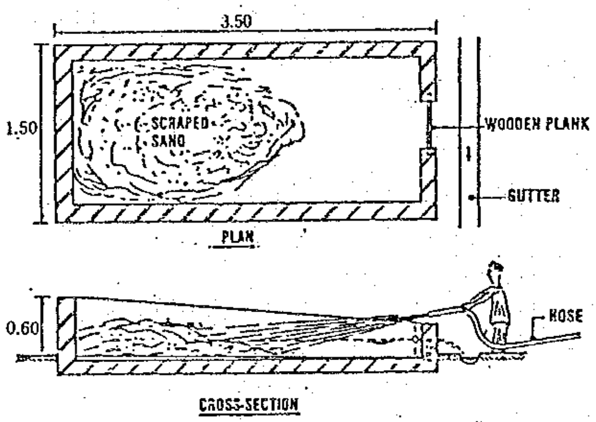


Fig. 5-14. Cleaning Sand (Ref. Book No. 1)

5.4. Groundwater Treatment Facilities

5.4.1. Aeration

1) Purpose of treatment

Groundwater sometimes contains iron, manganese, carbon dioxide, hydrogen sulphate, etc. Aeration aims to accelerate oxidation of those materials by supplying oxygen to raw groundwater. In many cases, aeration is co-used with the rapid sand filtration system.

2) Operation and maintenance

The spray nozzle type and the multiple tray type are most widely used for aeration.

The operation and maintenance procedures for these devices/facilities are illustrated in Fig. 5-15 for references, and the following discusses the O & M services for each type of aeration system.

a) Spray nozzle type

It is essential to carefully watch the nozzle for smooth and even spraying of raw water and to keep the nozzle free from clogging by sand and dust.

It is desirable to keep the water pressure more than 0.7 kg/cm^2 at the top of the nozzle.

b) Multiple tray type

i) The water shall flow down smoothly and evenly from trays to trays and try to prevent the coarse media from clogging by sand and dust.

ii) The coarse media like stone, when become dirty, should be changed to new media for securing smooth and effective flow of the water.

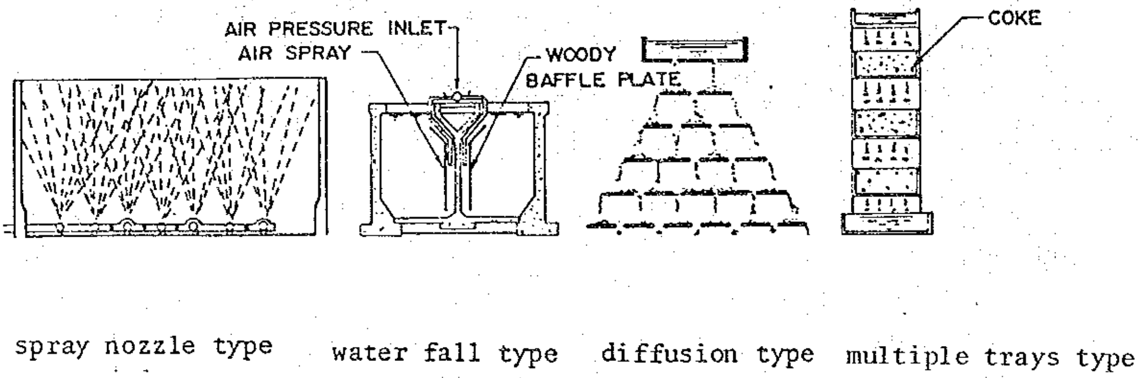


Fig. 5-15. Aerator Types (Ref. Book No. 5)

5.4.2. Iron Treatment Facilities

Iron in groundwater will be removed through treatment by sedimentation and filtration, after oxidized by aeration and chlorination. The sedimentation/filtration process can be sometimes omitted, when the iron contents are low in the raw water. (Refer to Fig. 5-16.)

The O & M services for the aeration system shall be rendered according to the previous paragraph, and those for the filters according to the paragraph on Rapid Sand Filters in the Report.

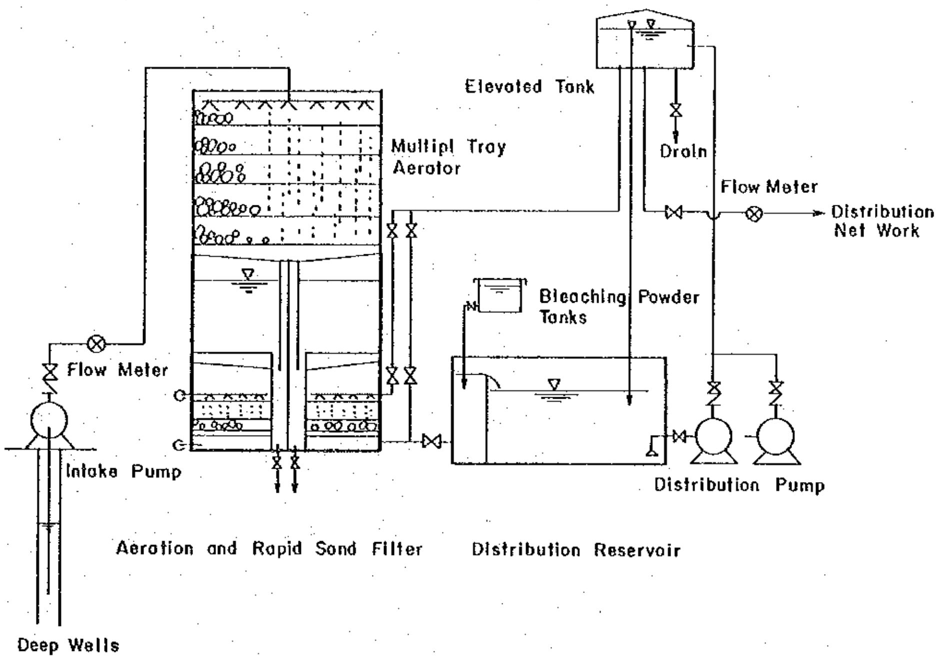


Fig. 5-16. Aeration and Rapid Sand Filter Process Flow Diagram

5.4.3. Manganese Treatment Facilities

Manganese, after oxidized by chlorination, shall be removed commonly by filtering through manganese sand filter. The feeding rate of chlorine for manganese treatment should be estimated through actual measurement of contents of Mn for appropriate dosing, since the amount of chlorine to be required for effective chlorination of Mn will become 1.3 times as much as the chemical reaction equation indicates.

When chlorination is carried out in the water containing any residual manganese, chlorine will react with residual manganese to bring about color 300 to 400 times as dense as the manganese residual density. Removal of manganese, therefore, should be practised in full attention to the above fact.

And it should be noted that even if the manganese contents in the water should be below 0.3 ppm of the maximum allowable level, the water might turn blacky in color even after treated. And sometimes, pre-chlorination may be required for total removal of manganese from the raw water.

5.5. Disinfection

5.5.1. General

The most important requirement for drinking water is to be free from any micro-organisms that will transmit diseases to consumers. Processes such as storage, coagulation/flocculation, sedimentation, and rapid filtration can reduce to varying degrees the bacterial contents of water. However, these processes cannot assure that the water produced is bacteriologically safe. Final disinfection will frequently be needed. In any cases where no other methods of treatment are available, disinfection may be resorted to as only one treatment against bacterial contamination of drinking water.

5.5.2. Operation and Maintenance

The batch mixing method is most commonly used. The strength of the batch should not be more than 0.65 percent of chlorine by weight; for example, 10 g of ordinary bleaching powder of 25 percent strength is dissolved in 5.0 liters of water, then the stock solution becomes 500 ppm. (Refer to Fig. 5-17.)

For disinfection of drinking water, one part of the stock solution may be added tentatively to 100 parts of the water to be treated. The initial dosage will be made by 5.0 ppm solution. If the chlorine residual after 30 minutes' contact is found to be greater than 0.5 ppm, the initial dosage can be reduced.

Operation is made according to the following procedures:

1) To analyse residual chlorine content in the distribution reservoir every day.
   The residual chlorine content should be more than 0.5 ppm.

2) To analyse residual chlorine content in the distribution pipe every day.
   The residual chlorine content should be more than 0.2 ppm.

3) To analyse E. col. (Escherichi & coli) in the distribution reservoir once a month.
   E. coli should be none.

4) To do chlorine in the coagulation basin if pre-chlorination is required.

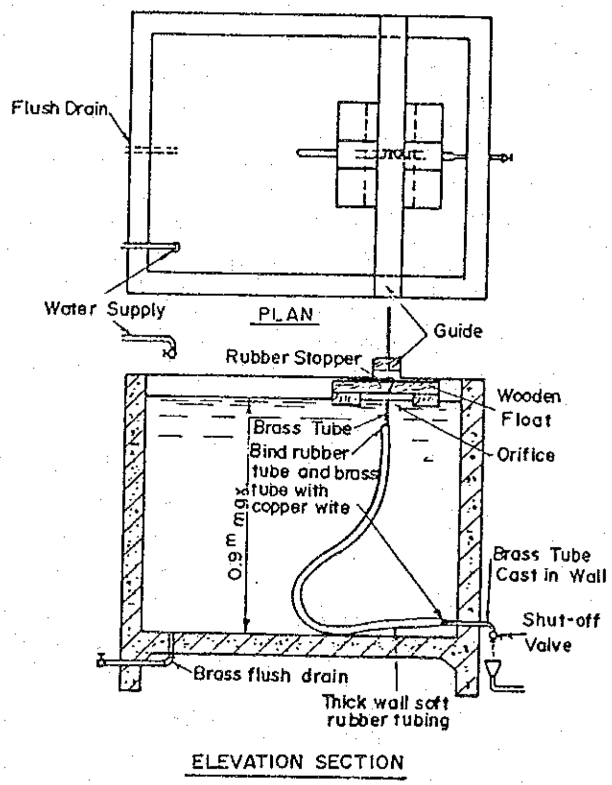


Fig. 5-17. Bleaching Powder Facilities
(Ref. Book No. 2)

CHAPTER VI. MANAGEMENT OF WATER DISTRIBUTION FACILITIES

6.1. General

The distribution facilities are specified into distribution reservoir, distribution pumps, elevated tank, water flow meter and distribution pipelines as shown in Fig. 6-1.

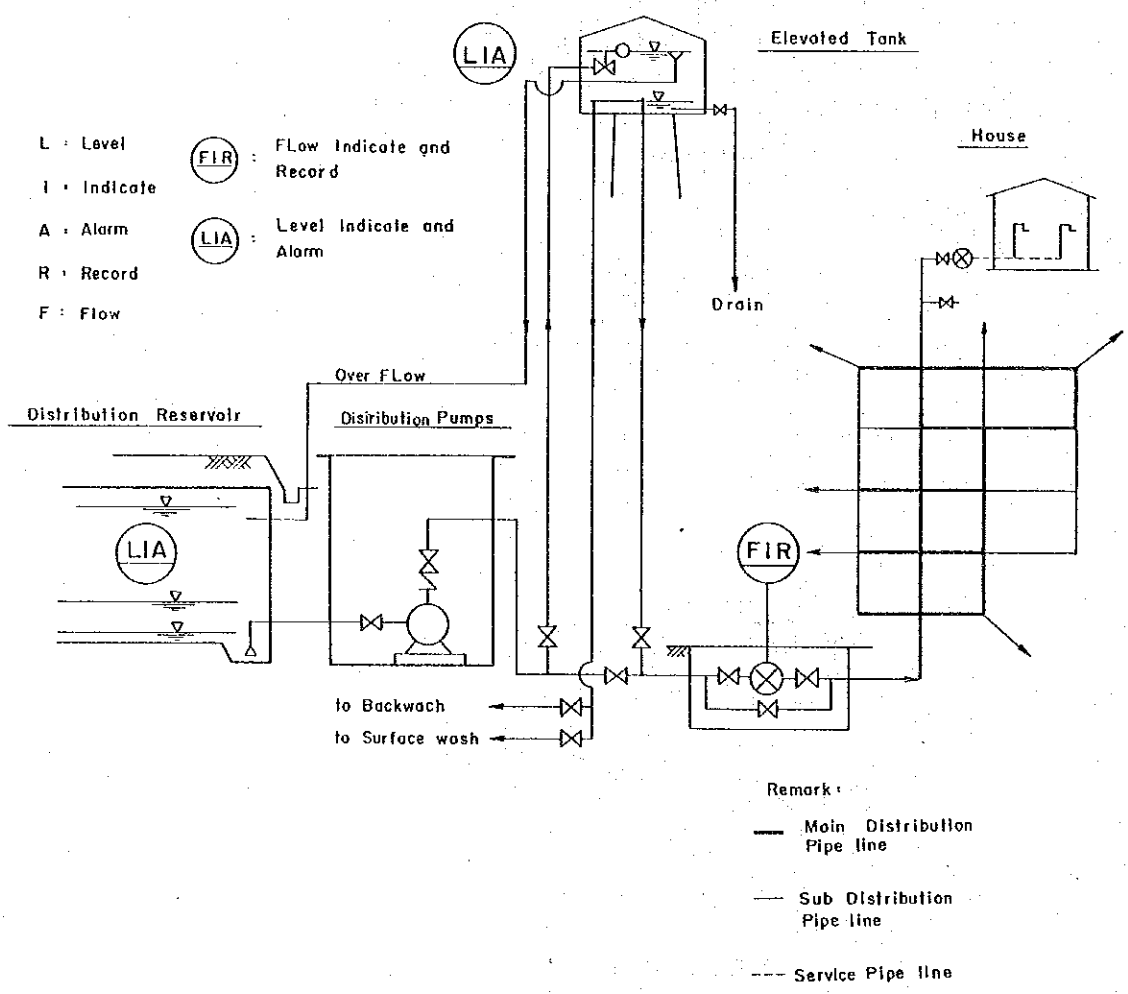


Fig. 6-1. Composition of Distribution Facilities

6.2. Management of Water Distribution Facilities

6.2.1. Distribution Reservoir

The operation and maintenance should be practised as follows:

1) Water level in the reservoir should be measured and recorded.

2) When water level reaches the designed highest water level, operation of the intake pumps and the treatment facilities should be stopped, and when water level reaches the mean water level, the pumps should be started again.

3) When the water level drawdowns to the lowest water level, the distribution pumps should be stopped, and when recovers to the low water level, distribution pumps can be started again.

4) Uniform mixing of chlorine by the chlorinator in distribution reservoir or an injection well should be maintained to operate in full efficiency.

5) The ventilator, man-hole, control room and water inspection hole should be usually locked to protect from pollution caused by rainwater, dust and small animals.

6.2.2. Distribution Pumps

1) The distribution pumps should be operated at hourly maximum demand, and when a fire breaks out, pump should be operated in full capacity for effective fire-hydrant operation.

2) Then pump should be operated according to the water level in the elevated tank.

Water level in the tank	Pump operation
Low water level	on
High water level	off
Highest water level	alarm
Lowest water level	"

3) The quantity of distributing water should be measured and recorded every hour.
The automatic recording system is preferable to be provided.

6.2.3. Distribution Pipeline

The operator shall make regular inspection on the following matters:

1) Damage existence of the water supply pipes should be checked and inspected periodically.

2) Functions and conditions of main valves, which should be recorded in the main register for easy and quick reference.

3) Fire-hydrants, which should be tested at least once a year.

4) Efficiency in effective usage of water supply, which is desirable to make efforts more than 80 percent of the distributing quantity; in other words, unaccounted-for-water such as water leakage should be less than 20 percent. This means the water leakage should be found at the earliest stage for repair without any delay. Detection method of water leakage can be referred to in Q-9 in the Questions and Answers.

For emergencies, the technical administrator and his staff should take action in consideration of the following matters:

1) Recovery set-up including infrastructure members like contractors should be organized soonest after completion of the projects so as to take quick and adequate countermeasures for emergencies.

2) Recovery activities should be started immediately, after troubles found, with necessary materials and equipment for repair and temporary works.

3) Spare pipes in various diameters as well as machinery and equipment, should be ready for use at any time for recovery works.

CHAPTER VII. MANAGEMENT OF MECHANICAL EQUIPMENT

7.1. Pumps

7.1.1. General

The pumps commonly used for small-scale waterworks are centrifugal pumps (volute pumps and turbine pumps), submersible pumps and borehole pumps. Since each type has its own operational characteristics, the operation and maintenance method can be referred to the handling manual supplied by each manufacturer.

Therefore, the operator should have sufficient knowledge by the operation manual of the pumps for successful operation.

The key items in the operation and maintenance of the pumps are as follows:

- The operator should thoroughly understand the manual operation procedures and the related notices of the pumps.

- The indicators of such instruments as ammeters and pressure gauges should be carefully watched.

- Even in a remote-controlled pump station, the regular patrol should be punctually observed in order to check bearing oil and temperature, gland packing condition, and to find out abnormal sounds and vibrations.

- It is essential to keep the operating records of the pumps in the major findings in the course of operation.

- The pumps should be overhauled at least once a year.

- Successful pump operation for the waterworks requires not merely to operate the pump units efficiently but to pay careful to an increase in operation efficiency of the total system.

7.1.2. Non-submersible Pumps (Refer to Fig. 7.1.)

1) Operation

a) Close the air-release valve and discharge valve after priming is completed. Open a suction valve completely, if provided.

b) Turn the operation switch on and off two or three times to check operating condition, and attach shaft coupling guard after operation check is completed.

c) Start continuous operation and open a discharge valve gradually.

d) Check operating pressure and current, harfmul vibration and noise so as to keep normal operation level.

e) Close the discharge sluice valve slowly to stop pump operation, if there is no check valve on the discharge piping. Turn off the operation switch after the sluice valve is completely closed.

f) Proceed to the subsequent operation without checking if all conditions are normal.

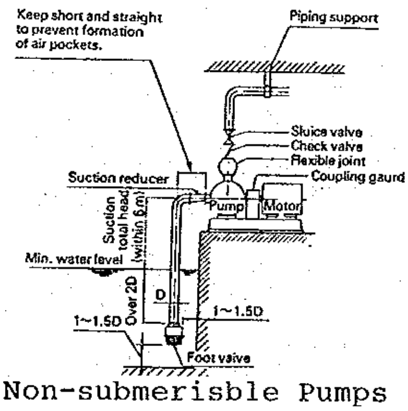


Fig. 7.1. Non-submerisble Pumps (Ref. Book No. 8)

2) Maintenance

a) Daily inspection

i) Extraordinary fluctuation of presence/current and abnormal vibration/noise are signs of troubles. The necessary repair works should be made as soon as possible.

ii) The maximum allowable bearing temperature should not exceed 80°C.

iii) The shaft sealing should be made tightly by mechanical seal to cause no water leakage. And it is required to replace the entire seal if leakage takes place.

Gland packing leakage should be kept down to a steady drip or trickle (approximately 20 ml/min.)

iv) Fig. 7.2 indicates the normal level of vibration when installation and piping are correct. Excessive vibration may be due to conditions such as incorrect centering, detective piping or loose foundation bolts.

b) The causes and remedies of the pump troubles are summarized in Table 7-1.

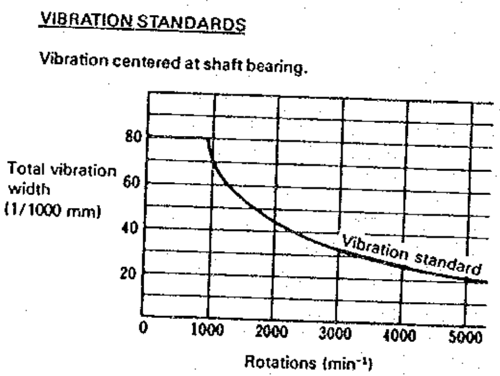


Fig. 7.2. Vibration Standard (Ref. Book No. 8)

Table 7-1. Pump Troubles and their Causes and Remedies (Non-submersible Pumps)

Trouble	Cause	Remedy
Motor does not start.	(1) Motor malfunction.	(1) Repair motor.
	(2) Power source malfunction.	(2) Inspect, repair, or consult power company.
	(3) Rotating parts in contact, rusted, burnt out.	(3) Manually rotate. Reassemble. Have repaired in specialist shop.
	(4) Foreign matter clogging contacting parts	(4) Remove foreign matter
Pump is operating but there is no water discharge. Does not obtain specified discharge volume.	(1) Pump not primed.	(1) Prime.
	(2) Valve closed, insufficiently open.	(2) Open valve.
	(3) Excessive piping loss.	(3) Re-examine original plan.
	(4) Suction height too high for pump.	(4) Re-examine original plan.
	(5) Cavitation.	(5) Consult specialist.
	(6) Rotation direction reversed.	(6) Correct rotation direction.
	(7) Rotation speed low.	(7) Check with tachometer.
	• Wrong number of poles in motor.	• Check nameplate and change.
	• 60Hz pump being used in 50Hz area.	• Check nameplate and change.
	• Voltage drop.	• Check power source and remedy.
	(8) Impeller clogged.	(8) Remove foreign matter.
	(9) Piping clogged.	(9) Remove foreign matter.
	(10) Air suction.	(10) Inspect, repair suction piping, shaft sealing.
	(11) Foot valve or suction piping end not submerged sufficiently.	(11) Extend suction piping and submerge end to sufficient depth.
	(12) Discharge piping leakage.	(12) Inspect, repair.
	(13) Impeller corroded.	(13) Check quality of liquid and consult specialist.
	(14) Impeller worn.	(14) Replace impeller.
	(15) Casing ring worn.	(15) Replace casing ring.
	(16) Liquid temperature too high. Volatile liquid.	(16) Re-examine original plan.
Water discharges but soon stops	(1) Insufficient priming.	(1) Prime sufficiently.
	(2) Air suction.	(2) Inspect, repair suction piping, shaft sealing.
	(3) Air pockets in suction piping.	(3) Reinstall piping.
	(4) Suction height too high for pump.	(4) Re-examine original plan.
Overloads (overcurrent).	(1) Head low. Excessive volume flow.	(1) Partially close discharge valve.
	(2) Rotation speed low.	(2) Check with tachometer.
	• Wrong number of poles in motor.	• Check nameplate and change.
	• 50Hz pump being used in 60Hz area.	• Check nameplate and change.
	(3) Rotating parts in contact. Shaft bent.	(3) Have repaired in specialist shop.
	(4) Liquid density, viscosity too high.	(4) Re-examine original plan.
Bearing overheats.	(1) Bearing damaged.	(1) Replace bearing.
	(2) Excessive pump operation with discharge valve insufficiently opened.	(2) Open sufficiently.
Pump vibrates. Excessive noise.	(1) Piping vibration.	(1) Reinforce piping support.
	(2) Rotation direction reversed.	(2) Check with arrow and rewire.
	(3) Coupling rubber worn.	(3) Replace coupling rubber.
	(4) Rotating parts in contact. Shaft bent.	(4) Have repaired in specialist shop.
	(5) Cavitation.	(5) Consult specialist.
	(6) Excessive discharge volume.	(6) Partially close discharge valve.
	(7) Insufficient discharge volume.	(7) Operate at specified flow level.
	(8) Excessive pump operation with discharge valve insufficiently open.	(8) Open sufficiently
Excessive leakage from from shaft seal.	(1) Damaged mechanical seal.	(1) Replace mechanical seal.
	(2) Excessive influx pressure.	(2) Re-examine original plan.
	(3) Incorrect installation of packing.	(3) Reinstall.
	(4) Damaged packing.	(4) Replace packing.
	(5) Shaft or sleeve worn.	(5) Replace with new parts.
	(6) Excessive influx pressure.	(6) Re-examine original plan.
	(7) Shaft bent.	(7) Have repaired in specialist shop.
	(8) Excessive water flushing pressure.	(8) Adjust to appropriate pressure.
Shaft sealing overheats.	(1) Packing too tight.	(1) Adjust.
	(2) Packing tightened unevenly.	(2) Adjust.
	(3) Inappropriate water flushing pressure, volume.	(3) Adjust to correct pressure and flow.
	(4) Shaft sleeve worn.	(4) Replace with new part.
	(5) Lantern ring positioned incorrectly.	(5) Correct position.
	(6) Excessive influx pressure.	(6) Re-examine original plan.

Source: Instruction Manual, EBARA Corporation, 1984

7.1.3. Submersible Pumps (Refer to Fig. 7.3)

1) Operation

a) The pumps life will be extended by stable discharge.

b) Keep the coupling gauge cock closed except the cases specified, because the gauge may be broken when left open. (Refer to Fig. 7.4.)

c) Adjust the primary power source if voltage fluctuates extraordinarily (± 5%) or the current becomes unbalanced (over 10%).

2) Maintenance

a) Daily inspection

The daily check of current and voltage fluctuation is desirable but weekly check at least permissible. As long as the current fluctuation remains within the rated value, there is no problem in power supply, but extreme fluctuation will indicate sand clogging in the pump.

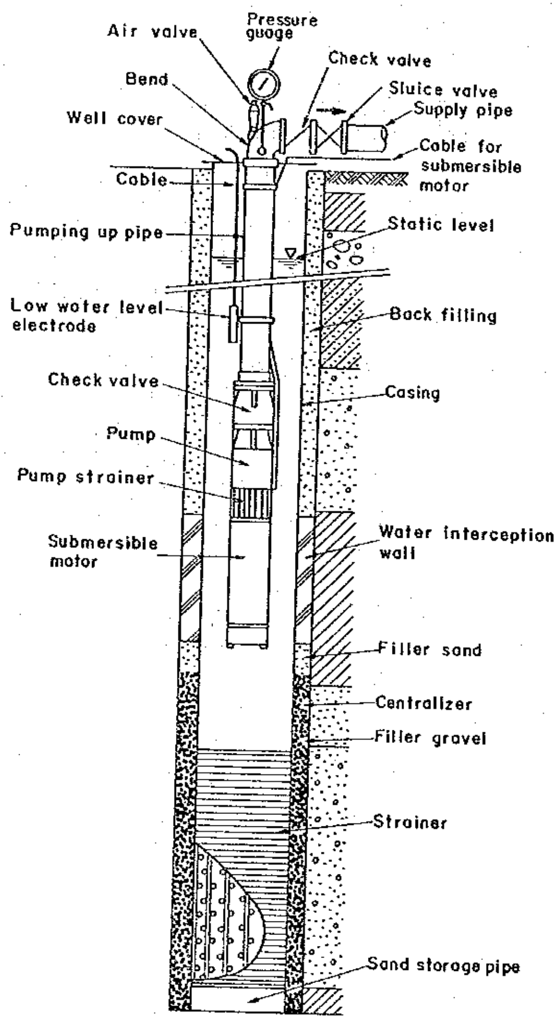
b) Other regular inspection

i) Insulation resistance shall be measured once a month. Pump operation will not be affected with a reading of 1 MΩ or more, but if resistance drops suddenly, even when above 1 MΩ , it is a sign of trouble and repair will be required.

ii) The regular overhaul of the pumps shall be made to extend the pump life, but the pumps should not be dismounted or taken out of the wells except the cases of major repair and aforesaid overhauling.

c) Notices to the pump storage

While the pumps will not be operated for a long time, they shall be locked to prevent the pump units from sand clogging and corrosion. And it is recommended that the operation for maintenance is practised from time to time during a long spell of operation halt.



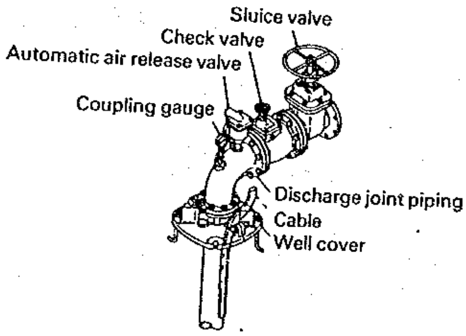


Fig. 7.4. Attachment of Submersible Pump (Ref. Book No. 8)

Fig. 7.3. Well and Submersible Pump (Ref. Book No. 5)

The following notices should be observed:

i) House the pumps to prevent from direct sunlight.

ii) Avoid installing the pumps in the place quite free from high temperature and humidity.

iii) Cover the pump.

iv) Keep the pump unit dry well before casing.

v) Inspect the pumps thoroughly before starting operation.

The causes and remedies of the pump troubles are shown in Table 7-2.

Table 7-2. Pump Troubles and their Causes and Remedies (Submersible Pump)

Trouble	Cause	Remedy
Does not start. Starts, but immediately stops.	(1) Wiring disconnected or cut. (2) No power. (3) Dry operation prevention electrode, water tank electrode or pressure switch damaged. (4) Reverse rotation. (5) Star-delta switchover time too long. (6) No-phase; voltage drop (over 10%). (7) Circuit breaker functioning. (8) Pump or motor locked. (9) Magnetic switch flutter. (10) Protective relay selection poor. (11) Motor burned out.	(1) Repair or replace. (2) Contact power company. (3) Replace. (4) Correct rotation. (5) Set to 3 seconds. (6) Contact power company. (7) Repair or replace point of short circuit. (8) Remove pump and repair. (9) Replace. (10) Replace with appropriate relay. (11) Remove pump and repair or replace.
Overcurrent during operation.	(1) Reverse rotation. (2) Voltage drop (over 10%). (3) Voltage unbalance (over $\pm 2.5\%$ between each phase). (4) Pump clogged with sand. (5) Pump or motor shaft worn.	(1) Correct rotation. (2) Contact power company. (3) Contact power company. (4) Clean well. (5) Remove and repair.
No water.	(1) Pump exposed. (2) Reverse rotation. (3) Hole in pump or piping.	(1) Lower pump position. (2) Correct rotation. (3) Remove and repair.
Do not get rated flow. Not enough discharge.	(1) Inside of pump worn. (2) Hole in piping. (3) Piping seat packing damaged. (4) Scales inside piping. (5) Foreign matter clogging impeller or casing. (6) Foreign matter clogging pump strainer. (7) Sluice valve damaged. (8) Water level extremely low. (9) Reverse operation.	(1) Replace worn parts. (2) Repair. (3) Replace. (4) Remove scales and clean. (5) Remove, disassemble and clean. (6) Remove, disassemble and clean. (7) Repair or replace. (8) Replace with a pump having higher total head. (9) Correct rotation.
Insulation resistance low.	(1) Motor deteriorated. (2) Motor burned out. (3) Submersible cable scratched. (4) Water leaking into connection of cable under water.	(1) Romove and replace motor. (2) Remove and replace motor. (3) Remove and repair. (4) Remove and repair.
Vibration & noise.	(1) Water hammer in piping above ground. (2) Sluice valve closed too far. (3) Built in check valve damaged. (4) Piping vibrating.	(1) Take countermeasure to prevent water hammer. (2) Increase opening of sluice valve. (3) Remove and repair. (4) Improve piping support.

Source: Instruction Manual, EBARA Corporation, 1984

CHAPTER VIII. WATER QUALITY CONTROL

8.1. General

One of the main purposes of water works is to contribute to the improvement of living and sanitary conditions by securing water quality and maintaining an abundant supply of clean water at a low cost.

In order to attain the purpose, it is necessary to make a proper operation of the whole water supply facilities such as water source facility, water treatment plant and distribution systems, and to maintain them rationally, efficiently and hygienically.

Water quality control is classified into the following three procedures along the water flow from the water source to the water tap.

1) Water quality control for water source
2) Water quality control for treatment
3) Water quality control for distribution

The technical administrator and operator should pay a close attention to the characteristics of the raw water and the treatment methods for the different kinds of quality of various water sources. In addition, the water quality standard is shown in Table 8-1, and the check items on water quality are listed in Table A-2 in Questions and Answers.

Table 8-1. Drinking Water Standards Thailand*

Physical Condition

Item	Highest Desirable Level	Maximum Permissible Level
colour	5	15
taste	Unobjectionable	Unobjectionable
odour	Unobjectionable	Unobjectionable
turbidity	5	20
PH range	6.5 to 8.5	Under 9.2

Chemical Condition

Item	Highest Desirable Level (ppm)	Maximum Permissible Level (ppm)
total solids	500	1,500
Fe	0.5	1.0
Mn	0.1	0.3
Fe + Mn	0.5	1.0
Cu	1.0	1.5
Zu	5.0	15
Ca	75	200
Mg	50	150
So	200	250
Cl	250	600
F	0.7	1.0
NO_3	45	45
alkylbenzyl sulfonates, ABS	0.5	1.0
Phenolic-substances, as phenol	0.001	0.002

Remarks : Total Hardness (as Calcium Carbonate) less than 300 ppm is defined to a good water as standard.

Toxin

Item	Highest Desirable Level (ppm)
Hg	0.001
Pb	0.05
As	0.05
Se	0.01
Cr Hexavalent	0.05
CN	0.2
Cd	0.01
Ba	1.0

Bacteriological Condition

Item	Highest Desirable Level
Standard Plate count (Colonies/cm^3)	500
MPN (Coliform Organism/100 cm^3)	less than 2.2
E. coli	none

*/ : Data Source PWD.

PART II. QUESTIONS AND ANSWERS

[Q-1] Raw water must be protected from pollution by waste water and sewage.

How can the amount of pollutants contained in the raw water be measured?

[A-1] Fish breeding tanks can be used to measure the contents of pollutants in the raw water polluted. (See Fig. A-1.)

The amount of pollutants in the raw water can be estimated by carefully watching fish behaviors for pollutants, in other words, by recognizing the critical amount of pollutants to kill or writhe the fishes in the tanks.

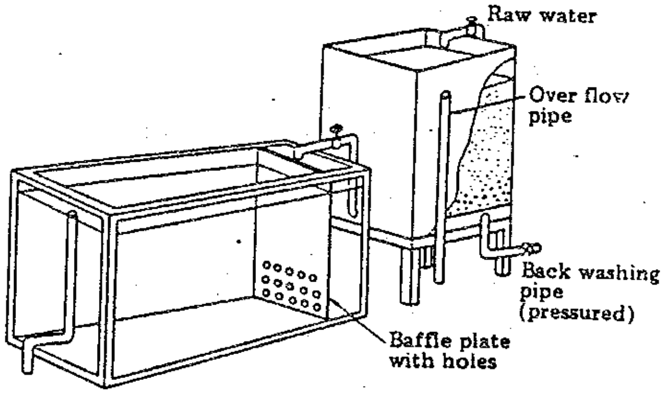


Fig. A-1. Fish Breeding Tank (Ref. Book No. 6)

[Q-2] The turbidity of treated water will sometimes increase depending on the raw water quality.

What countermeasures can be taken for reducing turbidity?

[A-2] The countermeasures can be taken in following the procedures mentioned hereunder.

1) pH value of the raw water is measured. pH value ranging from 6.0 to 8.0 are found adequate for coagulation. Ph values less than 6.0 show acidic water and dosing of alkaline materials like Soda Ash is required.

2) Jar Test is carried out and flocs formation shall confirm.

3) The alum feeding rate is determined based on the jar test and the amount of alum to be fed shall arrange taking into account raw water discharge.

4) The conditions for coagulation and flocculation are recorded.

[Q-3] Red or black water comes out of the water tap.

Why is the tap water sometimes found colored? What countermeasures can be taken in such cases?

[A-3] There are two causes considered for red water; one is iron contents in raw water and the other is rust caused from corrosion of pipings.

1) When iron is found in raw water, effective filtration is essentially required to clan the water.

2) When red water comes out of the tap, rust from corrosion of the pipings affects to the water. Therefore, it is necessary to thoroughly clean the pipings, and it may be required to replace the pipings, if corrosion advances.

3) Black water often caused by manganese. It is necessary to remove manganese even a very small amount at the filtration plant.

[Q-4] How can the algae growth and bad taste and odors be controlled?

[A-4] 1) Prevention of algae growth

a) Pre-chlorination, in which chlorine is dosed in the receiving well of raw water, should be carried out.

b) Settling sludge should not be accumulated in the sedimentation basin for a long time, and should be removed from the basin in early stage of deposition.

2) Betterment of taste and odors

a) Groundwater sometimes contains considerable amount of chloride and hardness. Ordinarily, the water containing more than 300 ppm chloride or more than 300 ppm total hardness is unsuitable for drinking water.

b) Surface water such as river water or reservoir water sometimes contains considerable amount of organic matters and nutrients caused by human or animal waste. These matters are often associated with offensive taste or odors.

c) In order to improve offensive taste or odor, the following meausres can be taken:

i) Aeration
ii) Activated carbon treatment
iii) Chlorination

iv) Ozonization
v) Slow sand filtration

In addition, it is necessary to protect the environment surrounding the water source.

[Q-5] Please explain about the washing mechanism for the rapid sand filter.

[A-5] The washing processes are specified into surface wash and backwash. Both processes require pressured water. The washing mechanism is as follows:

1) Washing system (refer to Fig. A-2)

a) Surface washing is started with opening valve(1). Thickness of sand bed (ha) is commonly 0.60 m.

b) After two minutes of surface washing, backwash shall start by opening valve(2). The sand bed is expanded to (hb) by backwash water with velocity V.
Expansion rate: E (%)

$$E = \frac{hb - ha}{ha} = 20 \text{ to } 50 \ (\%)$$

$$V = 0.5 - 0.7 \ (m/min)$$

The reasonable expansion rate (E) of sand bed is the value when the backwash water velocity is ranging 0.5 to 0.7 (m/min).

c) After four to six minutes of opening valve(2), valve(1) shall be closed, then surface washing stops. Sand bed is still expanding.

d) After four to six minutes of closing valve(1), valve(2) shall be closed and all washing processes end.

2) Washing pressure and velocity are shown in Table A-1 and can be referred to the design manual.

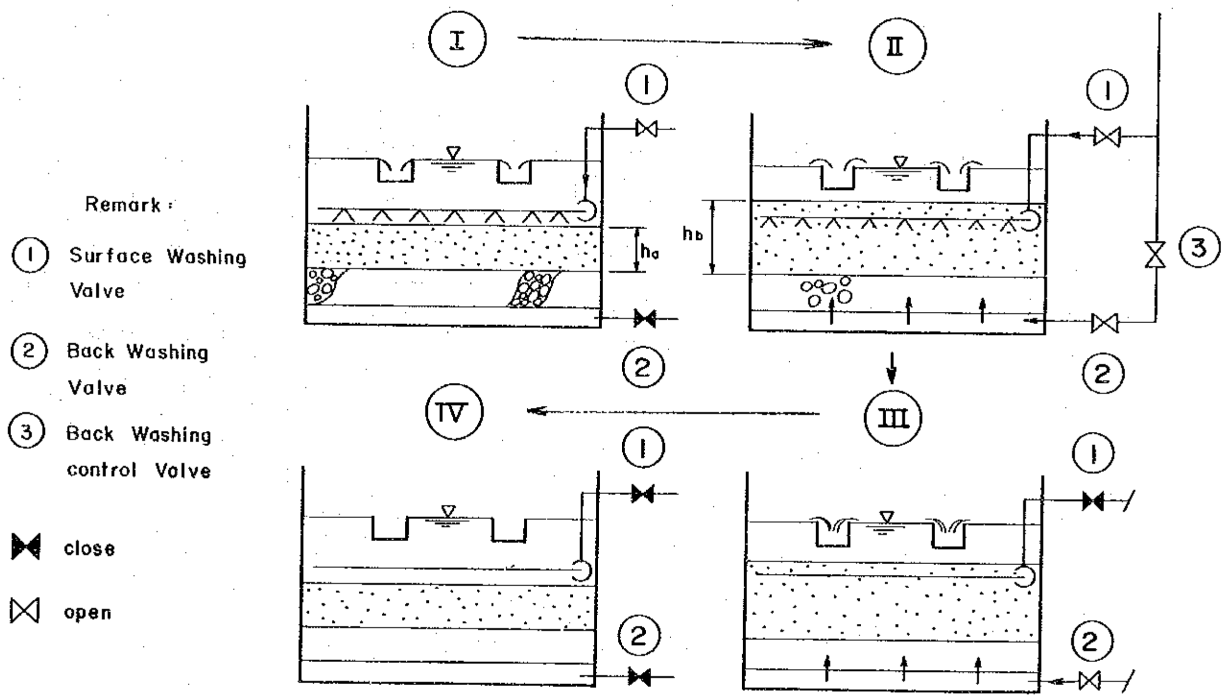


Fig. A-2. Washing System

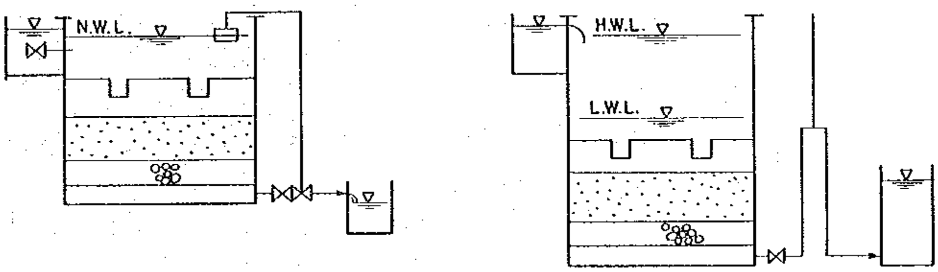
Table A-1. Washing Method of Rapid Sand Filter
(Ref. Book No. 4)

Items \ Washing Method	Surface and Backwash: Fixed Type Surface-Wash	Surface and Backwash: Rotary Type Surface-Wash	Back-Wash without Surface-Wash
Pressure of Surface-Wash Water (kg/cm^2)	1.5 to 2.0	3.0 to 4.0	--------
Flow Rate of Surface-Wash Water ($m^3/m^2/min.$)	0.15 to 0.20	0.05 to 0.10	--------
Duration Time of Surface-Wash (min.)	4 to 6	4 to 6	--------
Pressure of Back-Wash Water (kg/cm^2)	0.25 to 0.50		0.25 to 0.50
Flow Rate of Back-Wash Water ($m^3/m^2/min.$)	0.5 to 0.7		0.6 to 0.9
Duration Time of Back-Wash (min.)	4 to 6		4 to 6

Note: Pressure of back-wash water and surface-wash water are values at discharge points (orifice or jet) of underdrain system and surface-washing system, respectively.

[Q-6] In Thailand, the control device of rapid filtration is specified into the following two types as shown in Fig. A-3.

Which is more suitable for the Sanitary District water treatment system?



A) Level Control Type B) Natural Balance Flow Type

Fig. A-3. Control Device of Filtrated Water

[A-6] Type(B) is more suitable than Type(A) because of the following reasons:

1) No mechanical equipment is used with Type(B), so that the maintenance is easy.

2) For Type(B), the positive pressure can be always kept in the sand bed, and this is a very important factor because air comes into the sand bed if the negative pressure works in the sand bed.

[Q-7] What methods are recommendable for effective and simplified tests for water quality and flocculation?

[A-7] 1) Water Quality Test

a) pH
pH of water can be roughly tested with litmus paper by color check.

b) Turbidity
Turbidity samples shall be prepared in test tubes by NTU of 10, 20, 30, 50, and 100, and the comparative checks shall be made between test water and those standard water samples.

c) Color
The color checks shall be prepared with color units of 5, 10, 15, 20, etc., respectively, and the comparative checks shall be made between the color charts and test water.

d) Iron
An appreciable amount of bleaching powder shall be added to test water to carefully watch its color change.

2) Flocculation Test (Simplified Jar Test)

The following are the procedures for the testing:

a) A test water sample shall be put in a one-litre beaker. About five percent alum solution, which is stocked to be readily available for daily works, shall be diluted into 0.5 percent solution, and then the solution of five milliliters shall be dosed into the test water by pipette.

$$\text{Dosing Amount} = 50\ \text{mg/ml} \times \frac{5\ \text{ml}}{10} = 25\ \text{mg}$$

Dosing Rate = 25 mg/l (ppm)

b) The test water shall be stirred up with glass rod for two to three minutes for rapid mixing.

c) The pH value of the water shall be checked with litmus paper to confirm the pH value ranging from 6.0 to 8.0.

d) Alkali shall be added to the water until becoming the pH value more than 6.0, if the pH value is found below 6.0.

e) After rapid mixing, the water shall be stirred up slowly to allow usual checking the flocs formed therein.

f) And then, another stirring shall be made up for about 5 minutes to carefully watch the flocs formation.

g) In such a way, the similar flocculation tests shall be repeated with different feeding rates of alum so as to find and record the most adequate feeding rate of alum.

3) For chemical tests/experiments, it is recommended that the instruments illustrated in Fig. A-4 are ready for use at any time.

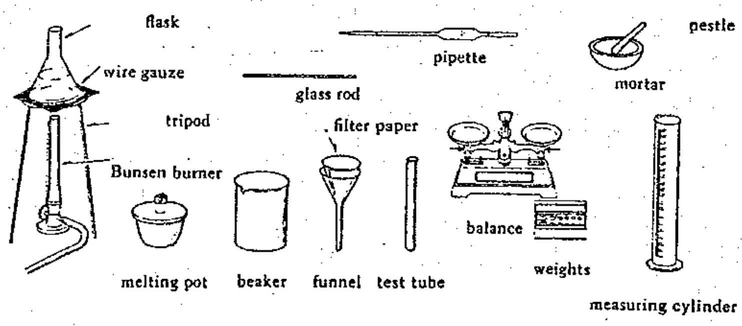


Fig. A-4. Test Instruments

[Q-8] How can effective inspection be made for the total waterworks systems?

[A-8] The inspection list of the waterworks is shown in Table A-2. Daily recording sheet is illustrated in Table A-3.

Table A-2. Checklist of the Waterworks

Facilities	Checks Items	Watching			Recording			Remark
		Daily	Weekly	Monthly	Daily	Weekly	Monthly	
Intake	Water level	o			o			Alarm on the LWL, HWL.
	Raw water quality (PH, Turbidity)	o						
	Water quantities	o			o			
	Pumps operation	o			o			
	Engins operation	o			o			
	Electric load	o			o			
Receiving Well	Water quantity	o			o			
	Water quality (PH, Turbidity)	o			o			
	(All Items)			o		o		
Chemical dosing	Alum dosing amount	o			o			
	Soda dosing amount	o			o			
	Pre-chlorin	o			o			
	Alum Solution content		o			o		
	Soda Solution content		o			o		
Flocculation	Floc form	o			o			
	Water head loss			o				
Sedimentation	Clear water quality (PH, Turbidity)	o			o			
	Sludge volume			o				
Filtration	Clear water(Turbidity)	o			o			
	Water level	o			o			
	Washing time	o			o			
	Sand condition			o			o	
Chlorination	Dosing amount	o			o			
	Chlorin content			o			o	
	Residual chlorin	o			o			Reservoir Distribution Pipeline
Distribution Reservoir	Water level	o			o			
	Clear water (PH, Turbidity)	o			o			
	(All Item)						o	
	Pump operation	o			o			
	Engine operation	o			o			
	Electric load	o			o			
	Water distribution quantities	o			o			
Service works	Household			o			o	
	Population			o			o	
Distribution pipe line	Flow condition	o			o			

SD ________

Table A-3. OPERATION DAILY REPORT

Date: 10:00 AM ____ day ____ month ____ year Operator: ________, ________ / ________, ________

FACILITIES		CHECK AND RECORDING ITEMS	
1. Intake	1.1.	Water level	; ____ m, Planned HWL ____ m, Planned LWL ____ m
	1.2.	Raw water quality	; PH ____, Turbidity ____ NTU
	1.3.	Water quantitites	; ____ m^3/h x Operation ____ hr/day = ____ m^3/day
	1.4.	Pumps operation	; No.1 ____ $m^3/min.$ x ____ hr, No.2 ____ $m^3/min.$ x ____ hr
	1.5.	Engine operation	; ____ mr/day
	1.6.	Electric load	; Ampere Meter Record ____ A.day before ____ A, USL ____ A,
2. Receiving Well	2.1.	Measuring water quantities	; ____ m^3/hr on the weir, flow meter, etc.
	2.2.	Water quality	; PH ____, Turbidity ____ NTU.
3. Chemical Dosing	3.1.	Jar test data	; Alum feeding ____ mg/l, Alkality feeding ____ mg/l, Floc formation ____
	3.2.	Alum dosing amount	; (2.1) ____ m^3/hr x (3.1) ____ mg/l ÷ (3.5) Solution ____ % = ____ l/min.
	3.3.	Alkali dosing amount	; (2.1) ____ m^3/hr x (3.1) ____ mg/l ÷ (3.6) Solution ____ % = ____ l/min.
	3.4.	Pre-chlorine	; (2.1) ____ m^3/hr x ____ mg/l ÷ (7.2) Solution ____ % = ____ l/min.
	3.5.	Alum solution content	; Feeding solid alum ____ kg, Water volume ____ m^3, Solution ____ %
	3.6.	Alkali solution content	; Feeding alkali powder ____ kg, Water volume ____ m^3, Solution ____ %
4. Flocculation	4.1.	Coagulation water quality	; PH ____, Turbidity ____ NTU, Floc formation ____
5. Sedimentation	5.1.	Clear water quality	; PH ____, Turbidity ____ NTU
	5.2.	Sludge remove	; Drain valve open: number ____ x open time ____ min/day
6. Filtration	6.1.	Clear water quality	; Turbidity ____ NTU, Color ____ unit
	6.2.	Water level	; ____ m, Minimum Water Level ____ m, Head Loss ____ m
	6.3.	Washing time	; No.1 Backwash ____ min., Surface wash ____ min., Number ____ /day No.2 Backwash ____ min., Surface wash ____ min., Number ____ /day
	6.4.	Elevated tank water level	; ____ m, Volume ____ m^3 on the after washing
7. Chlorination	7.1.	Dosing amount	; (2.1) ____ m^3/hr x dosing ____ l/min. ÷ Solution ____ % = ____ l/min.
	7.2.	Chlorine content	; Breaching powder feeding ____ kg ÷ Water volume ____ m^3 = Solution ____ %
	7.3.	Residual chlorine	; Reservoir ____ mg/l, Main distribution pipe ____ mg/l Water service tap: No. ____ mg/l, No. ____ mg/l, No. ____ mg/l
8. Distribution Reservoir	8.1.	Water level	; ____ m, Water volume: Area ____ m^2 x ____ mH x number ____ = ____ m^3
	8.2.	Clear water quality	; PH ____, Turbidity ____ NTU, Color ____ units
9. Distribution Pumps	9.1.	Pump operation	; No.1 ____ m^3/m x operation time ____ hr, Pump condition ____ No.2 ____ m^3/m x operation time ____ hr, Pump condition ____ No.3 ____ m^3/m x operation time ____ hr, Pump condition ____
	9.2.	Engine operation	; Operation time ____ hr/day, Condition ____
	9.3.	Electric load	; Ampere meter record ____ A, day before ____ A, USL ____ A
10. Elevated tank	10.1.	Water level	; ____ m x Area ____ m^2 = Volume ____ m^3
	10.2.	Level control	; Float valve condition ____
11. Distribution Quantities	11.1.	Measuring meter	; Flow record ____ m^3 day before ____ m^3, Distribution ____ m^3/day
	11.2.	Pressure	; Water pressure ____ m H_2O
	11.3.	Water supply	; Water supply time: AM ____ hr, PM ____ hr, Total ____ hr/day
12. Distribution Pipeline	12.1.	Operation	; Valve ____ Pipe ____ Meter ____

Remarks:

[Q-9] How can water leakage be detected? What kind of detection method is available?

[A-9] Water leakage from pipelines of waterwork can generally be classified into two: (1) ground leakage, and (2) underground leakage. The former is visible leakage from the surface and joint of the pipes, and it is very easy to find water leakage. The latter, however, is quite hard to detect water leakage without physical investigations.

The following equipment are used to find location of pipe laid under the ground, and to detect water leakage from the pipes. Pipe detectors, which detects location of pipes, can be classified into iron pipe detector for metallic pipe and non-iron pipe detector for non-metallic pipes such as asbestos cement pipe and unplasticized polyvinyl chloride pipe. The method of leakage detection from pipe is usually adopted to receive leakage sound which is transmitted through the underground. Suitable equipment for detection are sound wave detector, sound bar detector, electric hammer drill and boring bar, etc.

This water leakage detection, however, required much experience and high technology of the operator. In order to realize this work, PWD must establish training programmes for the operators.

[Q-10] How many number of personnel would be engaged in the O & M?

[A-10] The recommendable personnel of O & M waterworks is as shown in Table A-4.

Table A-4. Number of Personnel to be Engaged in the O & M

Pupil / Treatment Capacity (m^3/Hr)	General Admin-istrator	Technical Admin-istrator	Chief Operator	Chief Officer	Worker and Officer	Total
200	Concurrently (1)	1	1	1	3	6 (1)
150	(1)	1	1	1	3	6 (1)
100	(1)	1	1	1	2	5 (1)
50	(1)	1	1	1	1	4 (1)
30	(1)	1	1	1	1	4 (1)
20	(1)	1	1	1	-	3 (1)

RECOMMENDATION ON THE IMPROVEMENT
OF
THE WATERWORKS FACILITIES
IN
THE EXISTING SANITARY DISTRICTS

TABLE OF CONTENTS

CHAPTER I. INTRODUCTION

The waterworks systems were constructed in 155 sanitary districts from 1965 to 1983 in Thailand.

The two-phased field surveys were carried out on the ten existing sanitary districts (hereinafter called ESD) waterworks facilities in the Northeastern region of Thailand from October 1984 to January 1985 (Phase I) and from June 1985 to September 1985 (Phase II).

The purpose of this report, on the basis of the findings of the surveys, is to identify any problems and clarify the situation of the water supply facilities in the ten ESDs and to recommend their improvement or rehabilitation plans.

Since the recommendations describe a general improvement plan, further considerations or detailed discussions can be referred to Design Manual or O/M Manual which are prepared separately during this survey period.

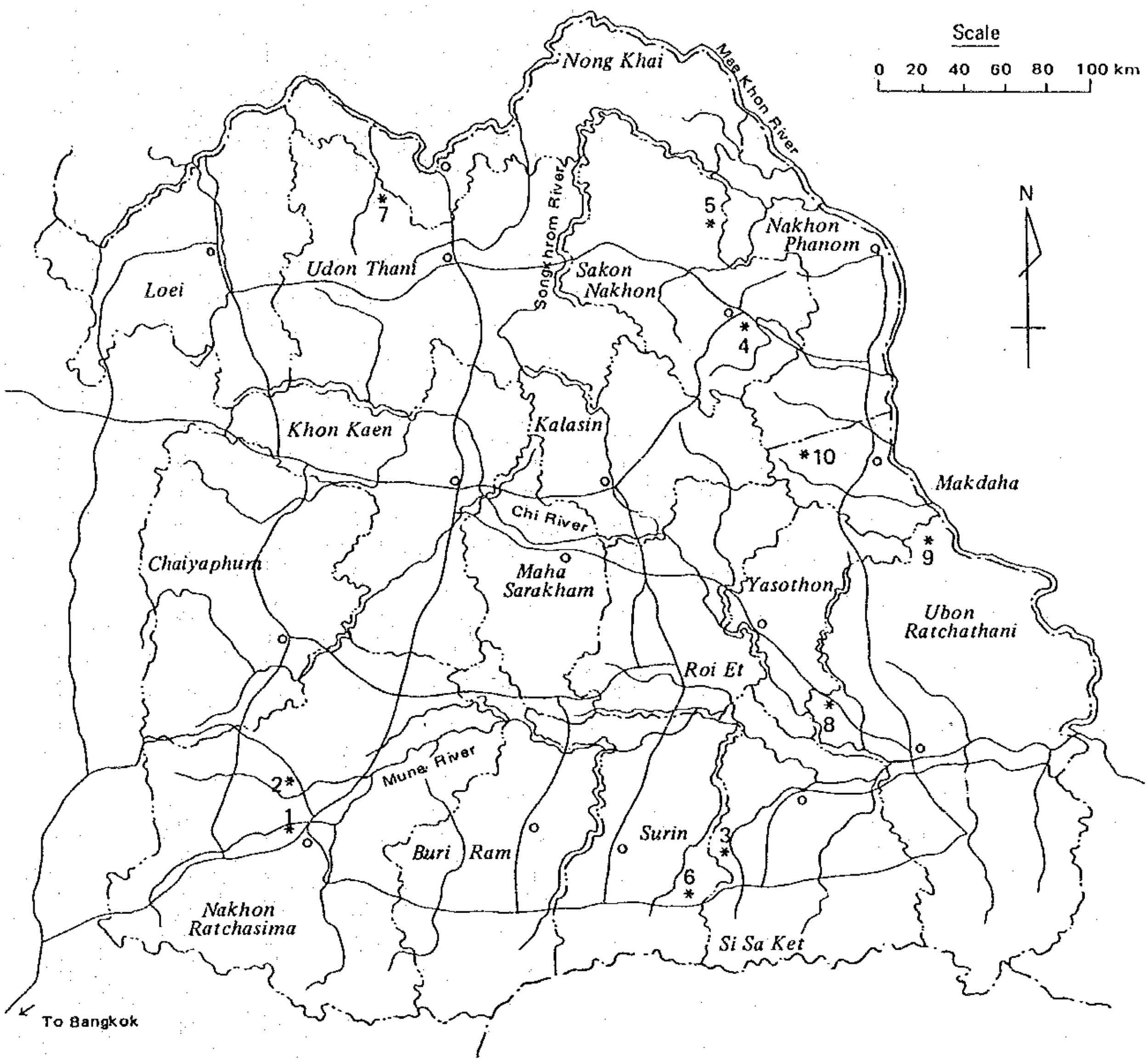
CHAPTER II. PRESENT CONDITIONS OF EXISTING SANITARY DISTRICT WATERWORKS

2-1. Findings of the Field Surveys on the ten ESD.

The location map of the ten ESDs and their inventory made on data available from the authorities concerned are shown in Fig. 2-1 and Table 2-1.

Data and information on the water sources and water quality of the ten ESDs are shown in Tables 2-2 and 2-3.

Fig. 2–1 Location of 10 ESDs



<u>LEGEND</u>

— · —	National Boundary
— · · —	Provincial (Changwat) Boundary
o	Provincial Capital
———	National Highway
(river symbol)	River
* 1	ESD Studied

Existing Sanitary District With Water Works (ESD)

1. Cho Ho
2. Non Thai
3. Prang Ku
4. Tha Rae
5. Akat Amnuai
6. Sankha
7. Ban Phu
8. Khuang Nai
9. Chanuman
10. Khamcha-i

Table 2-1 Inventory of Existing SD Water Works

No.	ESD	Amphoe	Changwat	Construction Year	Water Source	Production Capacity (cu.m/hr)	Treatment System	Service Area (sq.,km)
1	Cho Ho	Muang	Nakhon Ratchasima	1977	Khlong Phai Canal Lam Ta Khon Res.	50	Rapid Sand Filtration	9.0
2	Non Thai	Non Thai	Nakhon Ratchasima	1972	Chorakee Pond	30	Rapid Sand Filtration	7.1
3	Prang Ku	Prang Ku	Sri Sa Ket	1970	Ground water	10	Infiltration Gallery	2.82
4	Tha Rae	Muang	Sakon Nakhon	1968	Nong Han Reservoir	50	Rapid Sand Filtration	3.0
5	Akat Amnuai	Akat Amnuai	Sakon Nakhon	1969	Ground water	30	Infiltration Gallery	2.25
6	Sankha	Sankha	Surin	1975	Reservoir	30	Rapid Sand Filtration	2.25
7	Ban Phu	Ban Phu	Udon Thani	1966	Ground water	20	Aeration Rapid Filtration	6.00
8	Khuang Nai	Khuang Nai	Ubon Ratchathani	1970	Ground water	30	Infiltration Gallery	7.00
9	Chanuman	Chanuman	Ubon Ratchathani	1972	Me Khong River	20	Rapid Sand Filtration	2.00
10	Khamcha-i	Chamcha-i	Mukdahan	-	Huai Mut Reservoir	30	Rapid Sand Filtration	3.67

Table 2-2. Water Source of the ESD

No.	SD Name	Construction Year	Source	Capacity	Status	Remark
1	Cho Ho	1977	Lam Takhong reservoir	-	Sufficient	
2	Non Thai	1972	Pond	800,000 cu.m	Shortage	Planning of intake canal
3	Prang Ku	1970	Deep Well	11,000 cu.m/year	Shortage	Water source will be changed into river
4	Tha Rae	1968	Nong Han Lake	-	Sufficient	
5	Akat Amnuai	1969	Deep Well	53,000 cu.m/year	Sufficient	Water source will be changed into river
6	Sankha	1975	Reservoir	300,000 cu.m	Sufficient	
7	Ban Phu	1966	Deep Well	57,000 cu.m/year	Sufficient	
8	Khuang Nai	1970	Deep Well	25,000 cu.m/year	Shortage	Water source will be changed into river
9	Chanuman	1972	Mekhon river	-	Sufficient	
10	Khamcha-i	1984	Huai Muk reservoir	6.3 MCM	Sufficient	

Note; Yield of well was estimated by water charge.

Table 2-3. Existing SD Raw Water Quality

			Field Test					Laboratory Test			
No.	ESD	Water Source	PH	Turb. unit	Temp. °C	DO ppm	COND. ms/cm^2	PH	Turb. unit	Alkali ppm	Chloride ppm
1	Cho Ho	Reservoir	7.8	49	28.2	2.5	0.5	7.75	45	157	92
2	Non Thai	Pond	7.3	78	26.7	2.7	0.6	7.10	80	78	102
3	Prang Ku	Ground water	7.5	5	31.6	3.1	1.9	-	-	-	-
4	Tha Rae	Reservoir	7.5	6	24.0	2.5	0.3	7.35	6.3	40	18
5	Akat Amnuai	Ground water	7.5 9.0 7.6	5 8 5	25.5 21.7 27.7	0.4 2.2 1.6	0.5 0.2 0.5	-	-	-	-
6	Sankha	Reservoir	7.3	15	27.0	47	0.1	7.10	17.9	20	11
7	Ban Phu	Ground water	8.5	5	25.0	2.1	1.7	8.35	7.5	205	540
8	Khuang Nai	Ground water	6.0	7	27.0	3.3	0.7	5.85	10.0	15	56
9	Chanuman	River	8.2	160	24.6	4.2	0.7	7.95	144	75	14
10	Khamcha-i	Reservoir	7.8	9	22.8	3.3	0.2	7.50	9.3	45	4

Note; Test date NOV., DES. 1984.

2-2. Present Conditions of the Existing Waterworks

2-2-1. General Description

This section describes the present conditions of the existing waterworks systems for the ESD where problems and constraints exist in the systems.

2-2-2. Water Sources and Water Quality

1) Surface Water

a) ESD 2. Non Thai

The water source is a pond. Water shortage of the pond which is water source takes place in the dry season due to its small catchment area. At present, there is a plan to provide a link canal between the existing pond and the Lam Chiang Klai irrigation canal.

The water quality is assumed to become worse especially in the dry season. Chloride, iron and manganese will be also contained in the water.

2) Groundwater

a) ESD 3. Prang Ku

The water source is groundwater, and the operation time of the supply system is only two hours per day due to insufficient yield. At present, the SD is planning to convert the water source from groundwater to the Huai Sam Lam river water.

b) ESD 5. Akat Amnuai

The pH value of the No.2 groundwater is higher than the maximum permissible level by the water quality standard in Thailand. Consequently, the groundwater is not used for drinking.

Pumps are automatically operated according to the water level fluctuation in the elevated tank.

c) ESD 8. Khuang Nai

The water source of this ESD is groundwater. There are two deep wells but one unit is currently not operated.

Aeration and rapid filtration systems are adopted for treatment.

The water quality is not suitable for drinking because the water contains iron contents. The yield is not sufficient. Consequently, the sanitary district has a plan to construct a new treatment plan.

2-2-3. Treatment Facilities

1) Surface Water Treatment

The rapid sand filtration system is applied to most of the sanitary district waterworks.

The water treatment process commonly adopted is shown in Fig. 2-2.

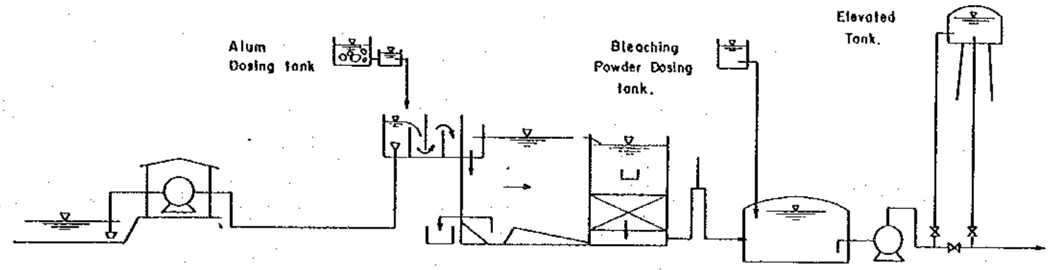


Fig. 2-2. Water Treatment Flow (Cho ho SD)

2) Groundwater Treatment

Groundwater is one of the most suitable water sources to small-scale waterworks, because the treatment system is so simple as to be easily operated at low cost. The water quality of groundwater in the Northeastern region of Thailand, however,is not suitable for drinking due to fairly high content of chloride, iron and manganese.

The groundwater treatment system that is most commonly used is shown in Figs. 2-3 and 2-4.

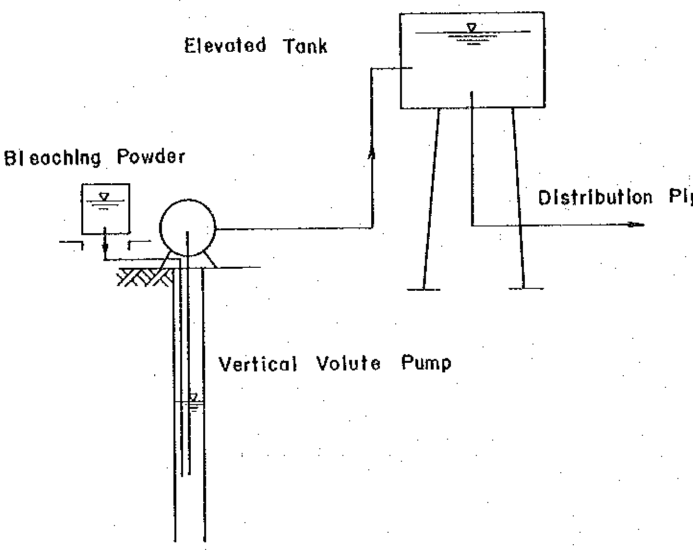


Fig. 2-3. Chlorination System

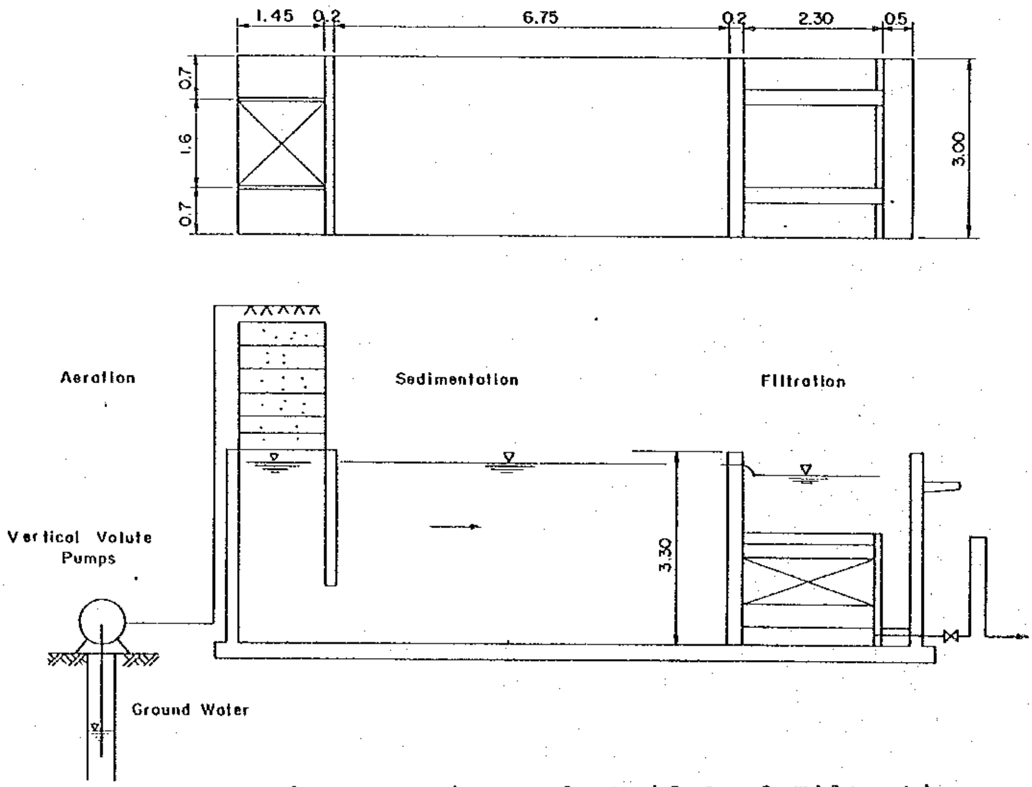


Fig. 2-4. Aeration and Rapid Sand Filtration System

CHAPTER III. RECOMMENDATIONS TO THE EXISTING WATERWORKS

3-1. Surface Water Treatment Facilities

3-1-1. General Items

1) Type of Water Treatment Facilities

The water treatment facilities of the ESD are specified into two types, hydraulic horizontal flow type and vertical jet mixer type.

The hydraulic horizontal flow type for flocculation is generally recommended for the sanitary district waterworks because the equipment of this type can treat any raw water changeable in turbidity and does not employ any complicated mechanical devices.

2) Measuring Devices of Water Quantity

Measuring devices at the treatment plant, distribution systems and service pipes should be installed at adequate points, respectively.

The measuring device for the inflow at treatment plant should be installed particularly at the chemical dosing point as shown in Fig. 2-1-1, so as to determine the amount of chemicals to be dosed as well as to control the treatment capacity.

Hydraulic weir type is recommended because it can be effectively operated in the combined use with the rapid mixing device of coagulants.

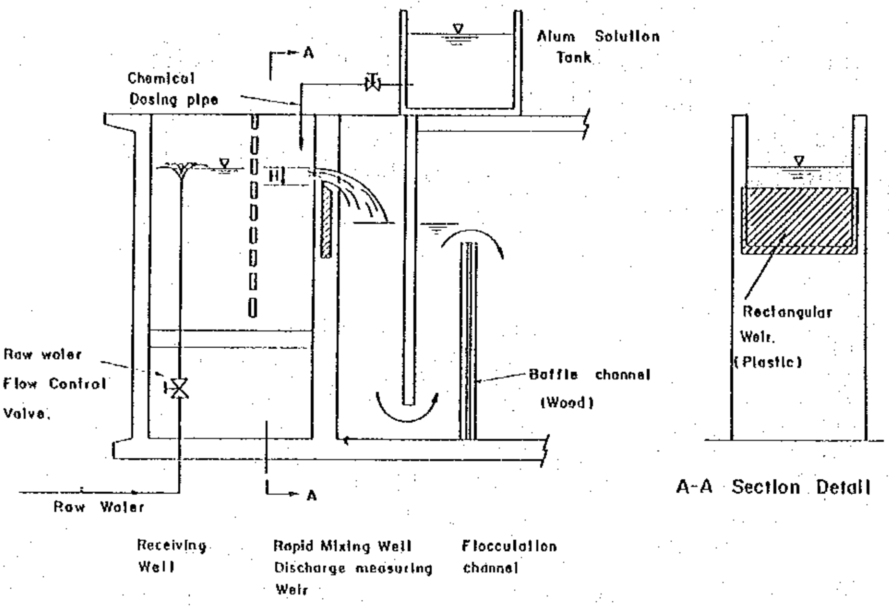


Fig. 3-1. Measuring Device for Inflow Quantity

3) Flocculation Facilities

The following two types, horizontal flow type (refer to Fig. 3-2) and hydraulic jet type (refer to Fig. 3-3) are generally used.

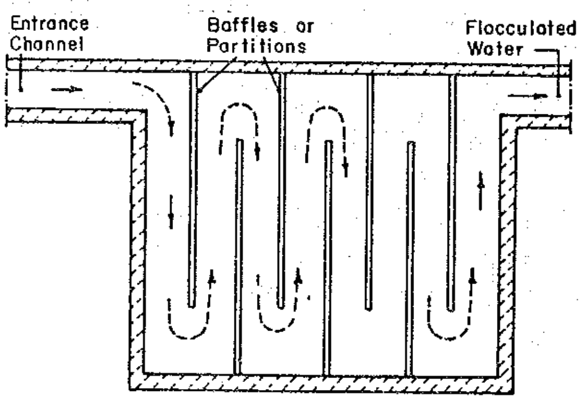


Fig. 3-2. Horizontal Flow Type (Ref. Book No.1)

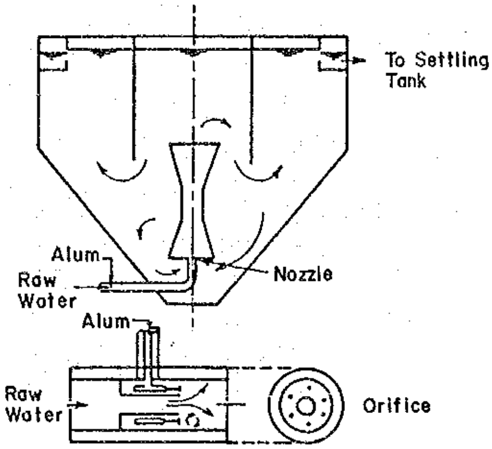
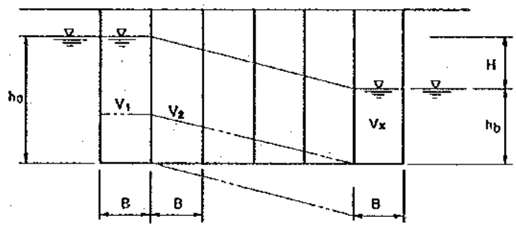


Fig. 3-3. Hydraulic Jet Type (Ref. Book No. 1)

In the majority of the flocculation basin of the horizontal flow type, the terminal flow velocity (V_x) is about twice the initial flow velocity (V_1). Consequently flocs are broken at the end of flocculator. (Refer to Fig. 3-4.)

Therefore, further design of the flocculator will require to pay attention on this problem.



$V_1 = Q / ha \times B$

⋮

$V_x = Q / (ha - H) \times B$

$V_x = V_1 \times \frac{ha}{ha - H} = V_1 \times \frac{0.5}{0.25} = 2V_1$

where : $H \geq 0.25$ (m)

$ha = 0.5$ (m)

Fig. 3-4. Horizontal Flow Calculation

4) Backwashing

When backwash velocity is higher than terminal velocity of the filter sand, it is impossible to wash the sand due to the fact that the sand is blown up by high velocity flow.

Backwash velocity should be controlled with appropriate velocity by a valve.

The ordinary backwash system is shown in Fig. 3-5.

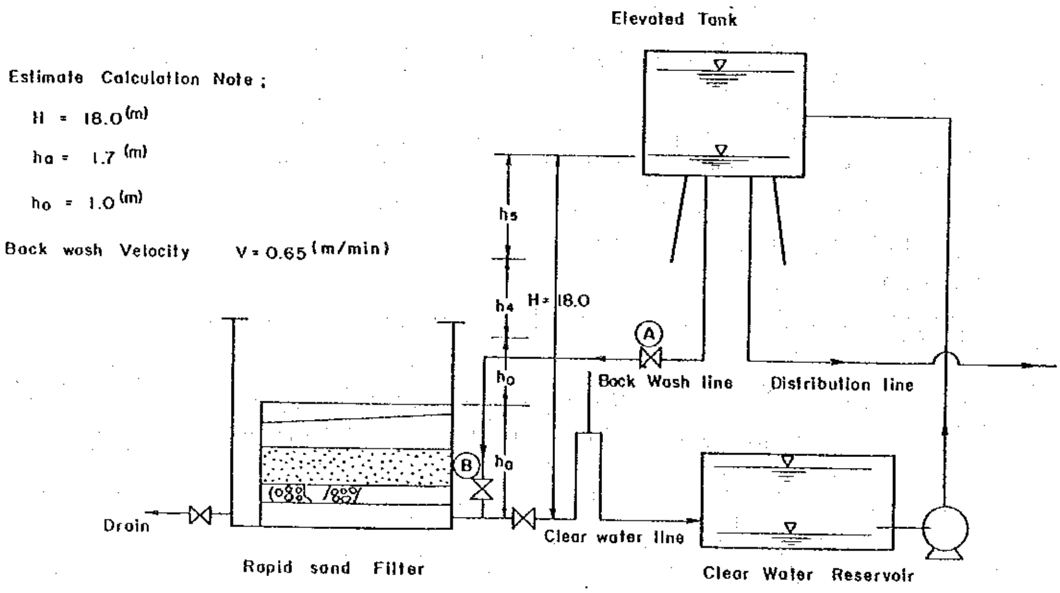


Fig. 3-5. Backwash System

Before starting the backwash, the valve A should be controlled according to the total head loss (h_f) which is (1) friction loss head of the backwash pipeline plus (2) resistance ratio of valve opening.

The valve opening ratio should be one-fifth or two fifths to keep an appropriate velocity constantly.

Details of the mechanism of backwashing can be referred to the Operation and Maintenance Manual.

3-1-2. Specific Items

1) General

As shown in Tables 3-1, 3-2, 3-3, the respective ESDs have specific problems in water quality resulting from improper operation of water treatment plants.

These problems will be solved by reviewing the whole waterworks and taking the general items discussed above.

2) ESD 1. Cho Ho

a) Judging from the Jar Test, flocs are formed adequately.

b) The turbidity of filtrated water is at the same level as that of settled water. This means that the water passes through the filter sand bed because the thickness of the bed is not uniform. In addition, filtered materials are carried to the outlet when backwash starts.

3) ESD 2. Non Thai

a) Flocculation and sedimentation are properly operated. The turbidity of filtrated water, however, should be less than 5.

4) ESD 4. Tha Rae

a) The turbidity of filtrated water is at the same level as that of settled water. This means that the settling water is not efficiently filtrated because the siphon type stand pipe is installed improperly as shown in Fig. 3-6.

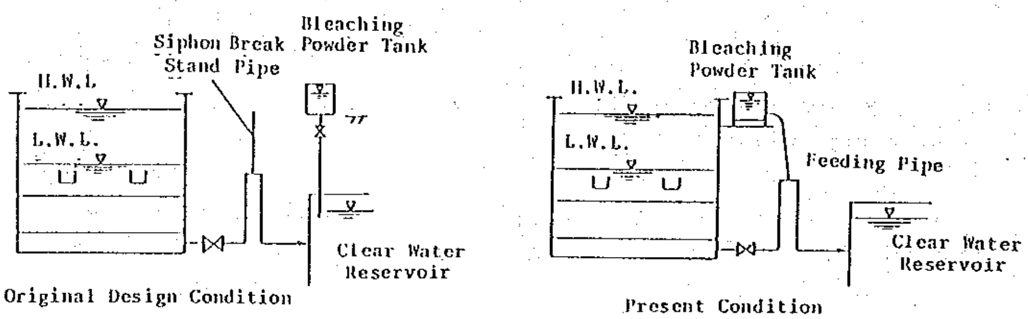


Fig. 3-6. Misuse of Siphon Type Stand Pipe

b) The survey reveals that people and domestic animals inhabit in the area of the water treatment plant. Since human faeces or domestic wastes may flow or run into the storage reservoir, the environment around the plant should be kept hygienically clean by preventing poultry from trespassing in the area.

5) ESD 6. Sankha

a) Since the alkalinity of raw water is low, some alkaline agents should be dosed with Alum. The pH value of raw water should be between 6.5 and 8.0 for effective formation of flocs. Therefore, the pH value measurement and the Jar Test should be carried out so as to determine the amount of alkaline agents. Soda ash is commonly used for the purpose in Thailand.

6) ESD 9. Chanuman

a) Raw water has overflown from the flocculation basin because the intake water exceeds the design capacity. The control valve "A" should be installed, as shown in Fig. 3-7, in order to control the intake quantity.

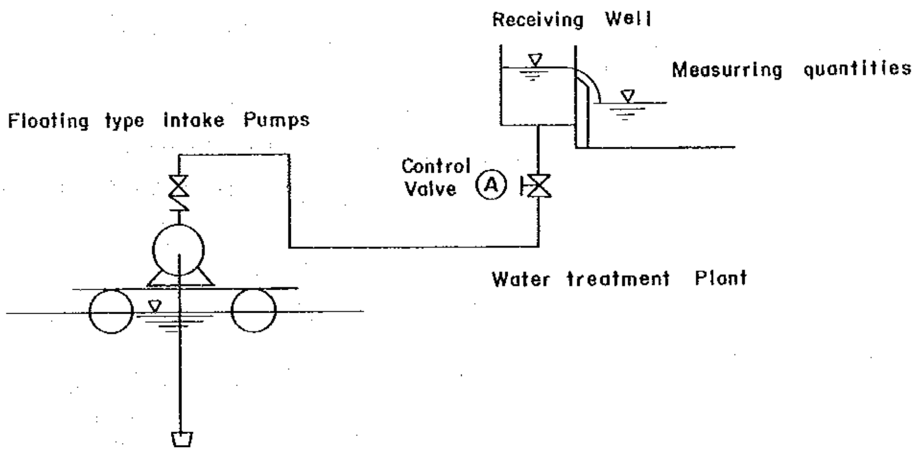


Fig. 3-7. Standard Design of Intake Facility

b) The turbidity of settled water and filtrated water is very high by the same problems as ESD-1 Cho Ho.

c) The turbidity of raw water is high all the year-round. A fairly large amount of sludge is accumulated in the sedimentation basin. Therefore, sludge should be drained every day.

3-2. Groundwater Treatment Facilities

3-2-1. General Items

As shown in Table 3-3, the respective ESDs have specific problems in water quality.

These problems can not be solved easily by ordinal treatment methods. In such cases, other water sources should be studied.

3-2-2. Specific Items

1) ESD 3. Drang Ku

The operation time of the supply system is only two hours per day due to insufficient water sources.

2) ESD 5. Akat Amnuai

The water quality of No.2 Well is not suitable as compared to the water quality standard in Thailand.

3) ESD 7. Ban Phu

The chlorine content of the groundwater is higher than the highest desirable level by the water quality standard in Thailand.

4) ESD 8. Khuang Nai

The treated water quality is still not suitable as drinking water. The sanitary district has a plan to construct a new treatment plant with appurtenant facilities.

3-3. Disinfection

Bleaching powder containing 30 to 35 percent chlorine is generally used, and 10 percent solution of bleaching powder is fed to the distribution reservoir. But the feeding ratio is not clarified, or residual chlorine is not inspected either. The daily inspection on the residual chlorine should be made at the water tap. Residual chlorine should be generally measured by the orthotolidine method and the dosage is 0.5 ppm (mg/l) after 30 minutes' contact.

3-4. Pumps

Two volute pumps, one is motor driven, and the other is engine driven unit for stand-by, are commonly installed. The survey reveals that only one is operated for daily services and another is out of order or taken away. All of the pumps should be regularly overhauled and properly maintained.

3-5. Distribution Pipes

Asbestos cement pipes are generally used and steel pipes with casing is used for crossing the railway or highway.

The following considerations should be given to the pipe installation:

1) The thickness of soil coverage of the pipe installed should be more than 1.0 m from the pipe top.

2) Sand bed should be provided under the pipe in order to protect pipe laid.

3) Pipes should not be installed in the waste water drains.

Table 3-1 The Quality of Raw Water (Surface Water)

Sampling Date Nov., Dec./1984

No.	ESD	Water Source	Treatment System	PH	Turb. unit	Temp. °C	DO ppm	COND. ms/cm^2	Alkali ppm	Chlorid ppm	Jar Test: Floc forming	Jar Test: A lum feeding ppm	Capacity m^3/hr
1	Cho Ho	Reservoir Canal	R_A	7.8	45	28.2	2.5	0.5	157	92	4/5	20	50
2	Non Thai	Pond	R_B	7.1	80	26.7	2.7	0.6	78	102	4/5	20	30
4	Tha Raw	Reservoir	R_A	7.4	6	24.0	2.5	0.3	40	18	2/5	10	50
6	San Kha	Reservoir	R_B	7.1	18	27.0	4.7	0.1	20	11	2/5	10	30
9	Chanuman	River	R_A	8.0	144	24.6	4.2	0.7	75	14	4/5	20-30	20
10	Khamcha-i	Reservoir	R_A	7.5	9	22.8	3.3	0.2	45	4	2/5	10	30

Remark ; R_A : Rapid sand filtration process standard
R_B : Rapid sand filtration process simple type standard
Turb : Turbidity (NTU), Temp : Temprate, $_2$DO : Dissolved oxygon
COND : Electric conductivity (mm: $semens/cm^2$)
Tar Tect : Flac forming index 5 is best condition.

Table 3-2. The Quality of Treated Water (R_A)

No.	ESD	Capacity (m^3/hr)	Treatment System	Flocculation Detentin Time (min)	Settling Tank Detention Time (hr)	Filter Flow Velocity (m/d)	Raw Water PH	Raw Water Turb.	Raw Water Alkali	Settling Water PH	Settling Water Turb.	Filter Water PH	Filter Water Turb.	Water Source
1	Cho Ho	50	R_A	20	3.0	120	7.8	45	157	7.1	28	7.7	27	Big Reservoir Canal
2	Non Thai	30	R_B	10	2.5	125	7.1	80	78	6.4	12	7.0	10	Small Pond
4	Tha Rae	50	R_A	20	3.0	120	7.4	6	40	7.3	5	7.0	5	Big Reservoir
6	Sank ha	30	R_B	20	3.0	120	7.1	18	20	5.5	11	5.7	5	Reservoir
9	Chanuman	20	R_A	20	3.0	120	8.0	144	75	6.0	30	8.0	10	Mekhong River
10	Khamcha-i	30	R_A	20	3.0	120	7.5	9	45	7.0	8	7.5	5	Big Reservoir

Table 3-3. The Quality of Ground Water and Treated Water

No.	ESD	Water Source	Treatment System	PH	Turb. unit	Temp. °C	DO ppm	COND. ms/cm^2	Alkali ppm	Chlorid ppm	Settling Wate PH	Settling Wate Turb. ppm	Filtrated Water PH	Filtrated Water Turb. ppm	Capacity m^3/hr
3	Prang Ku	Ground Water	C	7.5	5	31.6	3.1	1.9	-	-	-	-	-	-	10
5	Akat Amnuai	Ground Water	C	7.5 9.0 7.6	5 8 5	25.5 21.7 27.7	0.4 2.2 1.6	0.5 0.2 0.5	-	-	-	-	-	-	30
7	Ban Phu	Ground Water	$A+R_A$	8.4	7	25.0	2.1	1.7	205	540	-	-	8.5	7	20
8	Khuang Nai	Ground Water	$A+R_A$	6.0	10	27.0	3.3	0.7	15	56	6.0	8	6.0	7	30

Remark ; Treatment system C : Chlorination
Treatment system $A + R_A$: Aeration and Rapid Sand Filtration

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