Water Quality and Treatment Processes

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Water Quality and Treatment Process

1. Introduction

This Appendix - C is to present the results of water quality survey and experimental water treatment and to recommend the unit processes in treatment of water for the present proje-t.

Followings are the potential water supply sources for the present project:

- Amparai Tank;
- Kondavattavan Tank
- Kallarachel Anicut;
- Sambuveli Anicut; and
- Kaliodai Anicut.

Water was sampled at these sources and examined of its characteristics and reactions in treatment to find out optimum treatment processes and appropriate dosage. It should be noted, among the above five sources, Amparai Tank is currently used in supplying the service area with water and that "tank" is a terminology to refer to a reservoir or a pond in the country, and "anicut" is for a headwork in a river or a canal.

In this project area, Amparai and the Coastal Area, only two water treatment plants operate and supply the population with drinking water:

- Amparai Water Supply Scheme; and
- Kalmunai Water Supply Scheme.

These existing plants were also visited during the field survey and are duly commented in this Appendix.

The existing shallow well at Naipuddimunai is not dealt with in this study since the yield is limited and its use is scheduled to be ceased.

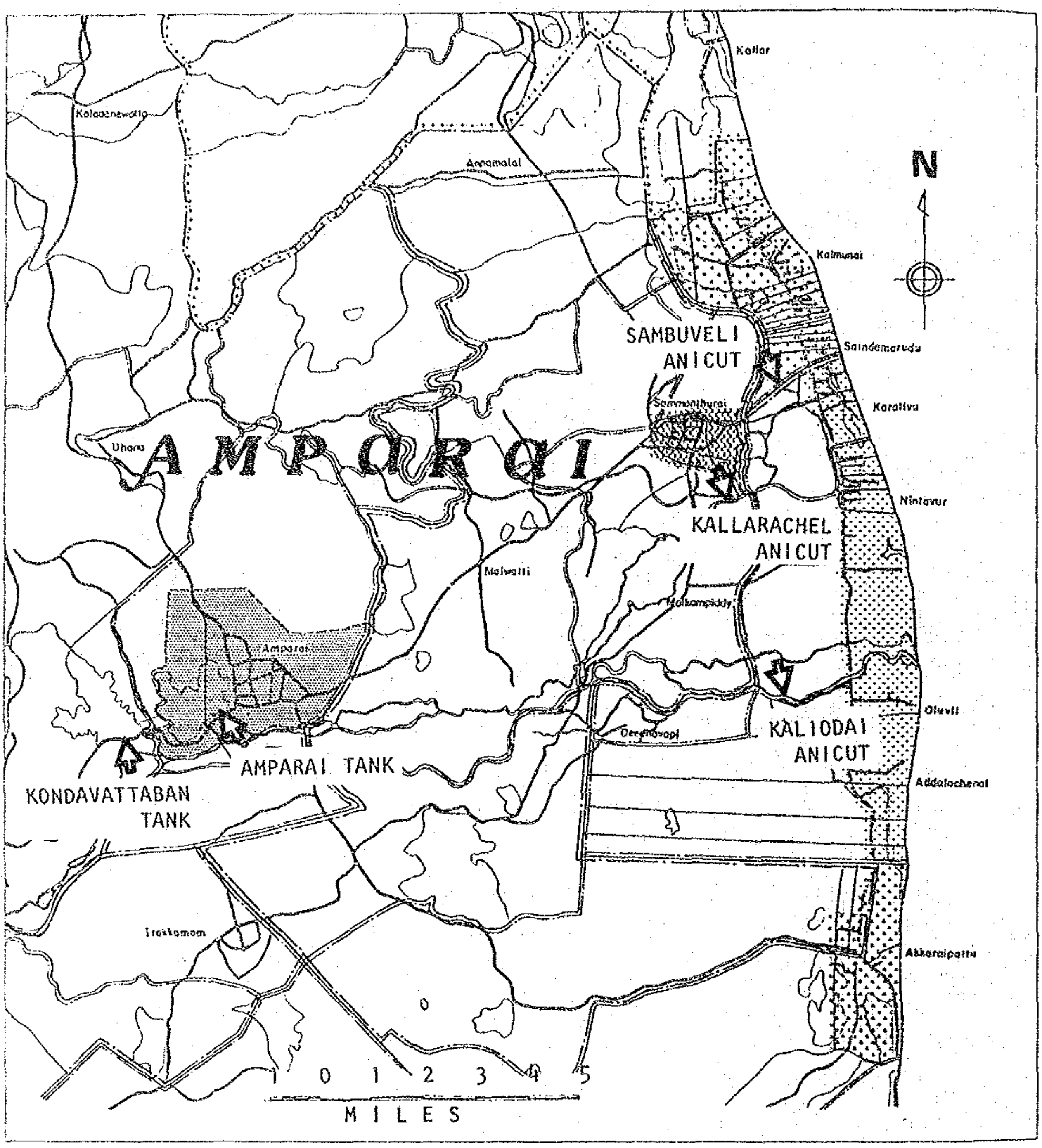


Fig. I LOCATION MAP

REFERENCE

+ + + + + District Boundary

D.R.O's Divison Boundary

Grama Sevaka Division Boundary

Municipal, Urban, Town & Village Council Limits

SAMPLING POINT

Remark

Study Area

KALMUNAI + SAINDAMARUDU

AMPARAI U.C.

AKKARAIPATTU T.C.

SAMMANTHURAI T.C.

Coastal arera–KARATIVU + NINTAVUR

2. Summary

- The present NWSDB Drinking Water Standards is considered appropriate except iron, of which limit should be studied in future if improved level of water quality is practised.

- The eutrophication in Amparai Tank is apparent so that water of the tank has high turbidity, objectionable odour, high pH and colour. Kondavattavan Tank is less eutrophic than Amparai Tank.

- Water quality of Kallarachel, Kaliodai, and Sambuveli Anicuts is within the controllable limit and less objectionable than tank water.

- In treatment of tank water, the dual filtration is recommended; slow sand filtration preceded by coagulation and prefiltration (roughing filtration).

- For anicut water treatment, ordinary rapid sand filtration preceded by coagulation is recommended.

- Improvement of raw water quality in Amparai Tank will be needed. Methods of improvement, i.e., algicide application, floating weeds control, or increasing raw water from Kondavattavan Tank are subject to further studies.

3. Water Quality Standards

This section deals with the water quality standards to be proposed for the present project and the methods of evaluation or a degree of water treatment for the project. Table 3.1 presents the drinking water standards established by the Government of Sri Lanka (hereinafter called "the National Standard") and the WHO International Standards applicable for developing countries for cross-reference. The National Standards was prepared based on the WHO Standards in part and is currently used in Sri Lanka throughout the country to control the quality of drinking water for the municipal and community water supplies.

For turbidity, the National Standards stipulates a less turbid level of requirement than the WHO's. Most of the treated anicut water are within the limit of the National Standards, while the treated tank water exceeds this limit. The WHO Standards may be tentatively applied until the WHO level is constantly achieved.

The limit given to iron contents is less severe than the WHO level. This is interpreted that the presence of iron is prevailing at some of the current water sources in the country and its removal is hardly done at present. Although the current limit is tentatively acceptable, iron presence will become objectionable to the consumers during the course of improvement of water supply conditions. Hence, the upgrading of limit to iron contents should be considered and materialized if the proposed water treatment plant is commissioned.

For other substances, the current levels are considered appropriate.

Table 3.1 Drinking Water Standards

Substances	(Unit)	Sri Lanka NWSDB (Highest desirable level)	Sri Lanka NWSDB (Maximum permissible level)	WHO International Standards (Highest desirable levle)	WHO International Standards (Maximum permissible level)
Chemical Substances					
Total Solids	(mg/l)	500	1,500	500	1,500
Colour (plantinum-cobalt)		5	50	5	50
Turbidity	(JTU)	2	10	5	25
Taste		unobjectionable		unobjectionable	
Odour		unobjectionable		unobjectionable	
Iron (Fe)	(mg/l)	0.3	1.0	0.1	1.0
Manganese (Mn)	(mg/l)	0.1	0.5	0.05	0.5
Copper (Cu)	(mg/l)	1.0	1.5	0.05	1.5
Zinc (Zn)	(mg/l)	5.0	15.0	5.0	15.0
Calcium (Ca)	(mg/l)	75	200	75	200
Magnesium (Mg)	(mg/l)	50	150	30	150
Sulphates (SO_4)	(mg/l)	200	400	200	400
Chlorides (Cl)	(mg/l)	200	600	200	600
pH	–	7.0 - 8.5	6.5 - 9.2	7.0 - 8.5	6.5 - 9.2
Total hardness	(mg/l)	100	500	100	500
Toxic Substances		(Upper limit of concentration)		(Upper limit of concentration)	
Lead (pb)	(mg/l)	0.05		0.1	
Arsenic (As)	(mg/l)	0.05		0.05	
Selenium (Se)	(mg/l)	0.01		0.01	
Chronium (hexaralent) (Cr^{+6})	(mg/l)	0.05		–	
Cyanide (CN)	(mg/l)	0.20		0.05	
Cadmium (Cd)	(mg/l)	0.01		0.01	
Barium (Ba)	(mg/l)	1.00		–	
Phonolic substances	(mg/l)	0.002	–	0.001	0.002
Substances which may affect Health					
Marcury (Hg)	(mg/l)	–		0.001	
Fluorides (F)	(mg/l)	1.5		0.6 - 1.7	
Nitrates (NO_3)	(mg/l)	45		–	
Chemical Indicators of Pollution					
COD	(mg/l)	10		–	
BOD	(mg/l)	6		–	
Total Nitrogen exclusive of NO_3	(mg/l)	1		–	
Ammonia	(mg/l)	0.5		–	
Carbon chloroform extract	(mg/l)	0.5		–	

Bacteriological Standards of NWSDB

Treated Water

a) Throughout the year, 90% of samples should not contain any coliforms in 100 ml;

b) No sample, throughout the year, should contain more than 10 coliforms in 100ml;

c) Any two consecutive samples should not contain more than 10 coliforms in 100 ml.

4. Water Quality Survey

As potential water sources for the present scheme, five sources, i.e. Amparai and Kondavattavan Tanks, and Kallarachel, Sambuveli and Kaliodai Anicuts, were examined of their water quality and estimation of yield. In addition to these proposed sources, the water quality survey also covers the water of Senanayake Samudra, Aligalge and Himidurawa Tanks. Since these three tanks are located upstream in the Gal Oya basin, which includes the potential water sources of the project, it is worthwhile to know their water quality as well as the relationships with the proposed water sources; the water of Senanayake Samudra Tank, located most-upstream, flows down to ocean, passing through the mentioned tanks and anicuts in the basin.

4.1 Water Quality at Tanks

The result of water quality analysis on future water sources is shown in Table 4.1.1 and that on upstream tanks, Senanayake Samudra, Aligalge and Himidurawa Tanks in Table 4.1.2. Past data collected by NWSDB was shown in Table 4.1.3 for Amparai Tank and Table 4.1.4 for Kondavattavan Tank.

1) Amparai Tank

Amparai Tank is a reservoir, whose water now exclusively used for water supply with a capacity of 8.8 million cu m (7,130 acft), surface area of 3.6 sq km (1.4 sq mi), catchment area of 17.0 sq km (6.6 sq mi) and average depth of 2.4 m (7.9 ft).

Amparai Tank water is characterized with:

i) high turbidity;
ii) oversaturation by dissolved oxygen;
iii) high pH;
iv) colour of greeny yellow;
v) low transparency;
vi) musty smell; and
vii) slightly high iron and ammonia nitrogen.

Table 4.1.1 Water Quality Analysis For Tanks of Potential Water Sources

Items	Unit	Amparai Tank		Kondavattavan Tank			
(Sampling Date)		(2 Mar 1982)		(9 Mar 82)		(2 Mar 82)	(9Mar 82)
Water Depth Samples		0^m	0.8^m	0^m	0.8^m	0^m	0^m
Water Temperature	C°	31.0	29.5	31.5	30.5	29.6	30.5
pH		7.6	7.4	8.8	8.6	8.6	8.8
Turbidity	Units	75	100	75	75	33	30
Colour	"	20	20	25	25	15	10
Alkalinity	mg/l	37	35	33	33	33	30
Potassium Permang-anate Consumed	"	55.3	55.3	-	-	37.9	-
Nitate Nitrogen	"	ND	ND	-	-	ND	-
Ammonia Nitrogen	"	0.16	0.16	0.10	0.10	0.10	0.07
Hardness	"	28	27	26	25	26	24
Chloride Ion	"	20	20	18	20	8	8
Phenols	"	ND	ND	-	-	ND	-
Iron	"	0.20	0.25	0.40 (0.10)	0.40 (0.10)	0.15	0.25 (0.10)
Manganese	"	0.02	0.02	0.04	0.05	0.02	0.04
Chronium	"	ND	ND	-	-	ND	-
Copper	"	ND	ND	-	-	ND	-
Coliform Group	Nos/ml	1	0	0	0	9	2
Total Colonies	"	25	37	243	504	62	150
Odour		musty	musty	musty	musty	musty	musty
Dissolved Oxygen	mg/l	8.2	6.8	9.0	8.8	7.0	7.0

Note: ND: Not detected
( ): for Dissolved iron

Table 4.1.2 Water Quality Analysis of Upstream Tanks

Items	Unit	Senanayake Samudra	Aligalga Tank	Himidurawa Tank
	(Sampling Date)	(2 Mar.1982)	(2 Mar.1982)	(9 Mar.1982)
Water Temperature	C°	26.5	30.0	30.5
pH		6.8	7.4	7.6
Turbidity		10	10	20
Colour		5	5	5
Alkalinity	mg/l	38	33	31
Potassium Permanganate Consumed	"	12.0	10.1	-
Nitate Nitrogen	"	ND	ND	-
Ammonia Nitrogen	"	0.08	0.16	0.05
Hardness	"	27	24	26
Chloride Ion	"	7	8	10
Phenols	"	ND	ND	-
Iron	"	0.50	0.20	0.25
Manganese	"	0.03	0.03	0.03
Chromium	"	ND	ND	-
Copper	"	ND	ND	-
Coliform Group	Nos/ml	0	0	0
Total Colonies	"	25	45	150
Dissolved Oxygen	mg/l	-	8.4	7.2

Note: ND: Not detected

Table 4.1.3. <u>Data of Raw Water Quality of Amparai Tank</u>

Items	1980								1981					
	Jan.	Feb.	May	June	July	Aug.	Oct.	Nov.	Jan.	Feb.	Mar.	Apr.	July	Nov.
Turbidity (JTU)	10	60	7.6	9.4	7.2	13.5	30	2.9	4.0	8.4	64	10	6.0	5.8
pH	7.2	7.2	7.0	6.8	6.8	7.2	7.2	6.5	6.8	7.6	6.2	7.6	7.0	6.7
Electric Conduc-tivity	110	135	140	135	142	145	195	135	120	150	120	120	200	120
Chloride Ion	40	14	24	22	22	19	28	18	20	24	12	20	36	18
Alkalinity	40	48	52	32	56	53	65	52	39	58	40	54	56	54
Dissolved Solids	74	90	91	86	89	91	-	89	80	99	69	78	135	79
Nitrates	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT
Nitrites	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT
Free Ammonia	0.35	0.35	0.06	0.08	0.05	0.84	0.12	0.42	0.04	0.25	0.08	-	0.15	-
Albuminoid Ammonia	1.05	0.55	0.18	0.15	0.18	0.76	0.36	0.64	0.15	0.50	0.15	-	0.20	0.40
Iron	0.08	2.4	0.50	0.48	0.70	1.0	0.24	0.32	0.20	0.46	0.40	0.30	0.70	0.40
Colour	15	45	10	15	15	75	28	8	10	25	30	5	10	20

MT: Minute Trace

Source: NWSDB

Unit: in mg/l except turbidity and pH

Table 4.1.4 Data of Raw Water Quality of Kondavattavan Tank

Items	1981								
	14May	25Jun	30Jul	12Aug	4Nov	23Nov	Max.	Min.	Aver.
Turbidity (JTU)	6.9	9.3	9.2	13.5	17.5	22	22	6.9	13.1
pH	6.7	6.8	6.6	6.9	6.8	7.0	7.0	6.6	6.8
Electric Conductivity	90	97	82	90	85	85	97	82	88
Chloride Ion	8	8	9	9	10	9	10	8	9
Alkalinity	54	31	41	48	42	45	54	31	44
Hardness	32	34	32	33	29	32	34	29	32
Dissolved Solids	59	61	51	58	56	55	61	51	57
Nitrates	MT	MT	MT	MT	MT	MT	MT	MT	MT
Nitrates	MT	MT	MT	MT	MT	MT	MT	MT	MT
Free Ammonia	0.08	0.06	0.06	1.12	0.98	-	1.12	0.06	0.46
Albuminoid Ammonia	0.18	0.30	0.15	1.58	1.70	-	1.70	0.15	0.78
Iron	0.70	0.45	0.55	0.90	0.28	0	0.90	0	0.48
Colour	12	12	10	45	70	55	70	10	34

MT : Minute Trace

Unit: in mg/l except turbidity and pH

Source: NWSDB

(i) through (v) are interpreted to be caused by extensive algal blooms due to eutrophication of the tank; (vi) this objectionable odour to consumers is attributed to the presence of some species of Actinomyces and plankton algae (Phormidium and others); (vii) this is considered due to deoxidized iron and nitrogen compounds under anaerobic condition in the sediment on the tank bottom where dissolved oxygen is consumed by decay of salvinia and other plankton algae. These characteristics imply following problems in treatment of this raw water:

i) high rate of alum dosage;
ii) less efficient sedimentation due to light alum flocs;
iii) rapidly increasing loss of head in the filters and clogging by uncoagulated plankton from sedimentation basin; and
iv) high rate of chlorination due to the presence of ammonia nitrogen.

Appropriate unit processes to cope with these problems are discussed in the chapter 5.

2) Kondavattavan Tank

Kondavattavan Tank, located upstream of Amparai Tank, is for irrigation purpose with a capacity of 11.3 million cu m (9,200 acft), brimmed water area of 3.6 sq km (1.4 sq mi), catchment area of 52 sq km (20.3 sq mi) and average depth of 3.1 m (10.2 ft).

The water quality of the tank is almost same as that of the Amparai Tank. Turbidity is at one-third to one-fourth of the Amparai Tank, and problem of eutrophication is not so serious as the Amparai Tank.

It should be noted that the tank is currently subject to the use by human and cattles for bathing. If the tank is used for water supply, it should be protected against such pollution.

3) Other Tanks

Senanayake Samudra Tank is located at the most upstream, functioning as a water source of other downstream irrigation tanks scattered in Amparai area and has a capacity of 950 million cu m (770,000 acft), surface area of 77.9 sq km (30.4 sq mi), catchment area of 995 sq km (388 sq mi) and average depth of 12.2 m (40 ft). The circumference of the tank is preserved as a wildlife sanctuary for wild elephants and other animals.

The water quality of this tank is better than those of the Amparai and Kondanvattavan Tanks. However, the water is coloured light green-yellow with poor transparency of 3m to 5m, and has musty smell and high content of iron of 5 mg/l, which shows the highest value among the five tanks.

The other two tanks, Aliglge and Himidurawa Tanks, are of similar water quality to that of Senanayake Tank.

4.2 Water Quality at Anicuts

The result of water quality analysis at the Kallarachel, Kaliodai and Sambuveli Anicuts which are proposed as future water sources is shown in Table 4.2.1.

As shown in the Table, turbidity, colour, organic matters, iron and coliform group show slightly higher values than the NWSDB Standards. However, these values can be easily contained to acceptable level by the water treatment process of prechlorination, flocculation and sedimentation, and filtration.

Since the field survey was carried out during the dry season in the country, no acute increase of turbidity was observed in any anicut. Rainfall and subsequent runoff usually upsurge turbidity of river water so that maximum turbidity of 1,000 units is assumed for the purpose of water treatment planning.

Table 4.2.1 Water Quality Analysis for Proposed Anicuts

Item	Unit	Kallarachel Anicut		Kaliodai Anicut		Sambuveli Anicut	
	(Sampling Date)	(2 Mar 82)	(16Mar 82)	(2 Mar 82)	(16Mar 82)	(2 Mar 82)	(16Mar 82)
Water Temperature	C°	29	29	33	29	30	29
pH		7.2	7.8	7.4	7.2	7.4	7.4
Turbidity	Degree	25	20	25	25	45	25
Colour	"	10	10	10	20	15	10
Alkalinity	mg/l	52	51	45	48	60	47
Potassium permanganate Consumed	"	23.7	-	23.7	-	23.7	-
Nitrate Nitrogen	"	0.2	-	0.6	-	0.2	-
Ammonia Nitrogen	"	0.10	0.07	0.07	0.05	0.10	0.07
Hardness	"	38	40	34	33	43	36
Chloride Ion	"	13	15	11	12	14	12
Phenols	"	ND	-	ND	-	ND	-
Iron	"	0.85	0.40	1.50	0.60	1.50	0.30
Dissolved Iron	"	-	0.25	-	0.40	-	0.25
Manganese	"	0.03	0.08	0.04	0.04	0.03	0.04
Chronium	"	ND	-	ND	-	ND	-
Copper	"	ND	-	ND	-	ND	-
Coliform Group	Nos/ml	1	0	0	5	0	0
Total Colonies	"	175	806	54	207	154	103
Dissolved Oxygen	mg/l	5.4	6.6	6.2	6.0	6.0	5.0

Note: ND - Not detected

In the meantime, while toxic matters and other objectionable substance to drinking water should be carefully monitored, the problems caused by these substances are not anticipated in the project area due to following reasons:

i) The contents of cyanide, phenols and chronium (Cr^{6+}) originate in industrial wastes. Since there is no factory in the area, the pollution will be hardly experienced.

ii) Sulfate ion is mainly caused by sea water intrusion. An indication of sea water intrusion, chloride iron, is observed at 10 - 15 mg/l level so that anicut water is not influenced by sea water and free of sulfate ion.

iii) Copper, Zinc, Lead, Arsenic, Cadmium and Selenium originate in waste from mines or industries. Since neither mines nor factories discharging these substances exist in the area, such heavy metals will not cause problems to the project.

As for the odour of the raw water of Kallarachel and Sambuveli Anicuts, which have the origin in Kondavattavan Tank, no objectionable odour was detected during the survey. This may be interpreted that the odourous constituents were oxidized by the purification process in river flow.

5. Water Treatment Unit Processes

This chapter is to present the recommendations on water treatment methods for the proposed water supply systems in Amparai and the Coastal areas.

During the field survey, experimental water treatment was carried out on the above sources to identify present and future problems in treatment, to find out an appropriate treatment, and to estimate running costs together with water quality analysis.

Since tank water and anicut water have distinctive characteristics and problems from each other, they are discussed separately in this study. The magnitude of problems may vary tank to tank and anicut to anicut, though the difference is considered insignificant. Thus, the tank water is, for this discussion, represented by Amparai Tank, which is a present water source, while anicut water is represented by Sambuveli anicut. In the meantime, the treated water of both Amparai and Kalmunai treatment plants was also analysed for the purpose of diagnosing the present operation of the plants.

5.1 Tank Water

Amparai Tank water is discussed in treatment for drinking water supply.

5.1.1 Present and future problems of tank water

As described in the Section 4.1 Water Quality of Tank 1) Amparai Tank, the eutrophication is the most serious problem that Amparai Water Supply Scheme faces at present and also in future. This eutrophication causes diverse problems in water treatment:

i) Odour;
ii) Light flocs formed;
iii) High rate of chlorination;
iv) Rapid increasing loss of head filter and eventually short running time; and
v) High rate of alum dosage.

The presence of some species of Antinomyces and plankton algae, Phormidium and others account for the odour of the tank water. The countermeasures will be discussed in succeeding sections.

The raw water contains a great number of plankton algae, which forms major part of flocs. The specific density of such floc is about 1.0, much lighter than ordinary nonorganic flocs of 2.5 to 2.6. Light flocs, failing to settle in the settling basin, may be carried to a filter, where these flocs may rapidly increase loss of head to shorten the running time. Longer detention time in the settling basin will be needed in treatment of light flocs.

Due to the presence of ammonia nitrogen and plankton, the break-point chlorination consumes high dosage of chlorine. This is considered uneconomical so that chlorination for the combined chlorine residual level should be practised. The combined chlorine residual will suffice instead of the free chlorine residual, if the raw water is not contaminated by human or livestock excreta.

Extensive bloom of plankton algae, due to eutrophication of the tank, consume considerable amount of bicarbonate in the water in photosynthesizing. This bicarbonate consumption results in high pH value, which require alum to lower the pH value to appropriate level for flocculation. Since the pH control with acid dosage needs skills and experience, additional dosage of alum is more practical in the project.

5.1.2 Coagulation Test

Coagulation tests were carried out at various dosage rates of aluminum sulfate and sodium chlorite.

1) Amparai Tank

Table 5.1.1 shows results of the coagulation tests on the raw water of Amparai Tank. The problems mentioned in the previous section were identified.

2) Kondavattavan Tank

Table 5.1.2 shows the result of the coagulation test on the raw water of the Kondavattavan Tank. The raw water quality shows almost similar nature to that of the Amparai Tank. The location of this tank, upstream of Amparai Tank, slows the eutrophication than that of the latter, so that the problems in treatment of water are considered still at lower level.

Table 5.1.1 Result of Coagulation Test on Raw Water of Amparai Tank

Item	Unit	Date of Test: 11 March 1982								Date of Test: 24 March 1982							
		Raw Water	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Raw Water	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Water Temperature	°C	30.5								28	29	29	29	29	29	29	29
Aluminium Sulfate Dosage	mg/l	0	50	50	75	75	75	30	40		50	50	50	75	75	75	75
Sodium Chlorite Dosage	mg/l		30	0	30	0	50	30	30		0	0	0	0	0	0	48
(Chlorine Dosage)	mg/l		3	0	3	0	5	3	3		0	0	0	0	0	0	4.8
Aeration Time	min		0	0	0	0	0	0	0		0	2L	5L	0	2L	5L	0
Rapid Mix Time	min		1	1	1	1	1	1	1		1	1	1	1	1	1	1
Slow Mix Time	min		10	10	10	10	10	10	10		10	10	10	10	10	10	10
Coagulation			B	B	A	B	A	D	C		B	B	B	B	B	B	A
Precipitation			C	C	B	C	A	D	C		C	C	C	C	C	C	A
pH		7.0	6.6	6.4	5.8	5.8	5.8	-	-	8.4	6.0	6.0	6.0	5.8	5.8	5.8	5.8
Turbidity	unit	80	42	55	25	30	23	100	75	100	40	40	40	40	40	40	27
Color	unit	30	7	20	5	7	5	-	-	30	-	-	-	15	15	15	10
Alkalinity	mg/l	35	19	18	7	8	7	-	-	36	-	-	-	6	6	6	6
Potassium Permanganate Consumed	mg/l	53.1								-	-	-	-	-	-	-	-
Ammonia Nitrogen	mg/l	0.33	0.33	0.07	0.33	0.07	0.03	-	-	0.50	-	-	-	0.13	0.33	0.10	0.10
Iron	mg/l	0.40	0.10	0.30	0.10	0.15	0.05	-	-	0.50	-	-	-	0.20	0.20	0.20	0.10
Dissolved Iron	mg/l	0.15	0.10	0.15	0.05	0.10	0.05	-	-	0.15	-	-	-	0.10	0.10	0.10	0.10
Manganese	mg/l	0.04	0.04	0.05	0.04	0.04	0.03	-	-	0.06	-	-	-	0.04	0.05	0.04	0.04
Dissolved Manganese	mg/l									-	-	-	-	-	-	-	-
Coliform Group	No/ml	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
Total Colonies	"	720	0	102	0	151	0	-	-	-	-	-	-	-	-	-	-
Residual Chlorine	mg/l	0	0 (0.6)	-	0.2 (0.6)	-	0.3 (0.8)	-	-	-	-	-	-	-	-	-	0 (0.2)
Odour		Musty	Musty	Musty	Musty	Musty	Musty	Musty	Musty								
Taste		-					Musty	Musty									

A: Excellent
B: Good
C: Fair
D: Poor

Table 5.1.2 Result of Coagulation Test on Raw Water of Kondavattavan Tank

Date of Test: 12 March 1982

Item	Unit	Raw Water	Case 1	Case 2	Case 3	Case 4	Case 5
Water Temperature	°C	30.0	30.0	30.0	30.0	30.0	30.0
Aluminium Sulfate Dosage	mg/l		30	50	30	50	30
Sodium Chlorite Dosage	mg/l		30	30	0	0	50
(Chlorine Dosage)	mg/l		3	3	0	0	5
Aeration Time	min		-	-	-	-	-
Rapid Mix Time	min		1	1	1	1	1
Slow Mix Time	min		10	10	10	10	10
Coagulation			B	A	B	B	B
Precipitation			C	C	C	C	C
pH		8.8	7.0	6.2	6.2	6.2	6.8
Turbidity	unit	35	23	23	35	25	25
Color	unit	10	2	2	7	8	2
Alkalinity	mg/l	30	22	13	20	13	23
Potassium Permanganate Consumed	mg/l	-	-	-	-	-	-
Ammonia Nitrogen	mg/l	0.10	0.03	0.03	0.10	0.10	0.03
Iron	mg/l	0.25	0.10	0.10	0.20	0.10	0.10
Dissolved Iron	mg/l	0.10	0.10	0.05	0.10	-	0.10
Manganese	mg/l	0.04	-	-	-	-	-
Dissolved Manganese	mg/l	-	-	-	-	-	-
Coliform Group	No/ml	2	-	-	-	-	-
Total Colonies	"	153	-	-	-	-	-
Residual Chlorine	mg/l	-	0.1(0.2)	0.2(0.3)	-	-	1.5(2.0)
Odour		Musty	Musty	Musty	Musty	Musty	Musty

Note:
A: Excellent
B: Good
C: Fair
D: Poor

5.1.3 Proposed Treatment Methods

The purpose of this section is to discuss the treatment methods which place emphasis on odour removal and efficient settling of light flocs due to eutrophication of tank water, to estimate running costs, and to recommend an appropriate method in treatment of tank water.

1) Discussion on unit processes

Following three systems are considered applicable in treatment of the raw water of Amparai Tank:

- Dual filtration
- Activated Carbon Absorption (powder form)
- Biological Oxidation

They are schematically presented in Fig. 5.1.

i) Dual Filtration

This system is slow sand filtration preceded by flocculation, sedimentation, and prefiltration (roughing filter or rapid filter). Slow sand filtration is considered very effective in odour removal; it also functions in treatment of water containing iron and organic matters. The object of prefiltration is to lighten the load on the slow sand filters and to permit a longer filter run since the turbidity of raw water ranges 75 to 100 units. The flocculation and sedimentation is a pretreatment to prefiltration. Thus, this system will be effective in treatment of highly turbid water containing odour, iron, and organic matters.

ii) Activated Carbon Absorption (powder form)

This method is an application of activated carbon powder to the raw water for removal of odourous constituents from the water. After 15 min - 1 hr carbon contact time, the water is coagulated, filtered, and chlorinated.

This method is effective in removal of odours and some of organic matters but not to iron and ammonium nitrogen removal. Prechlorination will be needed to the water of iron or ammonium nitrogen presence. The cost of activated carbon powder accounts for the expensive running cost of this system.

iii) Biological Oxidation

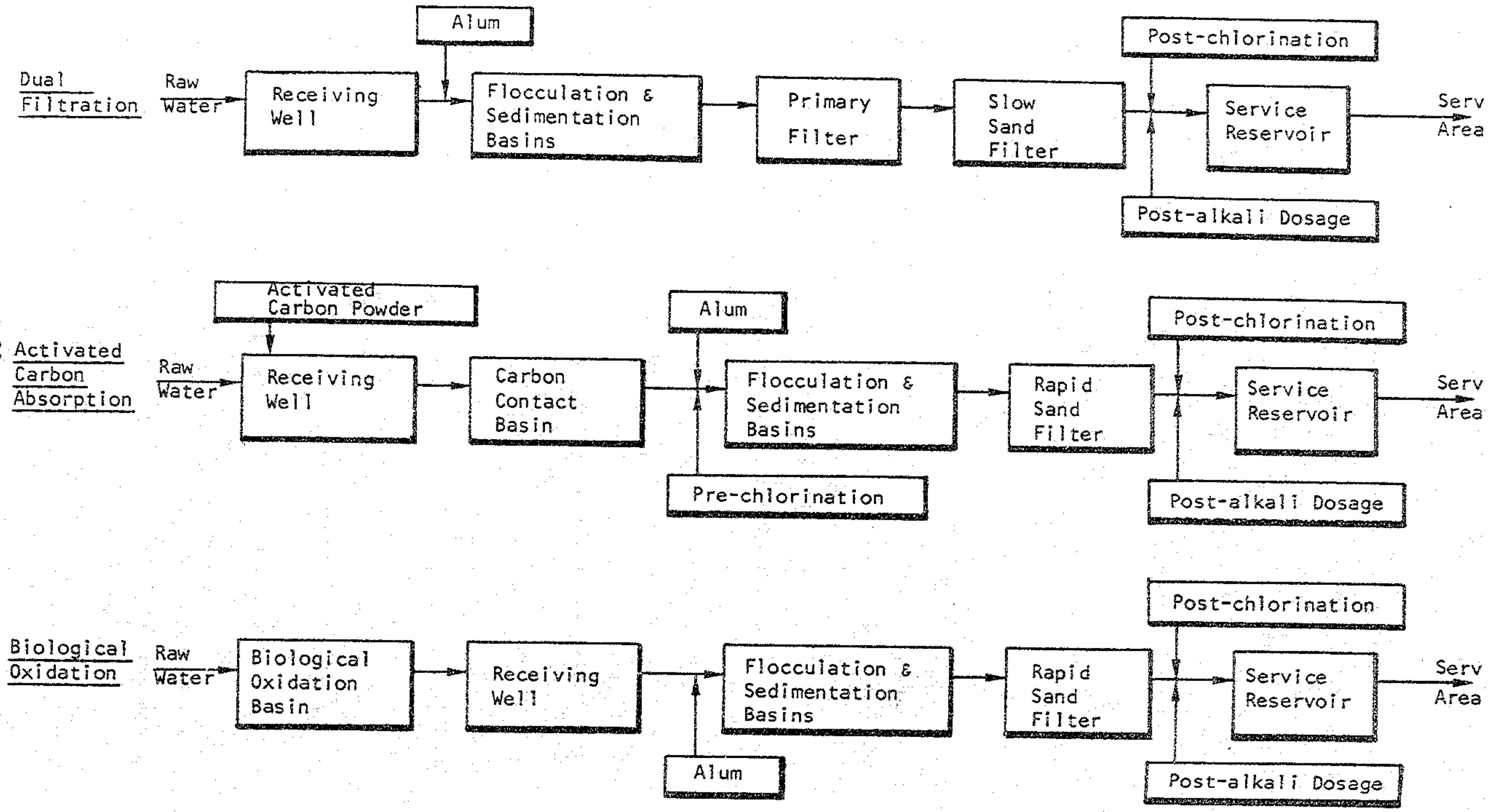
This is an application of the natural purification process observed in rivers or streams. The process is pictured below:

Plastic tubes, designed to produce maximum surface area, are placed in the basin; the basin is constantly aerated and water is circulated; a micro organism grows in laminar on the tube surface with sufficient supply of oxigen. Organic matters and odourous constituent in the water are oxidized by activities of micro organisms.

Although the introduction of this system is rather recent to water supply schemes, operations at several pilot plants show cost effective. The warm climate of the project area is also apparently preferable to the growth and the activity of micro organisms.

In an ordinary practice, this system precedes coagulation and filtration.

Fig. 5.1 Proposed Treatment Methods



2) Dosage

The rates of chemical dosage which is to be applied to the aforementioned three methods are estimated considering the present water quality and future deterioration. Table 5.1.3 is an estimate of chemical dosage.

Table 5.1.3 Estimated Chemical Dosage

(mg/l)

Chemicals	Treatment Methods			
	Dual Filtration	Activated Carbon	Biological Oxidation	Rapid Sand Filtration
Pre Chlorination	-	3 - 10	-	3 - 10
Alum	75*	50 - 90	25 - 45	50 - 90
Post Alkalization	12*	10 - 15		10 - 15
Post Chlorination	1 - 3	0 - 2	0 - 2	0 - 2
Activated Carbon Powder	-	0 - 100	-	-

* Required dosing period: four months a year

For the cost estimate purpose, annual chemical consumption and incurring chemical cost were estimated based on the following assumption:

Table 5.1.4 Chemical Dosage Assumption

(mg/l)

Chemicals	Treatment Methods			
	Dual Filtration	Activated Carbon	Biological Oxidation	Rapid Sand Filtration
Pre chlorination	-	6	-	6
Alum	85*	85	40	85
Post Alkalization	15*	15	6	15
Post Chlorination	2	1	1	1
Activated Carbon Powder	-	55	-	-

* Required dosing period: four months a year

3) Costs

A rough cost estimate was made on capital expenditure and operation and maintenance (O/M) expenditures. The results are shown in Table 5.1.5 by water treatment methods. Rapid sand filtration method is also included for reference purpose.

Table 5.1.5 Construction and Operation & Maintenance Cost

	(Unit)	Dual Filtration	Activated Carbon	Biological Oxidation	Rapid Sand Filtration
Construction Cost	('000 Rs)	46,260	37,270	40,810	36,250
O/M Cost	('000 Rs/yt)	2,596	10,388	2,729	3,282
Unit O/M Cost	(Rs/m3)	1.21	4.82	1.27	1.52
1983 Present Worth of Total Cost*	('000 Rs)	68,361	125,709	64,044	64,192

* Assumption was made as follows:

- 21 yr operation,
- construction completed in the first year.
- production (5,900 m^3/day) is supplied from 1995.
- discounted at 10% per annum.

Apparently the activated carbon powder method marks the highest O/M cost, eventually highest total cost in present worth. Others are in almost similar level of cost.

4) Performance and Maintenance

The performance, technical maintenance requirement, and system flexibility of four methods are compared and tabulated in Table 5.1.6.

5) Conclusion

Considering costs and performance, dual filtration method (slow sand filtration proceeded coagulation and prefiltration) is recommended for treatment of Amparai Tank water.

Table 5.1.6 Performance and Maintenance

Requirements	Dual Filtration	Activated Carbon Powder	Biological Oxidation	Rapid Sand Filtration
Treated water quality	Good and stable	Good but unstable	Fair (less effective in odour removal) but stable	Poor (Odour will be hardly removed.) and unstable
Technical maintenance	Skilled labour not needed, labour intensive in service.	Highest level of engineering required.	No skilled labour needed.	High level of engineering staff required.
System flexibility	High (Able to follow fluctuation of water quality)	Low (Full attendance by staff needed at change of water quality)	Medium	Low (Full attendance by staff needed at change of water quality)
Reputation	Good for odour removal, time-proven	Good for odour removal	Less due to recent introduction	Time - proven

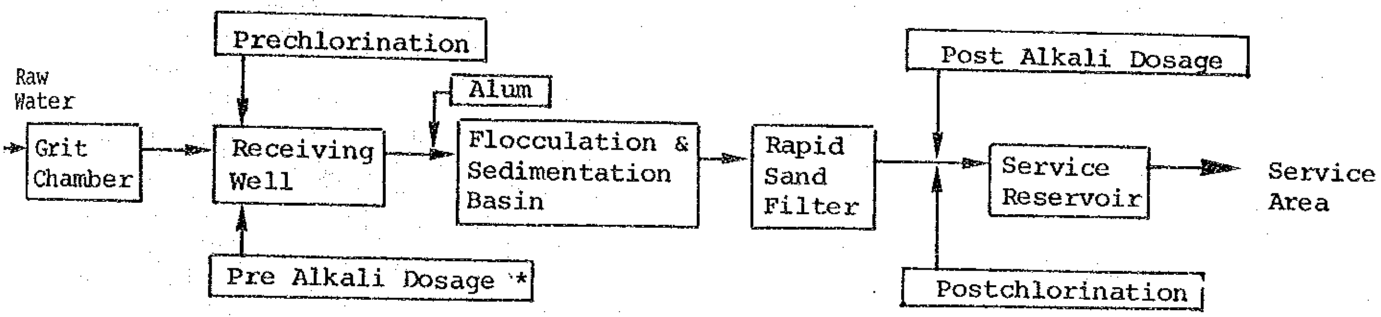
5.2 Anicut Water

Anicut water is characterized with fluctuation of turbidity due to rainfall and high iron contents. The presence of other substances and odour are much less serious than tank water.

Coagulation tests were carried out with three anicut water; the results are tabulated in Table 5.2.2. Table 5.2.3 and 5.2.4 are results of coagulation tests done by NWSDB. These results reveal that three anicuts are of similar water quality and coagulation reaction.

An ordinary rapid sand filtration is recommended in treatment of anikat water. The unit processes are schematically presented below:

Fig 5.2 Flow Chart of Treatment Process, Anicut Water



Note: * for high turbidity

Every unit process is conventional so that particular interpretation is not needed. Each chemical dosage is reasoned:

The prechlorination for oxidation of organic matters, iron and manganese. Break-point chlorination should be practised.

As alkalinity of the raw water is within a range of 40 mg/l- to 50 mg/l, the pre alkali dosage may not be always needed. In case of highly turbid raw water, however, eventual high rate of alum dosage requires pre alkali dosage as a coagulation aid.

The post alkali dosage should be applied for pH control to contain corrosiveness of water to pipe wall.

The postchlorination facility should be provided and practised in supplement the *prechlorination* to keep the residual chlorine at desired level in treated water.

Table 5.2.1 Estimated Chemical Dosages

Rate	Alum	Pre Alkali	Pre Chlorination	Post Alkali	Post Chlorination
Range	20 - 100	0 - 10	1 - 5	5 - 35	0 - 1
Average	30	0	2	10	*

(mg/l)

* As required to keep residual chlorine at 0.5 mg/l.

Table 5.2.2 Results of Water Treatment Test

Item	Unit	Kallarachel Anicut*1						Sambuveli Anicut*2					Kaliodai Anicut*3					
		Raw Water	Case 1	Case 2	Case 3	Case 4	Case 5	Raw Water	Case 1	Case 2	Case 3	Case 4	Raw Water	Case 1	Case 2	Case 3	Case 4	Case 5
Water Temperature	°C	30	30	30	30	30	30	31	31	31	31	31	30	30	30	30	30	30
Aluminium Sulfate Dosage	mg/l	-	20	20	20	30	10		20	20	10	30		20	20	20	30	10
Sodium Chlorite Dosage	mg/l	-	16	32	0	16	16		16	0	16	16		32	16	0	16	16
(Chlorine Dosage)	mg/l	-	1.6	3.2	0	1.6	1.6		1.6	0	1.6	1.6		3.2	1.6	0	1.6	1.6
Aeration Time	min	-	-	-	-	-	-		-	-	-	-						
Rapid Mix Time	min	-	1	1	1	1	1		1	1	1	1		1	1	1	1	1
Slow Mix Time	min	-	10	10	10	10	10		10	10	10	10		10	10	10	10	10
Coagulation		-	B	B	B	A	D		A	B	D	A		B	B	B	B	D
Precipitation		-	B	B	B	A	D		B	B	D	B		C	C	C	C	D
pH		7.2	6.8	6.8	6.8	6.8		7.4	6.8	6.8	-	6.6	7.8	7.0	7.0	7.0	6.8	7.2
Turbidity	unit	25	5	5	10	5	20	20	5	10	20	5	20	5	5	10	5	21
Color	unit	20	7	5	10	7	-	10	2	5	-	2	10	2	2	5	2	7
Alkalinity	mg/l	48	40	38	38	33	-	47	38	39	-	36	51	48	48	48	41	46
Potassium Permanganate Consumed	mg/l	-	-	-	-	-	-	-	-	-	-	-						
Ammonia Nitrogen	mg/l	0.05	0.05	0.02	0.02	0.03	0.02	-	0.07	0.02	0.05	-	0.07	0.05	0.05	0.05	0.05	0.05
Iron	mg/l	0.60	0.10	0.15	0.20	0.15	-	0.30	0.10	0.10	-	0.10	0.40	0.10	0.10	0.15	0.10	0.30
Dissolved Iron	mg/l	0.40	0.08	0.08	0.15	0.08	-	0.25	0.05	0.10	-	0.05	0.25	0.10	0.10	0.10	0.10	-
Manganese	mg/l	0.04	0.04	0.04	0.04	0.04	-	0.04	0.05	0.05	-	0.03	0.08	0.05	0.06	0.04	0.06	0.06
Dissolved Manganese	mg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coliform Group	no/ml	5	0	-	-	-	-	0	0	-	-	-	0	-	-	-	-	-
Total Colonies	"	207	0	-	-	-	-	103	0	-	-	-	806	-	0	-	-	-
Residual Chlorine	mg/l	-	0.1 (0.4)	2.0 (2.5)	-	0.4 (0.6)	-	-	0.3 (0.6)	-	-	0.4 (0.6)	-	1.7 (2.0)	0.4 (0.6)	-	0.4 (0.6)	0.4 (0.6)
Odour								musty	slight -ly musty	slight -ly musty	slight -ly musty	slight -ly musty	musty	slight -ly musty	slight -ly musty	slight -ly musty	slight -ly musty	slight -17 musty

Note: A: Excellent
B: Good
C: Fair
D: Poor

Date of Analysis:
*1 18 March 1982
*2 19 March 1982
*3 17 March 1982

Table 5.2.3 Coagulation Test of Kaliodai Anicut Water (By NWSDB)

Date of Test: 9 Nov.'81

Jar No.	Alum dose p.p.m.	Line dose p.p.m.	Dose p.p.m.	Result of Flocculation	Analysis of settled water				REMARKS
					Colour	Turbidity	pH	Alkalinity ppm.	
1	0	0	0	Raw water	140	60	7.4	63	
2	35	0	0	Minute amt of floc in suspension	15	9.8	6.9	57	
3	40	0	0	Floc settled in 6 min	5	3.4	6.8	55	
4	45	0	0	Floc settled in 5-1/2 min	5	2.6	6.7	53	
5	50	0	0	Floc settled in 6 min	5	3.1	6.6	52	
6	55	0	0	Floc settled in 6 min	5	4.8	6.5	51	
7	42	8	0	Floc settled in 5-1/2 min	5	2.2	6.9	55	
8	42	12	0	Floc settled in 6 min Good flocculation	5	1.8	7.0	56	
9	45	8	0	Floc settled in 5 min	5	1.1	6.8	54	
10	45	12	0	Floc settled in 5-1/2 min	5	1.9	6.9	56	

Best Dosage:-

Alum & 45 p.p.m.
Lime 8 p.p.m.

Total Iron of settled water of Jar No.8 is 0.14 ppm.

Table 5.2.4 Coagulation Test of Kallarachel Anicut Water (By NWSDB)

Date of Test: 5 Dec.'81

Jar No.	Alum dose p.p.m.	Lime dose p.p.m.	Dose p.p.m.	Result of Flocculation	Analysis of settled water				REMARKS
					Colour	Turbidity	pH	Alkalinity ppm.	
1	0	0	0	Raw water	175	98	6.4	27	
2	35	0	0	Minute amt. of floc in suspension	10	12.4	5.6	19	
3	40	0	0	Floc settled in 5 min	5	7.1	5.7	18	
4	45	0	0	Floc settled in 4 min	5	2.4	5.6	17	
5	50	0	0	- do -	5	3.4	5.5	15	
6	42	8	0	Floc settled in 5 min	5	4.9	5.9	21	
7	42	12	0	- do -	5	5.3	6.0	22	
8	45	8	0	Good flocculation Floc settled in 4 min	5	1.9	5.8	20	
9	45	12	0	Floc settled in 4-1/2 min	5	2.7	5.9	21	

Best Dosage:-

Alum & Lime: 45 ppm & 8 ppm

5.3 Existing Water Treatment Plants

There are two water treatment plants operating at present in the project areas; i.e. Amparai and Kalmunai plants. This Section aims to discuss findings of water quality analysis and recommended measures of ' improving present water quality.

1) Amparai Water Supply Scheme

The source of this system is Amparai Tank. Present water treatment consists of prechlorination and sedimentation processes, while pressure filters were abandoned twenty years back due to lack of competent manpower for operation and maintenance. This system will be in use until 1987 when the proposed New Amparai Water Treatment Plant is put into service.

The result of water quality analysis is shown in Table 5.3.2. The findings show high contents of turbidity, colour, ammonia nitrogen, iron, manganese, organic substances and a large number of total colonies of microbes. This result reveals that treated water is not in acceptable conditions. This is attributed to incomplete removal of turbidity, and insufficient chlorination; the current coagulant dosage of 22 mg/l is considered insufficient; mixing flocculation facilities are not provided; the present chlorination rate of 3 mg/l seems below the required level and enough contact time is not provided.

To secure the safe water for human consumption, following improvement is recommended:

Table 5.3.1 Recommended Dosage for Existing Plant

UNIT PROCESSES	CURRENT PRACTICE	RECOMMENDED
Coagulant dosage	22 mg/l	75 mg/l
Prechlorination rate	3 mg/l	5 mg/l
Rapid-mixing	none	To be provided
Flocculation*	none	To be provided

* Installation of baffle walls (around-the-end type hydraulic flocculating facilities) is recommended.

Table 5.3.2 Water Quality Analysis For Amparai W.S.S.

Item		Raw Water			Settled Water		Standpost (800m)	Standpost (2300m)
Sampling Date		3 Mar 1982	10 Mar 1982	24 Mar 1982	3 Mar 1982	24 Mar 1982	3 Mar 1982	3 Mar 1982
Water Temperature	°C	30.5	30.5	28.0	30.5	28.0	29.5	30.6
pH		7.4	7.0	7.4	7.4	6.8	7.2	7.2
Turbidity	degree	150	85	100	45	75	45	42
Colour	"	20	30	30	15	30	15	15
Alkalinity	mg/l	34	35	36	34	30	28	26
Potassium Per-manganate Consumed	"	79.0	53.1	-	44.2	-	41.1	47.4
Nitate Nitrogen	"	ND	-	-	ND	-	ND	ND
mmonia Nitrogen	"	0.27	0.33	0.50	0.23	0.50	-	-
Hardness	"	27	-	28	37	-	34	34
Chloride Ion	"	20	-	20	22	-	21	22
Phenols	"	ND	-	-	-	-	-	-
Iron	"	0.20	0.40 (0.15)	0.50 (0.15)	0.05	0.25 (0.15)	0.05	0.05
Manganese	"	0.02	0.04	0.06	0.02	0.09	0.02	0.02
Chromium	"	ND	-	-	-	-	-	-
Copper	"	ND	-	-	-	-	-	-
Coliform Group	Nos/mg	0	0	-	0	-	0	0
Total Colonies	"	229	720	-	72	-	6	6
Residual Chlorine	mg/l	-	-	-	0.2	-	0.1	0

Note: ND: not detected
( ): for Sissiloved iron

2) Kalmunai Water Supply Scheme

This system has its source in groundwater. Raw water is pumped up from two shallow wells and treated through aeration, slow sand filtration for iron removal and post chlorination for disinfection. The result of water quality analysis is shown in Table 5.3.3.

The quality of treated water meets the applicable standard. However, high contents of chloride of 290 mg/l and total hardness of 350 mg/l suggest influence of saline water. This also implies that the excessive pumping of groundwater will cause further degradation of the water quality in future.

Table 5.3.3 Water Quality Analysis For Kalmunai W.S.S.

Item		Raw Water	Finished Water	Standpost (1600 m)
Date		8 Mar 1982	8 Mar 1982	8 Mar 1982
pH		7.8	8.0	8.0
Turbidity	degree	less than 10	less than 10	less than 10
Colour	"	3	2	3
Alkalinity	mg/l	90	70	72
Ammonia Nitrogen	"	0.67	0.05	0.05
Hardness	"	350	-	-
Chloride Ion	"	290	-	-
Iron	"	1.30	0.10	0.15
Manganese	"	0.15	0.09	0.04
Coliform Group	Nos/ml	0	0	0
Total Colonies	"	21	0	80
Residual Chlorine	mg/l	-	2.0	0.1

6. Improvement of Raw Water Quality

6.1 Introduction

The water quality survey revealed the eutrophication of Amparai Tank is apparent; raw water is colored greeny yellow and highly odourous; transparency is only 0.2 - 0.3 m and Salvinia, one of the species of floating weeds is in bloom on the tank surface. Although the tank and its surrounding are protected at present against both actual and potential contamination sources of human and livestock, the eutrophication in the tank is expected to advance if no further countermeasure is provided.

This chapter deals with the eutrophication control of Amparai Tank in view of technical measures.

6.2 Technical Control Methods

Following methods are considered technically feasible for the eutrophication control of Amparai Tank:

i) application of algicide;
ii) floating weeds control;
iii) increasing raw water introduction from Kondavattavan Tank

Each method is interpreted and evaluated below:

i) Application of algicide

The method is to kill algae or contain growth of algae with sprinkling copper sulphate on the surface of the tank. The ordinary dosage rate of copper sulphate ranges 0.5 to 2.0 mg/l; the algicide-sprinkling may be needed once a month at an appropriate dosage rate of about 1.0 mg/l.

Based on the above assumption, annual requirement of copper sulphate is some 100 tons, which costs approximately Rs 4 million a year.

Adverse effect on fishes is also expected. The tolerance limit of mortality of copper sulphate varies species to species of fish; e.g. 0.14 mg/l for trout, a sensitive one, 0.5 mg/l for gold fish, and 2.0 mg/l for black bass, a durable species.

Thus, this method is considered uneconomical and to have undesirable effect to environment so that the application of copper sulphate should be strictly limited to the control of very acute growth of algae.

ii) Floating Weeds Control

Decay of the floating weeds causes problems in treatment of tank water; e.g. odour is attributable also to the decay of the weeds; the weeds may clog the intake facilities. Therefore, over-growth of the weeds should be contained to the acceptable level; a fence or a screen should be provided for an intake facilities; manual removal of weeds should be made to its over-growth.

iii) Increasing Raw Water

This is an undertaking to increase raw water inflow from Kondavattavan Tank to Amparai Tank to expedite the displacement of tank water. Currently 0.5 m^3/sec raw water is supplied to Amparai Tank and 4.5 m^3/sec is discharged to Moravil Aru from Kondavattavan Tank

The discharge of Kondavattavan tank is currently used for irrigation purpose. Therefore, the allocation of Kondavattavan Tank water is subject to further studies.

Selection of above countermeasures against eutrophication of Amparai Tank depends on further detailed studies.

FACILITIES OF WATER SUPPLY SCHEME

1. Introduction

Appendix-D contains the hydraulic calculation to be basis of determination of dimension for the facilities described in the subsection 7.3 Water Supply Facilities of Stage I Scheme.

2. Hydraulic Calculation

2.1 Amparai Area Water Supply Schemes

1) Flow Rate

Max daily demand	5,300 m^3/d=220.8 m^3/hr=3.68 m^3/min=61.1/sec
Intake/Treatment Flow rate	5,900 m^3/d=245.8 m^3/hr=4.10 m^3/min=68.1/sec

2) Intake Facilities

H.W.L. : 26.67 m M.S.L.

L.W.L. : 25.40 m M.S.L.

a. Intake Bay

Stop plank width B=0.8 m x 8 = 6.4 m

Overflow depth Francis Formula gives the overflow depth H as follows;

$$H = \left(\frac{Q}{1.84B}\right)^{2/3} = 0.47 \text{ m}$$

Overflow velocity : $V_1 = Q/B \cdot H = 0.40$ m/sec

Velocity in Intake Bay : $V_2 = Q/S = 0.03$ m/sec (S: Section)

b. Raw Water Main

Friction loss of main

$$hf = 10.666\, C^{-1.85} D^{-4.87} Q^{1.85} L$$

where : C=130 : Williams & Hazen coefficient

D=0.3 m : Diameter

Q =0.07 m^3/sec : Intake flow rate

L=400 m : Length

hf = 1.35 m

Minor loss of main

$hm = (fi + fb + fv + fe) \times V^2/2g$

where : fi=0.5 : Coefficient of influent loss

fb=0.56 : Coefficient of bend loss

fv=6.00 : Valve loss coefficient

fe=1.0 : Coefficient of effluent loss

hm = 0.41 m

Loss of raw water main

From calculation made in the above subsections, total head loss of raw water main is obtained as follows:

h = hf + hm = 1.76 m

3) Treatment Facilities

a. Mixing Well

Retention time (< 5 min) $T = \frac{V}{Q} = 4.8$ min

G-value $G = \sqrt{\frac{\omega\ Q\ hf}{V\mu}} = 182\ sec^{-1}$

GT-value G.T = 52,416

where : ω : Specific gravity of water

Q : Inflow rate

hf : Total head loss

V : Capacity of mixing well

μ : Viscosity of the fluid

Head loss

Weir 0.5 m

Baffling basin 1.0 m

b. Flocculation Basin

Retention time $T = \frac{V}{Q} = 30.7$ min

G-value $G = \sqrt{\frac{\omega\ Q\ hf}{V\mu}} = 32.4\ sec^{-1}$

Head loss 0.2 m

c. Sedimentation Basin

Retention time	$T = \frac{V}{Q} = 4.1$ hr
Overflow rate	$Wo = \frac{Q}{A} = 0.012$ m/min (A: Surface area)
Froude Number ($\geq 10^{-5}$)	$Fr = \frac{v^2}{gR} = 4.3 \times 10^{-5}$ (R : Hydraulic radius)
Weir load	$\frac{Q}{m} = 245$ $m^3/d/m$ (m: Length of weir)
Head loss	0.5 m

d. Rapid Sand Filter

Filteration rate	Q/A/T = 5.1 $m^3/m^2/hr$
Surface jet pressure (m)	Fixed type 30 m
Surface jet amount (m^3)	24 m^2 x 0.2 m^3/min x 5 min = 24 m^3
Surface jet time (min)	5 min
Backwashing pressure	3.0 m
Backwashing amount (m^3)	24 m^2 x 0.7 m^3/min x 5 min = 84 m^3
Backwashing time (min)	5 min
Head loss	1.2 m

e. Slow Sand Filter

Filtration rate	Q/A/T = 0.19 $m^3/m^2/hr$
Head loss	1.0 m

f. Clear Water Reservoir

Retention time	6 hr
Head loss	3 m

4) Transmission Facilities

a. Flow Rate

	(Daily max.)	(Flow rate)
for existing service reservoir	2,700 m^3/d x 1.0	= 2,700 m^3/d
for proposed elecated tower	2,600 m^3/d x 1.5	= 3,800 m^3/d
Total	5,300 m^3/d	6,600 m^3/d

b. Pipelines

The flow chart and results of hydraulic calculation are shown in Table D.1.

Abbreviations used in the results of calculation are as follows:

(I) - (J)	:	Pipeline from Junction I to Junction J
C	:	A Hazen-Willaims roughness coefficient
D	:	Diameter (mm)
Q	:	Discharge (m^3/day)
I	:	Hydraulic gradient (o/oo)
V	:	Velocity (m/sec)
L	:	Length of each pipeline (m)
HL	:	Head loss of each pipeline (m)
TH	:	Total head loss (m)
HW	:	Dynamic head above sea level (m)
GH	:	Ground height above sea level (m)
H	:	Residual pressure (m)

c. Pump

Capacity of pump station		:	6,600 m^3/d = 458 m^3/min ≒ 0.0764 m^3/sec
Pump head;	static head	:	42.5 m
	pipe loss	:	7.5
	pipe loss around pump	:	3.0
	Total head	:	53.0 m

Number of Pumps	:	3 set (including one stand-by)
Capacity of a pump	:	2.3 m^3/min
Specification of pump	:	2.3 m^3/min x 53 m x 37 kW volute pump (horizontal type)

5) Distribution Facilities

The flow chart and results of hydraulic calculation are shown in Table D.2.

TABLE D.1 HYDRAULIC CALCULATION OF TRANSMISSION MAIN

Amparai Area

STAGE I

I	J	C	D (mm)	Q (m^3/d)	I (%)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	P											
P	1	130	Ø350	6,600	1.87	900	1.7	1.7	0.79	77.5	-	-
1	2	130	Ø250	2,700	1.84	1,800	3.3	5.0	0.64	72.5	-	-
2	3	130	Ø250	3,900	3.63	1,600	5.8	7.5	0.92	70.0	40.0	30.0

FLOW CHART

Q, q : m^3/d
L : m

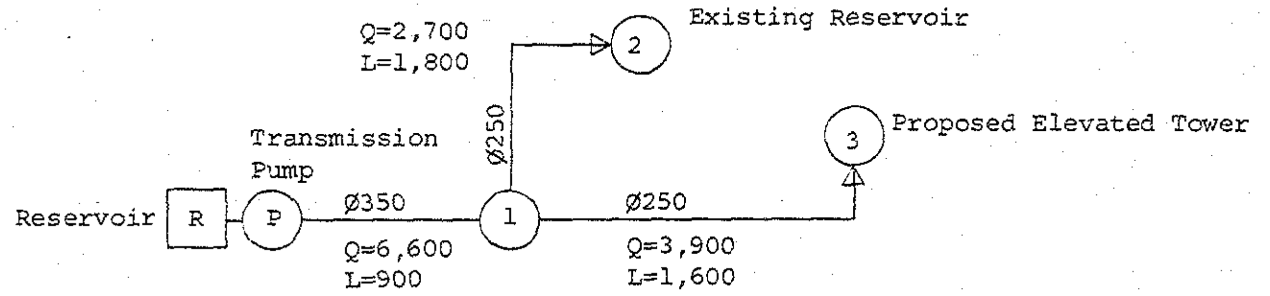


TABLE D.2 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

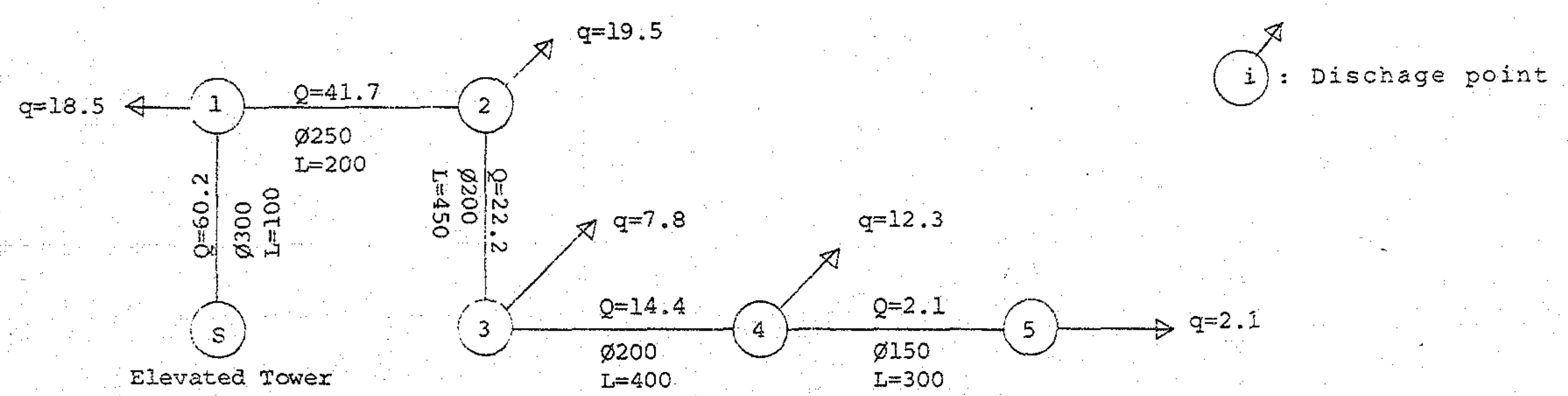
Amparai Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (%)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S							0		65.5	40.0	25.5
S	1	130	Ø300	60.2	2.55	100	0.3	0.3	0.85	65.2	39.0	26.2
1	2	"	Ø250	41.7	3.14	200	0.6	0.9	0.85	64.6	36.0	28.6
2	3	"	Ø200	22.2	2.90	450	1.3	2.2	0.71	63.3	30.0	33.3
3	4	"	Ø200	14.4	1.31	400	0.5	2.7	0.46	62.8	29.0	33.8
4	5	"	Ø150	2.1	0.15	300	0.1	2.8	0.12	62.7	28.0	34.7

FLOW CHART

Q, q : l/s
L : m



2.2 Coastal Area Water Supply Scheme

1) Flow Rate

Max daily demand   22,100 m^3/d=920.8 m^3/hr=15.35 m^3/min=256 l/sec

Intake/Treatment
Flow rate   24,300 m^3/d=1,012.5 m^3/hr=16.88 m^3/min
=281 l/sec

2) Intake Facilities

H.W.L. : 3.0 m M.S.L.

L.W.L. : 0.5 m M.S.L.

a. Intake Bay

Velocity in intake bay   V=Q/S=0.04 m/sec

b. Raw Water Main

Friction loss of main

$$hf = 10.666\ C^{-1.85} D^{-4.87} Q^{1.85} L$$

where : C=130 : Williams & Hazen coefficient

D=0.5 m : Diameter

Q=0.28 m^3/sec : Intake flow rate

L=850 m : Length

hf = 3.09 m

Minor loss of main

$$hm = (fi + fb + fv + fe) \times V^2/2q$$

where : fi=0.5 : Coefficient of influent loss

fb=0.37 : Coefficient of bend loss

fv=6.00 : Valve loss coefficient

fe=1.0 : Coefficient of effluent loss

hm = 0.57 m

Loss of raw water main

From calculations made in the above subsections, total head loss of raw water main is obtained as follows:

$$h = hf + hm = 3.66 \text{ m}$$

3) Treatment Facilities

a. Mixing Well

Retention time	$T = \frac{V}{Q} = 3.5$ min
G-value	$G = \sqrt{\frac{\omega Q hf}{V\mu}} = 214 \text{ sec}^{-1}$
G.T-value	G.T = 44,864
Head loss	
Weir	0.5 m
Baffling basin	1.0 m

b. Flocculation Basin

Retention time	$T = \frac{V}{Q} = 32$ min
G-Value	$G = \sqrt{\frac{\omega Q hf}{V\mu}} = 31.8 \text{ sec}^{-1}$
Head loss	0.2 m

c. Sedimentation Basin

Retention time	$T = \frac{T}{Q} = 3.2$ hv
Overflor rate	$Wo = \frac{A}{Q} = 0.016$ m/min
Froude number	$Fv = \frac{v^2}{gR} = 3.3 \times 10^{-4}$
Weir load	$\frac{Q}{m} = 337 \text{ m}^3/\text{d/m}$
Head loss	0.5 m

d. Rapid Sand Filter

Filtration rate	$Q/A/T = 5.2\ m^3/m^2/hr$
Surface jet pressure (m)	Fixed type 30 m
Surface jet amount (m^3)	$65\ m^2 \times 0.2\ m^3/min \times 5\ min = 65\ m^3$
Surface jet time (min)	5 min
Backwashing pressure (m)	3.0 m
Backwashing amount (m^3)	$65\ m^2 \times 0.7\ m^3/min \times 5\ min = 228\ m^3$
Backwashing time (min)	5 min
Head loss	1.2 m

e. Clear Water Reservoir

Retention	6 hr
Head loss	3 m

4) Transmission Facilities

a. Pump for Sammanthurai

Flow rate : 2,500 m^3/d (Max. daily demand x 1.0)

Capacity of pump station : 2,500 m^3/d=1.74 m^3/min=0.029 m^3/sec

Pump head;	Statical head	: 35.9 m
	Pipe loss	: 3.8 m
	Pipe loss around pump	: 2.3 m
	Total head	: 42.0 m

Number of pump : 2 set (including one stand-by)

Capacity of pump : 1.7 m^3/min

Specification of pump : 1.7 m^3/min x 42 m x 18.5 kW

b. Pump for Coastal

Flow rate

for Karavahu-North and Nintavur

Max. daily demand x 1.5

for Reservoir in booster pump station

Max. daily demand x 1.0

Total 25,750 m^3/day

Capacity of pump station : 25,750 m^3/d = 17.88 m^3/mm
= 0.298 m^3/sec

Pump head;	Statical head	: 35.0 m
	Pipe loss	: 17.7 m
	Pipe loss around pump	: 2.3 m
	Total head	: 55.0 m

Number of pump : 5 sets (including 2 stand-by)

Capacity of a pump : 6.0 m^3/min

Specification of pump : 6.0 m^3/min x 55 m x 90 kW

c. Booster Pump

Flow rate : 10,950 m^3/day (Max. daily demand x 1.5)

Capacity of pump station : 10,950 m^3/d = 7.60 m^3/min
= 0.127 m^3/sec

Pump head;	Statical head	: 27.0 m
	Pipe loss	: 15.7 m
	Pipe loss around pump	: 2.3 m
	Total head	: 45.0 m

Number of pump : 3 sets (including one stand-by)

Capacity of a pump : 3.8 m^3/min

Specification of pump : 3.8 m^3/min x 45 m x 50 kW

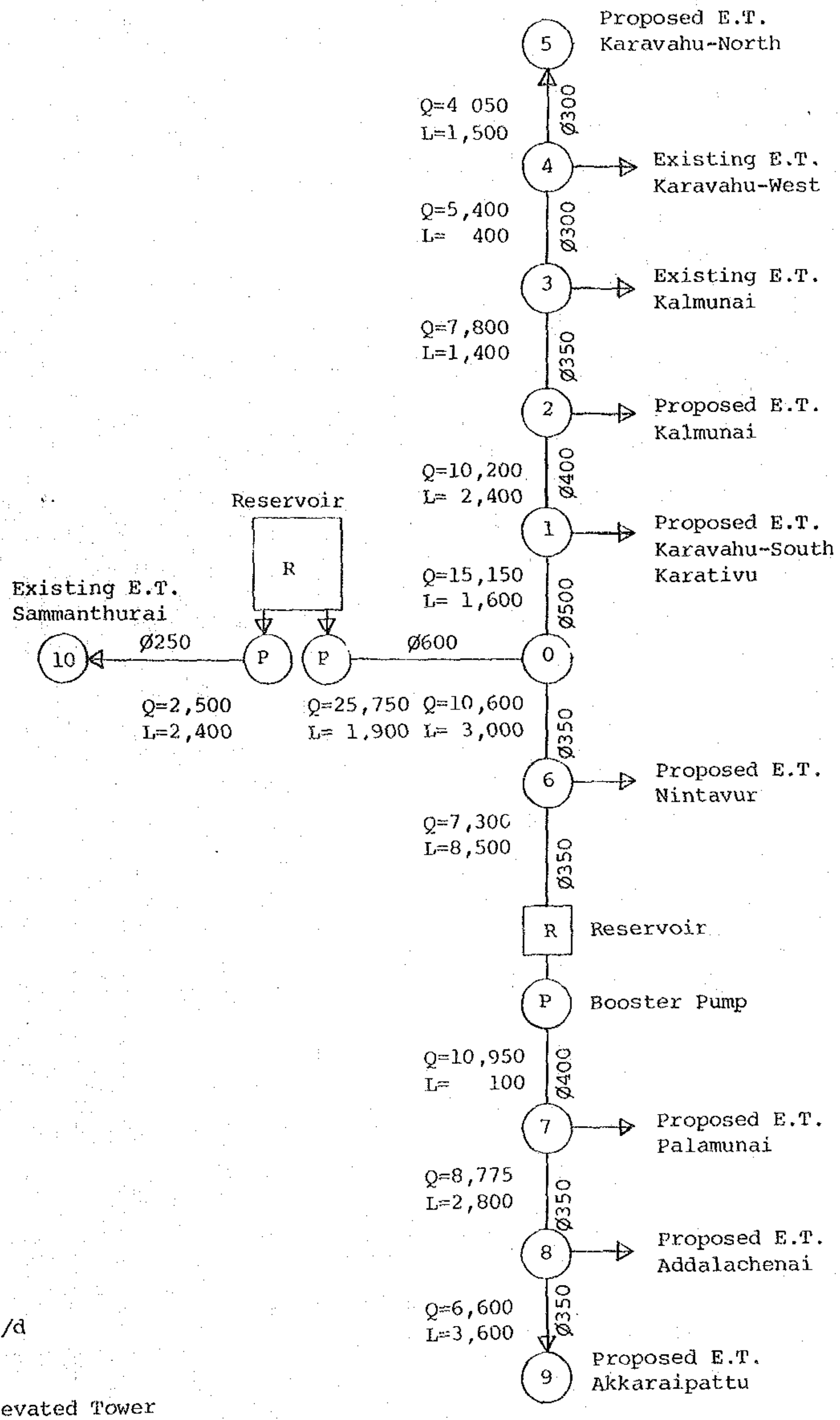
d. Pipelines

The flow chart and results of hydraulic calculation are shown in Fig.D.1 and Table D.3 rspectively.

5) Distribution Facilities

The flow chart and results of hydraulic calculation are shown in Table D.4 to Table D.9.

Fig. D.1 FLOW CHART OF TRANSMISSION MAIN
COASTAL AREA STAGE I



Q : m^3/d

L : m

E.T.: Elevated Tower

TABLE D.3 HYDARAULIC CALCULATION OF TRANSMISSION MAIN

COASTAL AREA

STAGE I

I	J	C	D (mm)	Q(m^3/d)	I (%)	L (m)	HL (m)	TH (m)	V(m/s)	HW (m)	GH (m)	H (m)
	P							0		53.7	-	-
P	0	130	Ø600	25,750	1.68	1,800	3.0	3.0	1.05	50.7	7.0	43.7
0	1	"	Ø500	15,150	1.53	1,600	2.4	5.4	0.89	48,3	7.0	41.3
1	2	"	Ø400	10,200	2.18	2,400	5.2	10.6	0.94	43.1	7.0	36.1
2	3	"	Ø350	7,800	2.54	1,400	3.6	14.2	0.94	39.5	7.0	32.5
3	4	"	Ø300	5,400	2.73	400	1.1	15.3	0.88	38.4	7.0	31.4
4	5	"	Ø300	4,050	1.61	1,500	2.4	17.7	0.66	36.0	6.0	30.0
0	6	130	Ø350	10,600	4.49	3,000	13.5	16.5	1.28	37.2	7.0	30.2
6	R	"	Ø350	7,300	2.25	8,500	19.1	35.6	0.88	18.1	8.0	10.1
	P		-					0		55.7	-	-
P	7	130	Ø400	10,950	2.49	100	0.2	0.2	1.01	55.5	8.0	47.5
7	8	"	Ø350	8,775	3.16	2,800	8.8	9.0	1.06	46.7	9.0	37.7
8	9	"	Ø350	6,600	1.87	3,600	6.7	15.7	0.79	40.0	10.0	30.0
	P									40.7	-	-
P	10	130	Ø250	2,500	1.60	2,400	3.8	3.8	0.59	36.9	18.6	18.3

TABLE D.4 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

Sammanthurai Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (‰)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S									33.8	18.6	15.2
S	1	130	Ø200	24.2	2.73	100	0.3	0.3	0.88	33.5	18.0	15.5
1	2	"	Ø200	16.7	1.71	400	0.7	1.0	0.53	32.8	15.0	17.8
2	3	"	Ø200	11.5	0.86	900	0.8	1.8	0.37	32.0	12.0	20.0
3	4	"	Ø150	3.1	0.31	500	0.2	2.0	0.18	31.8	11.0	20.8

FLOW CHART

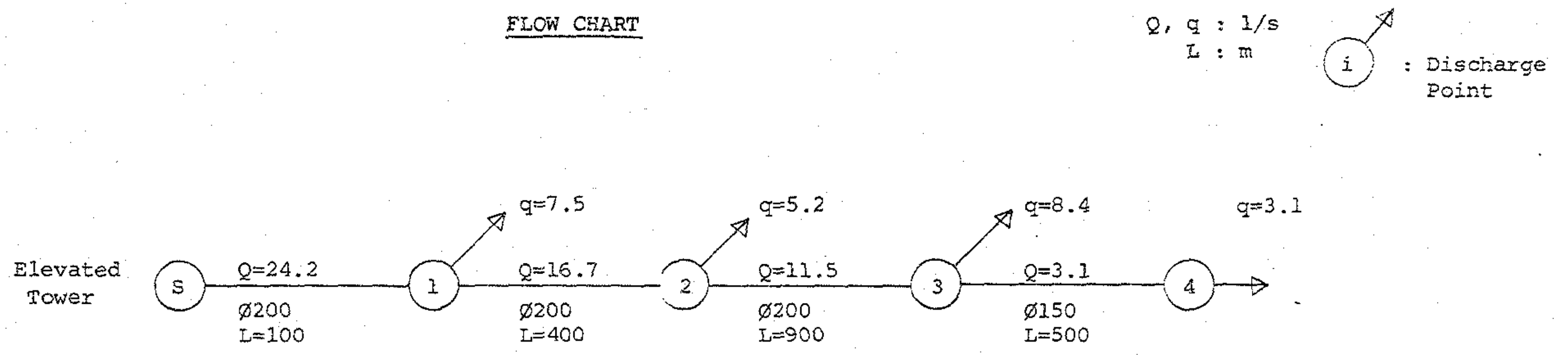


TABLE D.5 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

Kalmunai Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (%)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S									32.5	7.0	25.5
S	1	130	Ø300	23.3	0.44	200	0.1	0.1	0.32	32.4	7.0	25.4
1	2	"	Ø200	23.3	3.16	500	1.6	1.7	0.74	30.8	7.0	23.8
2	3	"	Ø150	12.8	4.23	200	0.8	2.5	0.72	30.0	7.0	23.0
3	4	"	Ø150	7.3	1.51	1,150	1.7	4.2	0.41	28.3	4.0	24.3

FLOW CHART

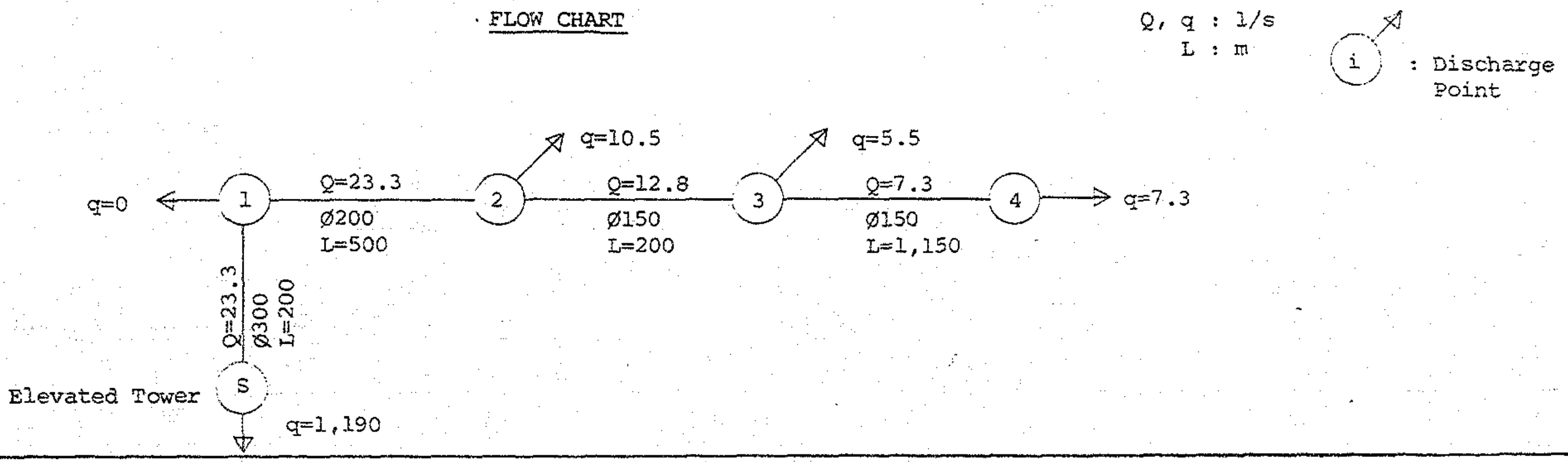


TABLE D.6 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

Karavahu-North Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (‰)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S									31.5	6.0	25.5
S	1	130	Ø300	62.5	2.73	100	0.3	0.3	0.88	31.2	6.0	25.2
1	2	"	Ø250	34.3	2.19	300	0.7	1.0	0.70	30.5	5.0	25.5
2	3	"	Ø200	25.8	3.83	500	1.9	2.9	0.82	28.6	2.0	26.6
3	4	"	Ø200	15.8	1.54	450	0.7	3.6	0.50	27.9	2.0	25.9
4	5	"	Ø150	6.2	1.11	400	0.4	4.0	0.35	27.5	2.0	25.5

FLOW CHART

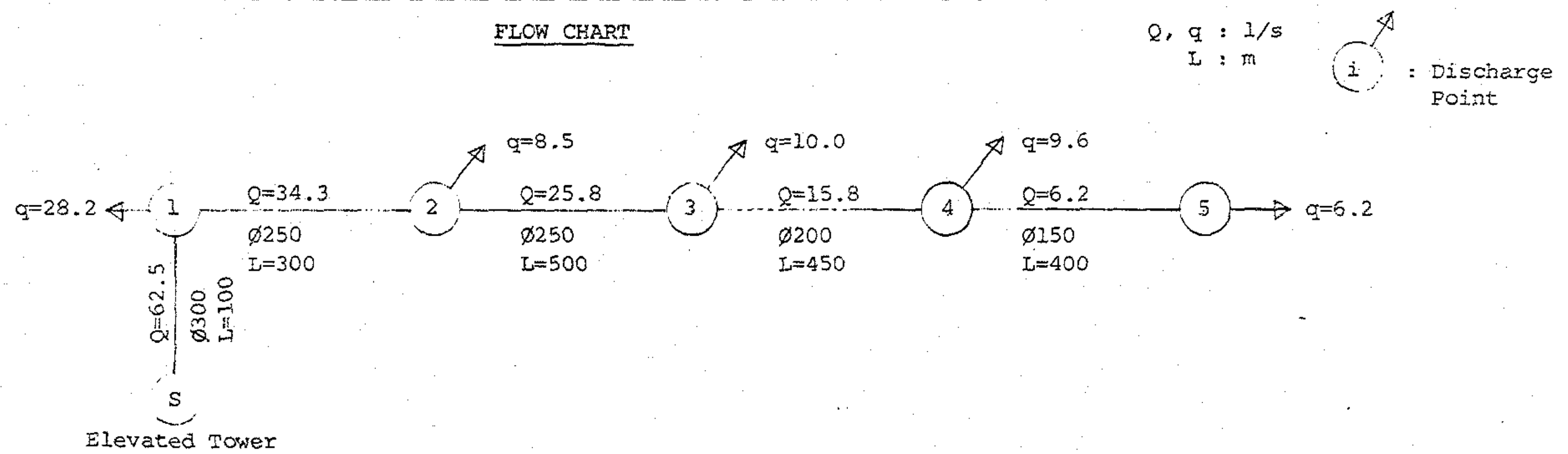


TABLE D.7 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

Karavahu-West Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (%)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S									22.0	7.0	15.0
S	1	130	Ø200	20.9	2.59	650	1.7	1.7	0.66	20.3	7.0	13.3
1	2	"	Ø200	12.5	1.00	350	0.4	2.1	0.40	19.9	7.0	12.9
2	3	"	Ø150	6.6	1.25	300	0.4	2.5	0.37	19.5	7.0	12.5

FLOW CHART

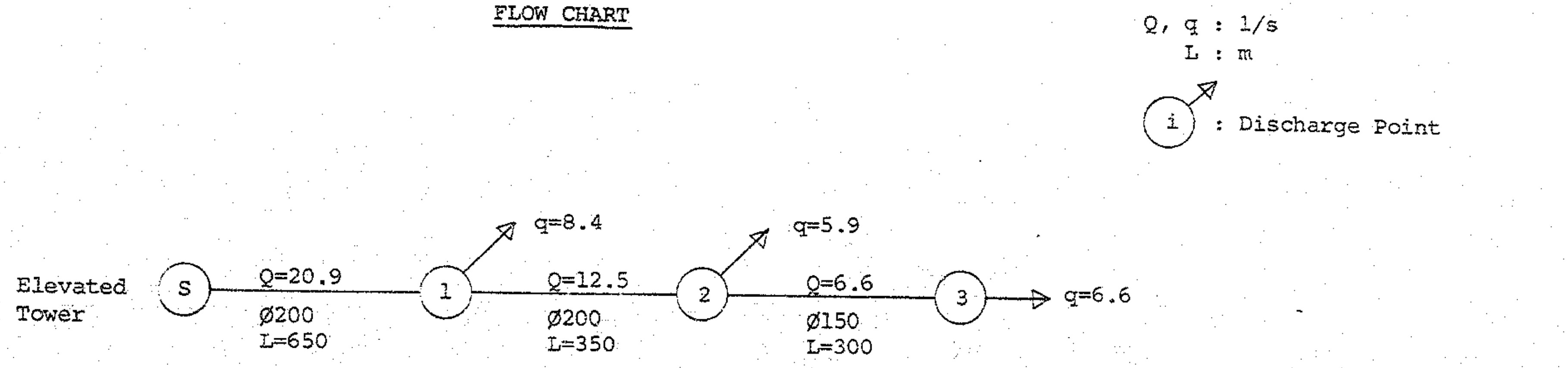


TABLE D.8 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

Karavahu-South, Karativu Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (%)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S									32.5	7.0	25.5
S	1	130	Ø300	76.4	3.96	100	0.4	0.4	1.09	32.1	7.0	25.1
1	2	"	Ø250	51.0	4.56	400	1.8	2.2	1.04	30.3	7.0	23.3
2	3	"	Ø250	38.8	2.74	650	1.8	4.0	0.79	28.5	7.0	21.5
3	4	"	Ø200	22.3	2.93	1,200	3.5	7.5	0.71	25.0	6.0	19.0
4	5	"	Ø200	17.2	1.80	200	0.4	7.9	0.55	24.6	5.0	19.6
5	6	"	Ø150	7.1	1.44	600	0.9	8.8	0.40	23.7	4.0	19.7

FLOW CHART

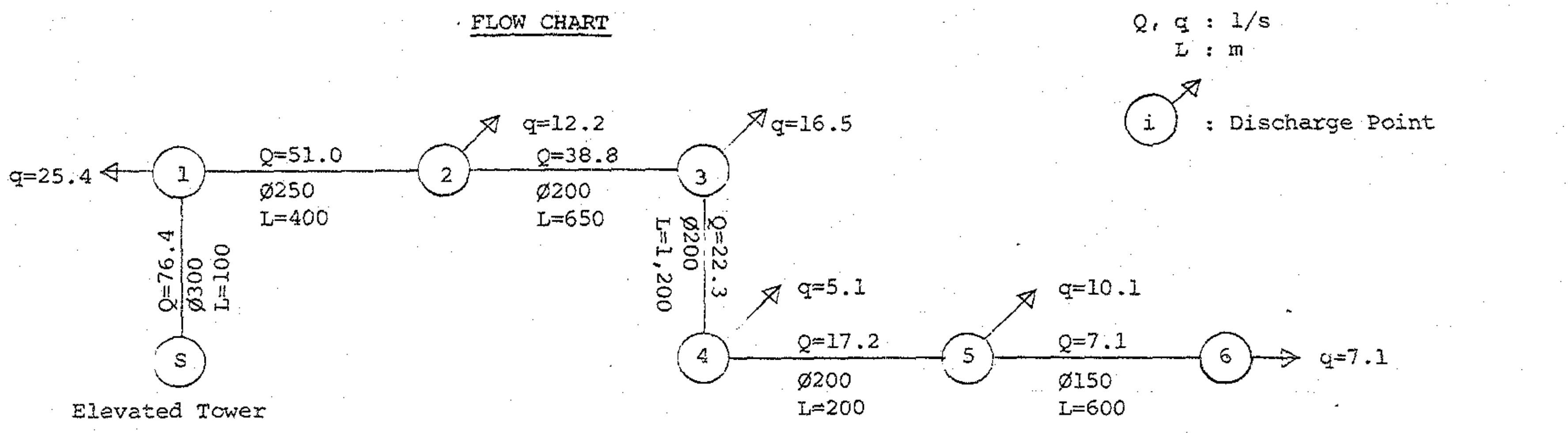


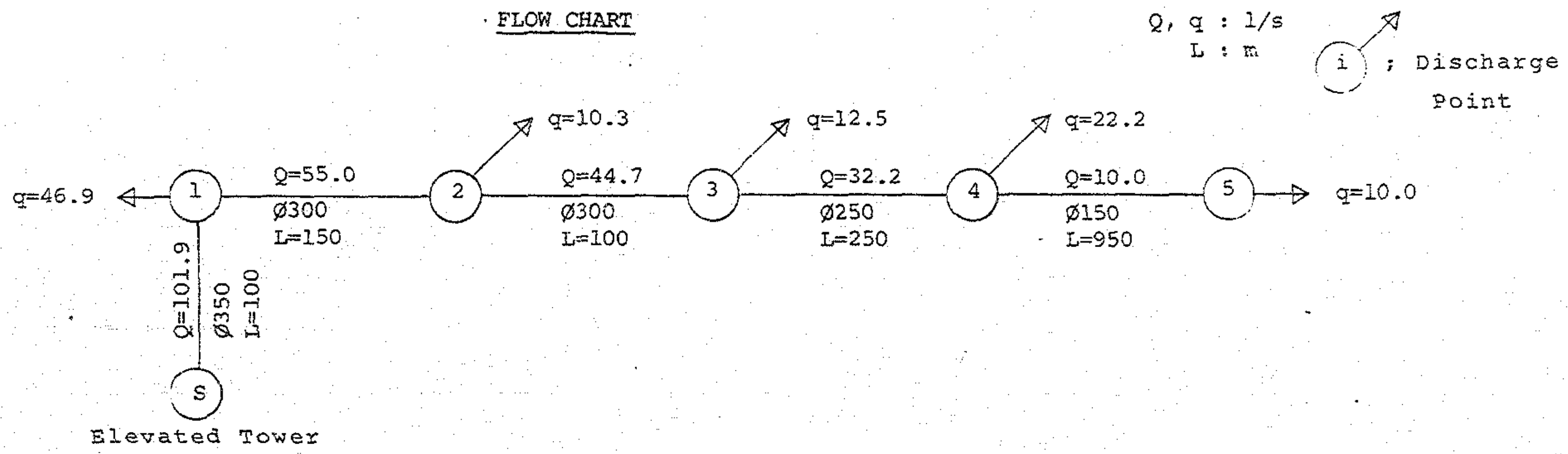
TABLE D.9 HYDRAULIC CALCULATION OF DISTRIBUTION MAIN

Akkaraipattu Area

STAGE I

I	J	C	D (mm)	Q (l/s)	I (%)	L (m)	HL (m)	TH (m)	V (m/s)	HW (m)	GH (m)	H (m)
	S									35.5	10.0	25.5
S	1	130	Ø350	101.9	3.18	100	0.3	0.3	1.06	35.2	10.0	25.2
1	2	"	Ø300	55.0	2.15	150	0.3	0.6	0.78	34.9	9.0	25.9
2	3	"	Ø300	44.7	1.47	100	0.1	0.7	0.63	34.8	9.0	25.8
3	4	"	Ø250	32.2	1.94	250	0.5	1.2	0.66	34.3	8.0	26.3
4	5	"	Ø150	10.0	2.69	950	2.6	3.8	0.57	31.7	7.0	24.7

FLOW CHART



3. Remodelling of the Existing Amparai Treatment Plant

In order to raise the efficiency of sedimentation, the remodelling shall be made for equipping a flocculation process in the existing sedimentation basin by construction of training walls. A conceptual design is shown in Fig. D-2. Specifications of the structures are described as below:

Training Wall

Material	:	Brick
Total length	:	30 meters
Height of wall	:	3.3 meters

Baffle Wall

Material	:	Brick

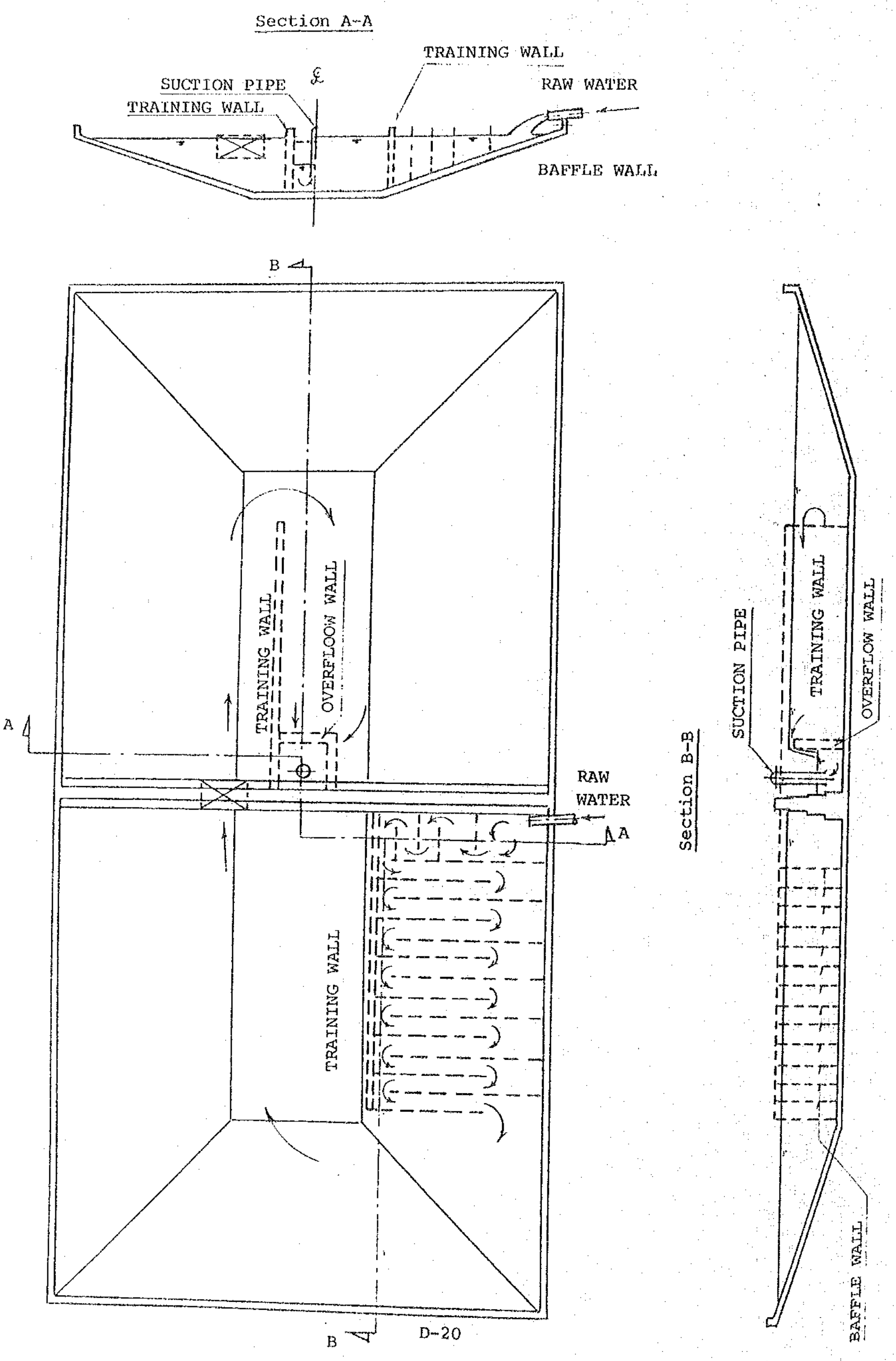
Overflow Wall

Material	:	Brick
Height of top	:	Height of H.W.L.

Chemical Solution Tank

Materials	:	Reinforced concrete
Capacity	:	3.5 m^3 for alum
		0.7 m^3 for slaked lime
		Batch type (one day capacity)
Dosage method	:	Gravity flow

Fig D-2 REMODELLING OF EXISTING AMPARAI TREATMENT PLANT



COST ESTIMATES

1. Introduction

2. Unit Price

3. Cost Estimates for Alternative Schemes

4. Present Worth Calculation

5. Breakdown of Cost Estimates

1. Introduction

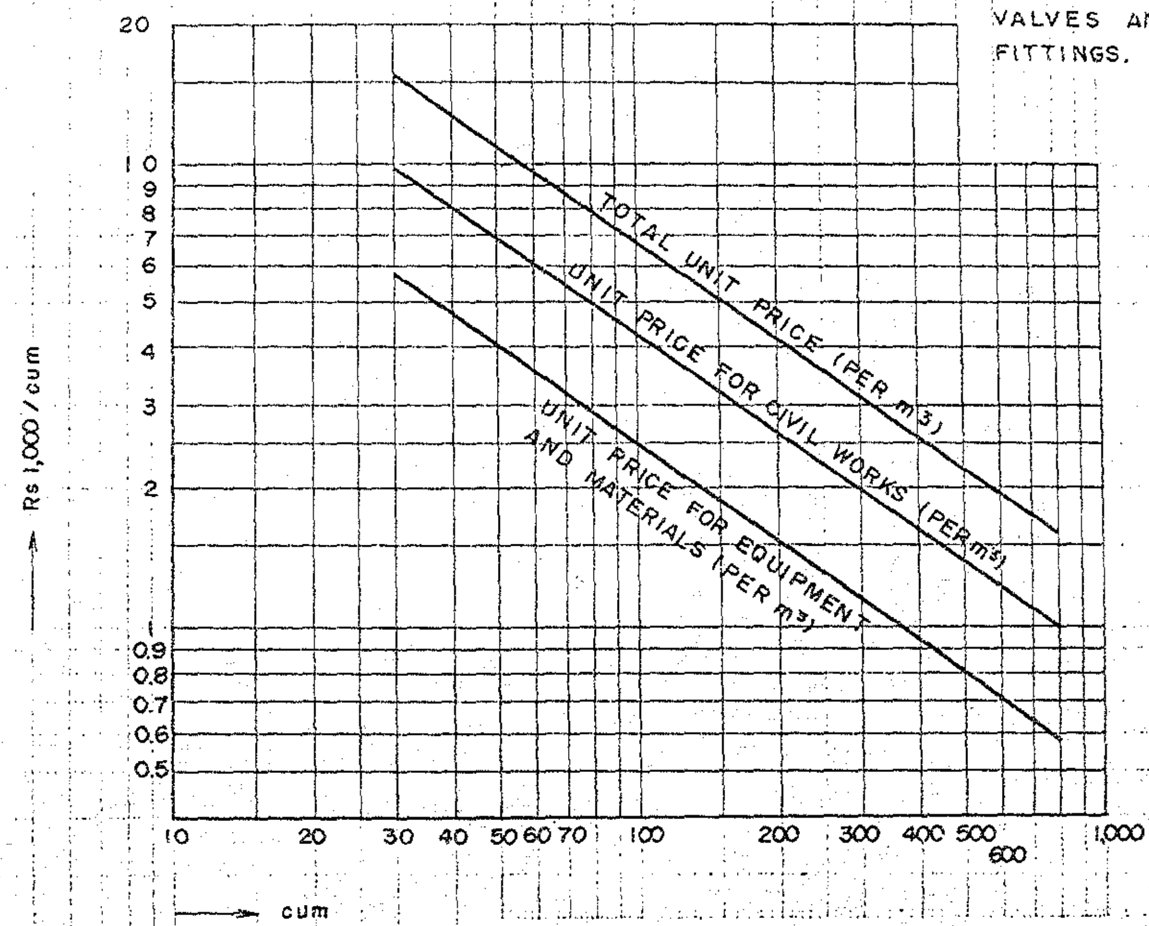
Appendix-D contains the data concerned with the project cost estimates such as the unit prices for labour, construction materials, civil works and pipelaying works as of December 1981,the breakdown of cost estimates for alternative schemes, the present worth calculation for alternative schemes and the breakdown of project cost for Amparai and Coastal areas water supply schemes.

2. Unit Price

Table E-1 UNIT PRICE OF LABOUR AND MATERIALS as of Dec. 1981

Items		Description	Unit		Price
Daily Wages for Labourer					
1. Unskilled worker				Rs	25.-
2. Skilled worker				"	50.-
3. Foreman				"	60.-
4. Carpenter				"	50.-
5. Brick				"	35.-
6. Masonry				"	35.-
7. Driver				"	25.-
Unit Price of Materials for Civil Works					
1. Portland cement		Domestics, 50 kg	bag	Rs	74.-
2. Aggregate		gravel	m^3	"	260.-
		broken stone	"	"	200.-
		sand	"	"	60.-
3. Reinforcement		round bar	kg	"	9.-
		deformed bar	"	"	9.-
4. Timber for scaffolding			m^3	"	3,000.-
5. Plank/board			"	"	3,000.-
Unit Price for Pipe Materials					
1. PVC pipe	50 mm	in dia domestics	m	Rs	45.-
	75 mm		"	"	82.-
	100 mm		"	"	115.-
	150 mm		"	"	220.-
	200 mm		"	"	425.-
	250 mm		"	"	615.-
2. Cast iron pipe	300 mm	in CIF Colombo	"	"	950.-
	350 mm		"	"	1,211.-
	400 mm		"	"	1,381.-
	450 mm		"	"	1,655.-
	500 mm		"	"	1,951.-
	600 mm		"	"	2,615.-

Items	Description	Unit		Price
Civil Works				
1. Concrete inclusive of mixing, placing, vibrating and curing	cement/aggregate ratio 1 : 2 : 4	m^3	Rs	1,500.-
	1 : 3 : 6	"	"	1,100.-
2. Forming work/shuttering		m^2	"	120.-
3. Mortar plastering including mixing and plastering	1 : 3	"	"	30.-
4. Dewatering	by pumps	day	"	240.-
5. Excavation		m^3	"	180.- (items 5–7)
6. Backfilling		"	"	
7. Disposal of excess soil	within 4 km	"	"	
8. Building such as pumping house		m^2	"	1,500.-
9. Restoration costs for pavement (for road crossing)		"	"	200.-
10. Allotment costs of power receiving (500 to 1,000 kW)		LS	"	0.35-0.45/kW



NOTE:

※ CIVIL WORKS INCLUDE EARTH WORKS; FOUNDATION, REINFORCED CONCRETE, SCAFFOLDING AND SO ON.

※ EQUIPMENT AND MATERIALS INCLUDE VALVES AND GATES, PIPES AND FITTINGS.

Fig E-1 UNIT PRICE FOR RECEIVING AND MIXING WELL (AS OF DEC 1981)

NOTE :

※ CIVIL WORKS INCLUDE EARTH WORKS, FOUNDATION, REINFORCED CONCRETE, SCAFFOLDING AND SO ON.

※ EQUIPMENT AND MATERIALS INCLUDE VALVES AND GATES, PIPES AND FITTINGS, AND EXPANSION JOINTS.

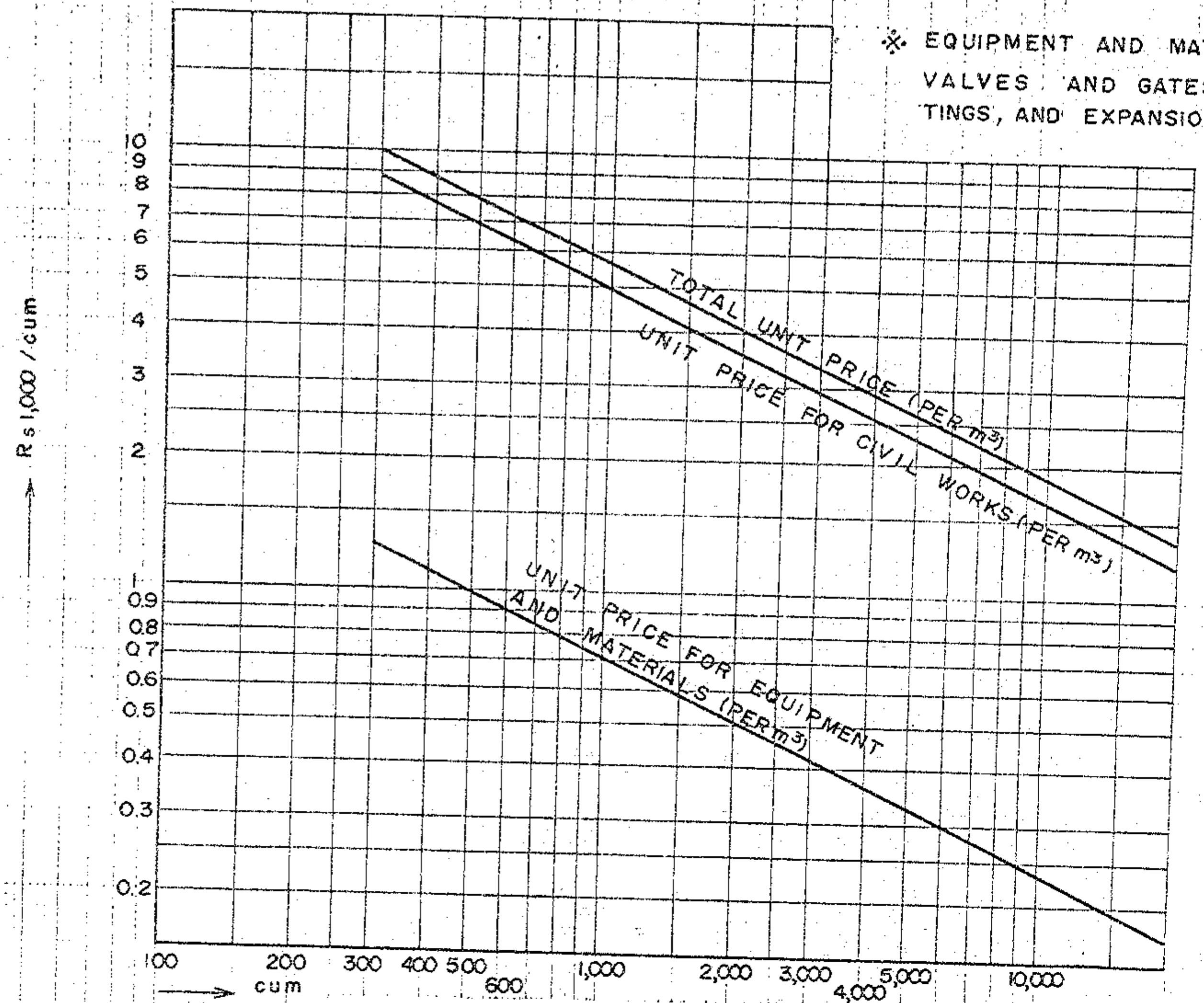


Fig E-2 UNIT PRICE FOR FLOCCULATION AND SEDIMENTATION BASIN (AS OF DEC 1981)

NOTE:

※ CIVIL WORKS INCLUDE EARTH WORKS, FOUNDATION, REINFORCED CONCRETE, SCAFFOLDING AND SO ON.

※ EQUIPMENT AND MATERIALS INCLUDE VALVES AND GATES, PIPES AND FITTINGS AND EXPANSION JOINTS, SURFACE WASH EQUIPMENT, UNDERDRAIN SYSTEM.

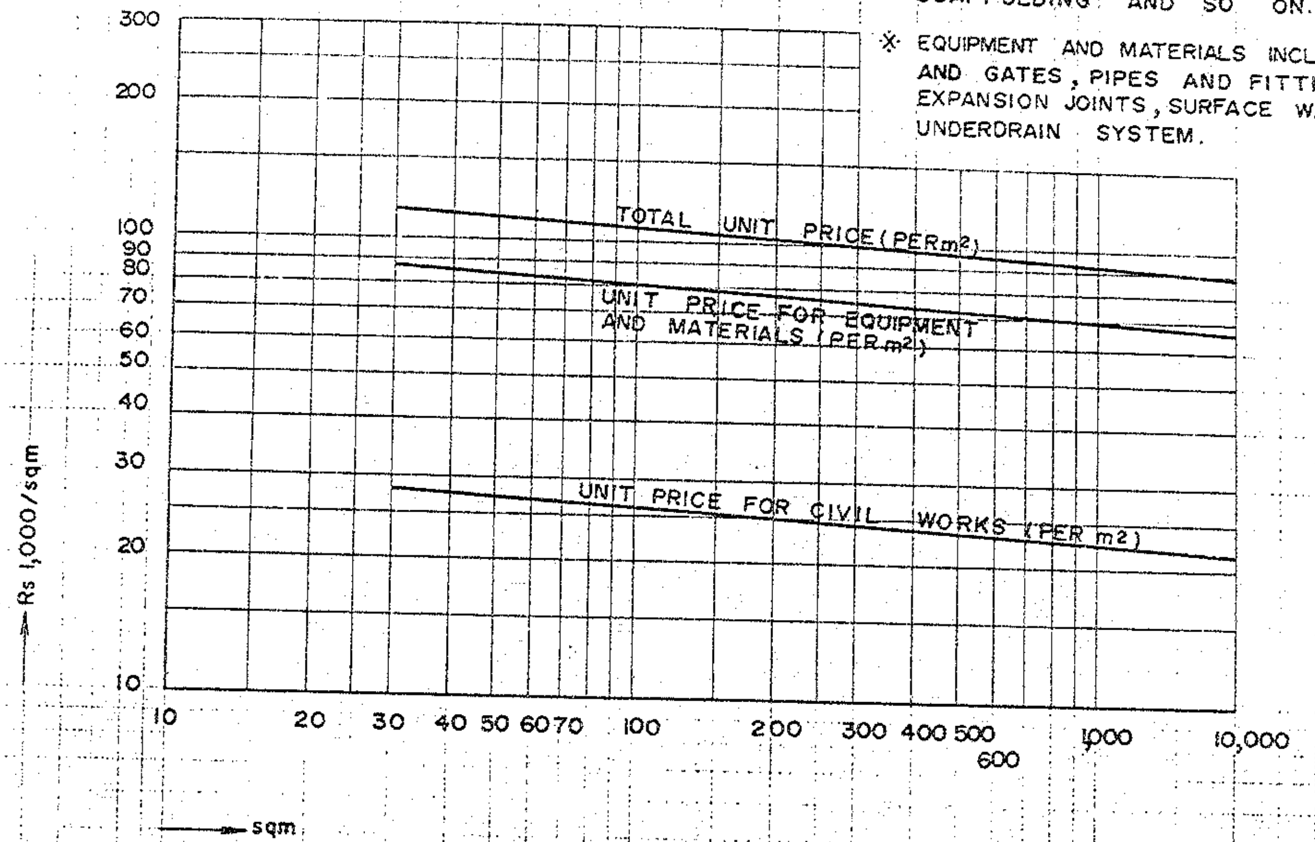
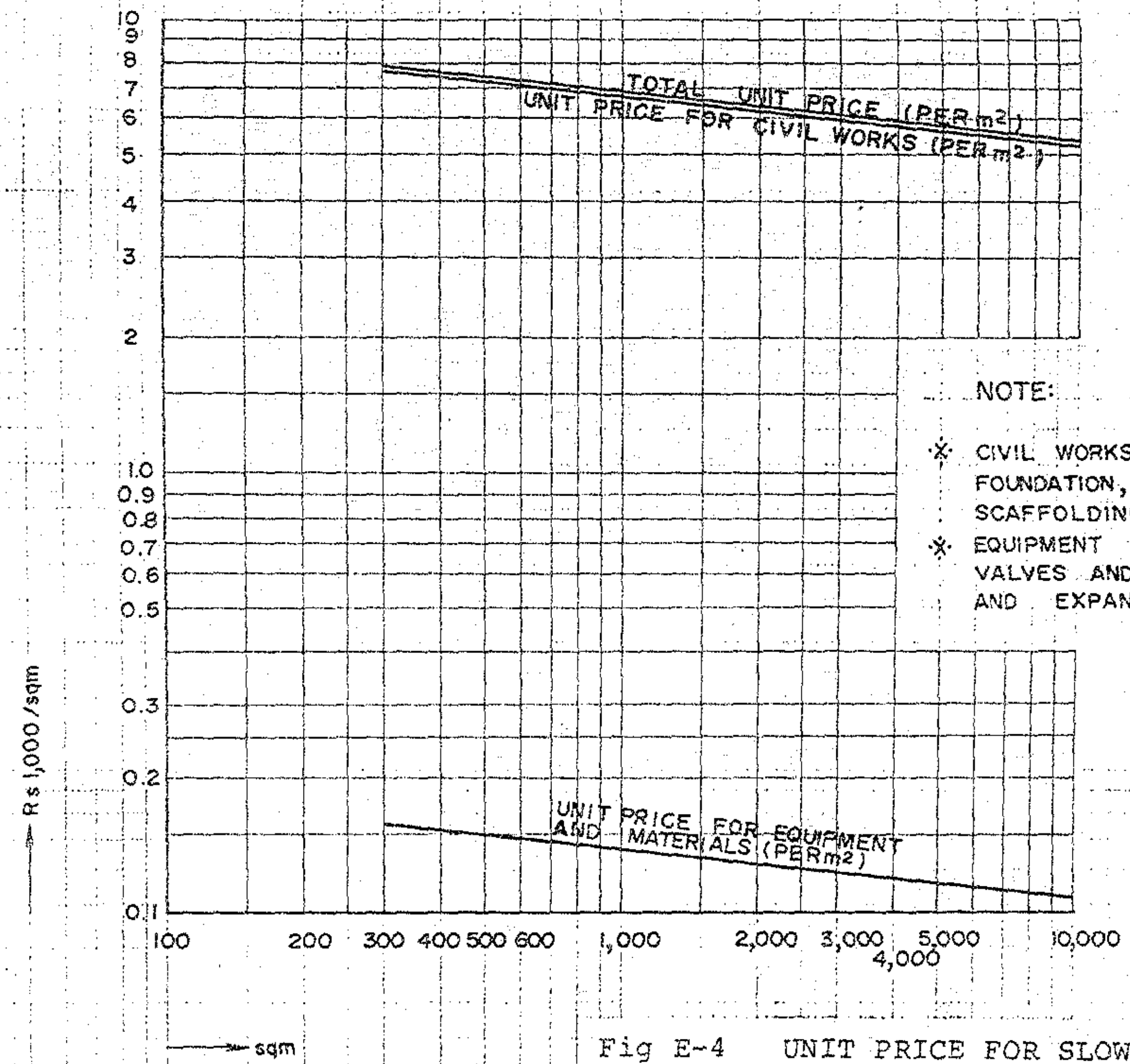


Fig E-3 UNIT PRICE FOR RAPID SAND FILTER (AS OF DEC 1981)

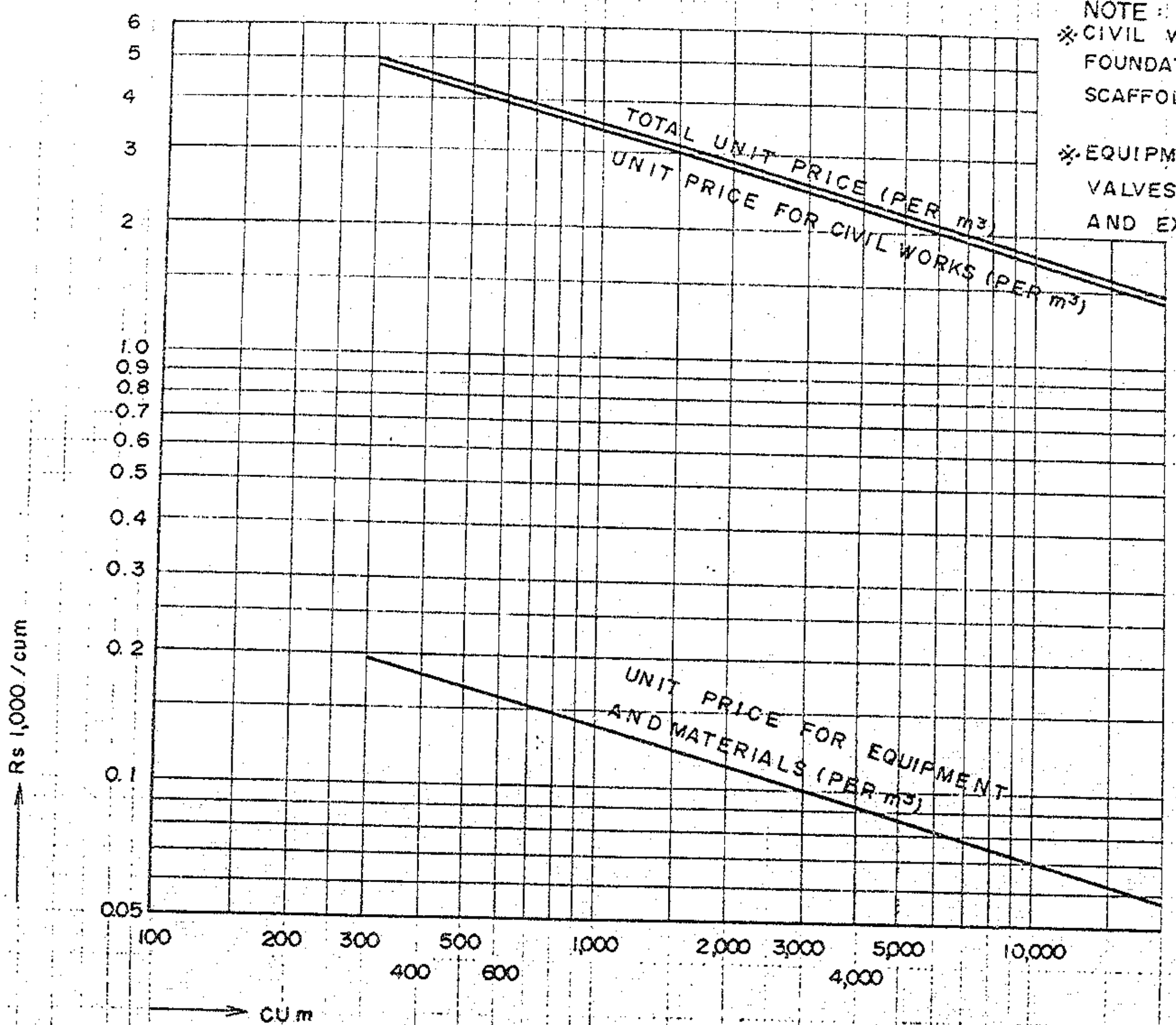


NOTE:

※ CIVIL WORKS INCLUDES EARTH WORKS, FOUNDATION, REINFORCED CONCRETE, SCAFFOLDING AND SO ON.

※ EQUIPMENT AND MATERIALS INCLUDES VALVES AND GATES, PIPES AND FITTINGS AND EXPANSION JOINTS.

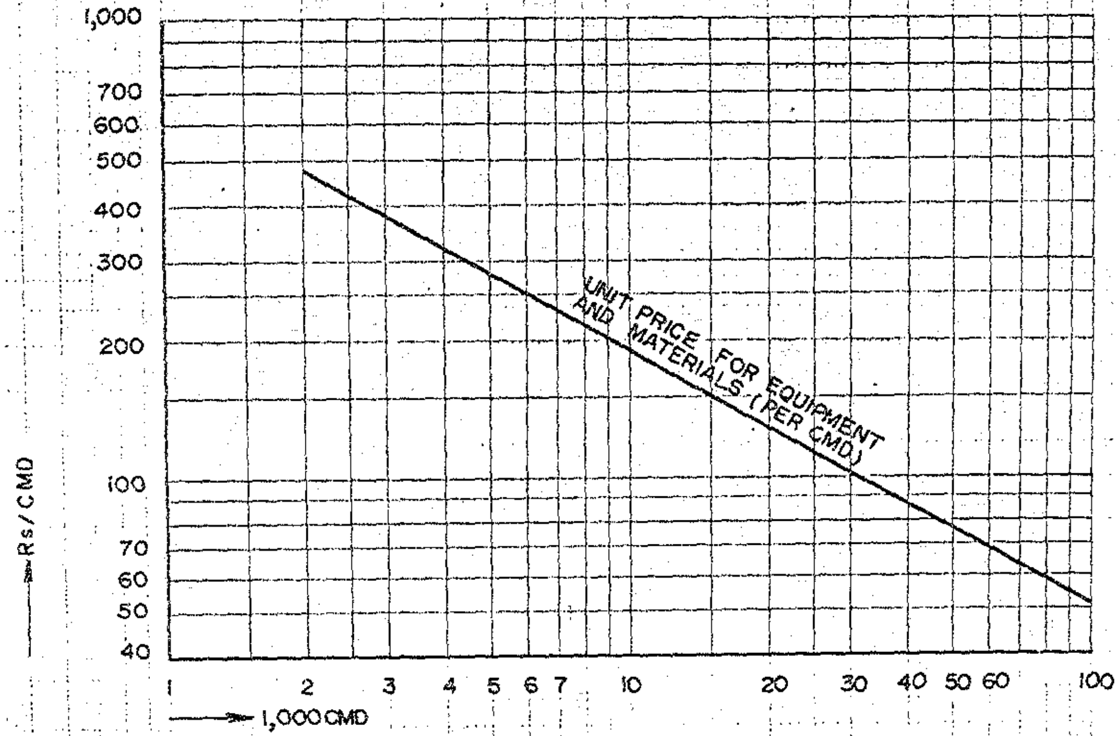
Fig E-4 UNIT PRICE FOR SLOW SAND FILTER (AS OF DEC 1981)



NOTE :
※ CIVIL WORKS INCLUDE EARTH WORKS FOUNDATION, REINFORCED CONCRETE, SCAFFOLDING AND SO ON.

※ EQUIPMENT AND MATERIALS INCLUDE VALVES AND GATES, PIPES AND FITTINGS AND EXPANSION JOINTS.

Fig E-5 UNIT PRICE FOR CLEAR WATER RESERVOIR
(AS OF DEC 1981)



NOTE:

ALUM : SOLUTION TANK AND STORAGE TANK WITH MIXERS FEEDING PUMP AND OTHERS

LIME : STORAGE HOPPER, SOLUTION TANK AND MIXER FEEDING PUMP AND OTHERS

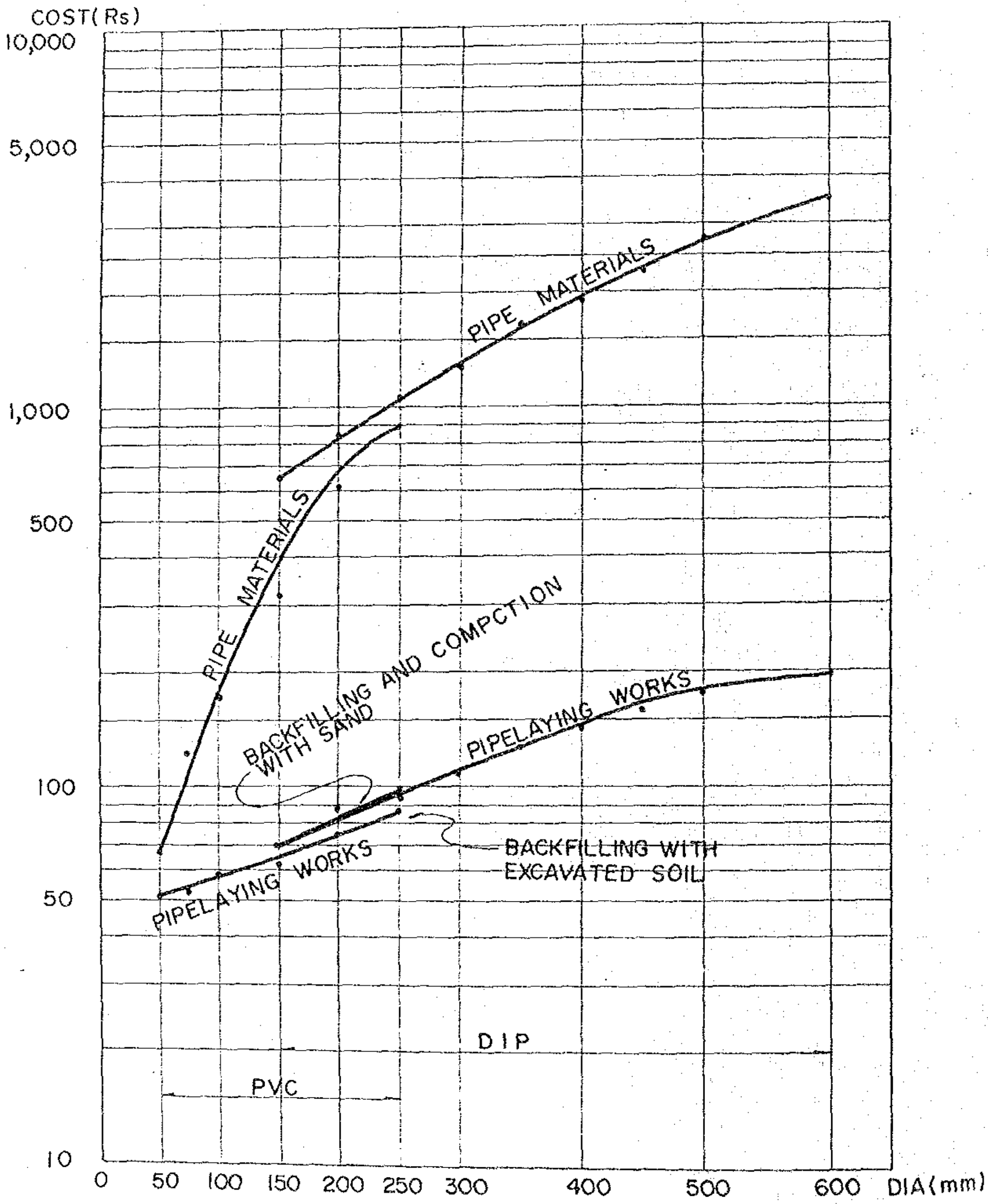
CHLORINE: CHLORINATOR AND ACCESSORIES, CHLORINE CONTAINERS, LEAKAGE CHLORINEGAS DETECTOR AND OTHERS

Fig E-6 UNIT PRICE FOR CHEMICAL FEEDING FACILITIES (AS OF DEC 1981)

Fig E-7 UNIT PRICE OF PIPE MATERIALS AND PIPELAYING WORKS

PIPE MATERIALS : PIPES, FITTINGS, VALVES AND JOINTING MATERIALS

PIPELAYING WORKS : EXCAVATION, BACKFILLING, PIPELAYING, CARRYING PIPEMATERIALS, OVERHEAD AND ESPECIALLY ANCHORAGE CONCRETE WORK FOR PVC



3. Cost Estimates for Alternative Schemes

Table E-2 COST ESTIMATES

FOR ALTERNATIVEE-A

Unit: Rs 1,000

PROGRAMME / DESCRIPTION	STAGE - I F/C	STAGE - I L/C	STAGE - II F/C	STAGE - II L/C	TOTAL F/C	TOTAL L/C
A. Intake Facilities	3,330	840	1,950	270	5,280	1,110
B. Treatment Facilities	11,310	18,720	7,190	21,780	18,500	40,500
C. Transmission Facilities	6,480	960	6,480	930	12,960	1,890
D. Distribution Facilities	6,170	2,630	3,630	3,420	9,800	6,050
E. Materials (Cement, Reinforcement)	6,340	-6,340	7,680	-7,680	14,020	-14,020
F. Land Acquisition Cost	-	-	-	-	-	-
G. Engineering Cost	-	-	-	-	-	-
Sub-Total	33,630	16,810	26,930	18,720	60,560	35,530
H. Duties and Taxes	-	10,000	-	6,800	-	16,800
Sub-Total	33,630	26,810	26,930	25,520	60,560	52,330
I. Physical Contingency	3,360	2,680	2,690	2,550	6,050	5,230
J. Price Contingency	3,010	6,510	2,380	5,930	5,390	12,440
Total	40,000	36,000	32,000	34,000	72,000	70,000
Total Costs	76,000		66,000		142,000	

Table E-3 COST ESTIMATES

FOR ALTERNATIVE-B

Unit: Rs 1,000

PROGRAMME / DESCRIPTION	STAGE - I		STAGE - II		TOTAL	
	F/C	L/C	F/C	L/C	F/C	L/C
A. Intake Facilities	9,260	1,540	7,880	970	17,140	2,510
B. Treatment Facilities	11,310	18,720	7,190	21,780	18,500	40,500
C. Transmission Facilities	6,480	960	6,480	930	12,960	1,890
D. Distribution Facilities	6,170	2,630	3,630	3,420	9,800	6,050
E. Materials (Cement, Reinforcement)	6,340	-6,340	7,680	-7,680	14,020	-14,020
F. Land Acquisition Cost	-	-	-	-	-	-
G. Engineering Cost	-	-	-	-	-	-
Sub-Total	39,560	17,510	32,860	19,420	72,420	36,930
H. Duties and Taxes	-	11,480	-	8,280	-	19,760
Sub-Total	39,560	28,990	32,860	27,700	72,420	56,690
I. Physical Contingency	3,960	2,900	3,290	2,770	7,250	5,670
J. Price Contingency	3,480	6,110	2,850	6,530	6,330	12,640
Total	47,000	38,000	39,000	37,000	86,000	75,000
Total Costs	85,000		76,000		161,000	

Table E-4 COST ESTIMATES

FOR ALTERNATIVE-C

Unit: Rs 1,000

PROGRAMME / DESCRIPTION	STAGE - I		STAGE - II		TOTAL	
	F/C	L/C	F/C	L/C	F/C	L/C
A. Intake Facilities	6,290	1,450	6,290	500	12,580	1,950
B. Treatment Facilities	31,480	30,950	26,180	27,480	57,660	58,430
C. Transmission Facilities	60,920	7,820	58,410	7,360	119,330	15,180
D. Distribution Facilities	31,360	20,650	27,770	22,500	59,130	43,150
E. Materials (Cement, Reinforcement)	13,370	-13,370	13,610	-13,610	26,980	-26,980
F. Land Acquisition Cost	-	60	-	-	-	60
G. Engineering Cost	55,000	2,500	44,000	4,000	99,000	6,500
Sub-Total	198,420	50,060	176,260	48,230	374,680	98,290
H. Duties and Taxes	-	36,660	-	33,540	-	70,200
Sub-Total	198,420	86,720	176,260	81,770	374,680	168,490
I. Physical Contingency	19,830	8,670	17,630	8,180	37,470	16,850
J. Price Contingency	15,740	17,610	14,110	18,050	29,850	35,660
Total	234,000	113,000	208,000	108,000	442,000	221,000
Total Costs	347,000		316,000		663,000	

Table E-5 COST ESTIMATES

FOR ALTERNATIVE-D

Unit: Rs 1,000

PROGRAMME / DESCRIPTION	STAGE - I F/C	STAGE - I L/C	STAGE - II F/C	STAGE - II L/C	TOTAL F/C	TOTAL L/C
A. Intake Facilities	6,380	1,750	6,380	520	12,760	2,270
B. Treatment Facilities	36,410	42,300	28,710	35,720	65,120	78,020
C. Transmission Facilities	50,730	6,750	48,660	6,350	99,390	13,100
D. Distribution Facilities	30,340	15,250	26,640	16,510	56,980	31,760
E. Materials (Cement Reinforcement)	14,430	-14,430	13,310	-13,310	27,740	-27,740
F. Land Acquisition Cost	-	60	-	-	-	60
G. Engineering Cost	55,000	2,500	44,000	4,000	99,000	6,500
Sub-Total	193,290	89,580	167,700	81,060	360,990	170,640
H. Duties and Taxes	-	35,400	-	31,270	-	66,670
Sub-Total	193,290	89,580	167,700	81,060	360,990	170,640
I. Phsycial Contingency	19,330	8,960	16,770	8,110	36,100	17,070
J. Price Contingency	15,380	19,460	13,630	17,830	28,910	37,290
Total	288,000	118,000	198,000	107,000	426,000	225,000
Total Costs	346,000		305,000		651,000	

Table E-6 COST ESTIMATES

FOR ALTERNATIVE-E

Unit: Rs 1,000

PROGRAMME / DESCRIPTION	STAGE - I		STAGE - II		TOTAL	
	F/C	L/C	F/C	L/C	F/C	L/C
A. Intake Facilities	6,780	2,070	6,780	660	13,560	2,730
B. Treatment Facilities	41,480	52,590	30,370	42,410	71,850	95,000
C. Transmission Facilities	50,540	6,750	48,470	6,320	99,010	13,070
D. Distribution Facilities	30,340	15,250	26,640	16,510	56,980	31,760
E. Materials (Cement, Reinforcement)	17,500	-17,500	15,340	-15,340	32,840	-32,840
F. Land Acquisition Cost	-	60	-	-	-	60
G. Engineering Cost	55,000	2,500	44,000	4,000	99,000	6,500
Sub-Total	201,640	61,720	171,600	54,560	373,240	116,280
H. Duties and Taxes	-	38,030	-	32,450	-	70,480
Sub-Total	201,640	99,750	171,600	87,010	373,240	186,760
I. Physical Contingency	20,160	9,980	17,160	8,700	37,320	18,680
H. Price Contingency	16,200	21,270	13,240	19,290	29,440	40,560
Total	238,000	131,000	202,000	115,000	440,000	246,000
Total Costs	269,000		317,000		686,000	

Table E-7 COST ESTIMATES

FOR ALTERNATIVE-F

Unit: Rs 1,000

PROGRAMME DESCRIPTION	STAGE - I		STAGE - II		TOTAL	
	F/C	L/C	F/C	L/C	F/C	L/C
A. Intake Facilities	5,570	1,160	5,570	470	11,140	1,630
B. Treatment Facilities	23,180	26,850	18,310	22,720	41,790	50,270
C. Transmission Facilities	50,540	6,790	49,270	6,540	99,810	13,330
D. Distribution Facilities	30,960	18,510	10,530	10,810	41,490	29,320
E. Materials (Cement, Reinforcement)	11,320	-11,320	8,330	-8,330	19,650	-19,650
F. Land Acquisiting Cost	-	60	-	-	-	60
G. Engineering Cost	55,000	5,000	44,000	4,000	99,000	9,000
Sub-total	176,570	46,750	136,010	36,210	312,580	82,960
H. Duties and Taxes	-	29,620	-	25,120	-	54,740
Sub-total	176,570	76,370	136,010	61,330	312,580	137,700
I. Physical Contingency	17,660	7,640	13,600	6,130	31,260	13,770
J. Price Contingency	13,770	17,990	10,390	13,540	24,610	31,530
Total	208,000	102,000	160,000	81,000	368,000	183,000
Total Costs	310,000		241,000		551,000	

Table E-8 COST ESTIMATES

FOR ALTERNATIVE-G

Unit: Rs 1,000

PROGRAMME DESCRIPTION	STAGE - I		STAGE - II		TOTAL	
	F/C	L/C	F/C	L/C	F/C	L/C
A. Intake Facilities	4,900	1,550	4,900	500	9,800	2,050
B. Treatment Facilities	28,220	35,200	21,010	28,880	49,230	64,080
C. Transmission Facilities	44,890	5,840	42,800	5,630	87,690	11,470
D. Distribution Facilities	30,340	15,250	9,840	7,180	40,180	22,430
E. Materials (Cement, Reinforcement)	13,050	-13,050	10,730	-10,730	23,780	-23,780
F. Land Acquisiting Cost	-	60	-	-	-	60
G. Engineering Cost	55,000	5,000	44,000	4,000	99,000	9,000
Sub-total	176,400	49,850	133,280	35,460	309,680	85,310
H. Duties and Taxes	-	29,950	-	24,440	-	54,390
Sub-total	176,400	179,800	133,280	59,900	309,680	139,700
I. Physical Contingency	17,640	7,980	13,330	5,990	30,970	13,970
J. Price Contingency	12,960	19,220	9,390	13,110	22,350	32,330
Total	207,000	107,000	156,000	79,000	363,000	186,000
Total Costs	314,000		235,000		549,000	

4. Present Worth Calculation

Table E-9 PRESENT WORTH CALCULATION ALTERNATIVE-A

DISCOUNT RATE 8.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST NET	CONSTRUCTION COST PRESENT WORTH	OPERATION AND MAINTENANCE COSTS PERSONNEL	OPERATION	TOTAL	PRESENT WORTH
1983	1.0000	0	0	0	0	0	0
1984	0.9259	8,800	8,148	0	0	0	0
1985	0.8573	56,100	48,097	0	0	0	0
1986	0.7938	11,100	8,812	900	227	1,127	895
1987	0.7350	0	0	1,790	467	2,257	1,659
1988	0.6806	0	0	1,790	499	2,289	1,558
1989	0.6302	0	0	1,790	528	2,318	1,461
1990	0.5835	0	0	1,790	551	2,341	1,366
1991	0.5403	0	0	1,790	593	2,383	1,287
1992	0.5002	0	0	1,890	627	2,517	1,259
1993	0.4632	0	0	1,890	663	2,553	1,183
1994	0.4289	7,700	3,302	1,890	699	2,589	1,110
1995	0.3971	48,700	19,339	1,890	745	2,635	1,046
1996	0.3677	9,600	3,530	1,890	868	2,758	1,014
1997	0.3405	0	0	1,990	960	2,950	1,004
1998	0.3152	0	0	1,990	1,062	3,052	962
1999	0.2919	0	0	1,990	1,168	3,158	922
2000	0.2703	0	0	1,990	1,285	3,275	885
2001	0.2502	0	0	1,990	1,408	3,398	850
2002	0.2317	0	0	1,990	1,542	3,532	818
2003	0.2145	0	0	1,990	1,688	3,678	789
2004	0.1987	0	0	1,990	1,843	3,833	761
2005	0.1839	0	0	1,990	2,008	3,998	735
2006	0.1703	0	0	1,990	2,008	3,998	681
2007	0.1577	0	0	1,990	2,008	3,998	630
SUB TOTAL		142,000	91,228	41,190	23,447	64,637	22,875
TOTAL							114,103

Table E-10 PRESENT WORTH CALCULATION <u>ALTERNATIVE-A</u>

DISCOUNT RATE : 12.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST		OPERATION AND MAINTENANCE COSTS			
		NET	PRESENT WORTH	PERSONNEL	OPERATION	TOTAL	PRESENT WORTH
1983	1.0000	0	0	0	0	0	0
1984	0.8929	8,800	7,857	0	0	0	0
1985	0.7972	56,100	44,723	0	0	0	0
1986	0.7118	11,100	7,901	900	227	1,127	802
1987	0.6355	0	0	1,790	467	2,257	1,434
1988	0.5674	0	0	1,790	499	2,289	1,299
1989	0.5066	0	0	1,790	528	2,318	1,174
1990	0.4523	0	0	1,790	551	2,341	1,059
1991	0.4039	0	0	1,790	593	2,383	962
1992	0.3606	0	0	1,890	627	2,517	908
1993	0.3220	0	0	1,890	663	2,553	822
1994	0.2875	7,700	2,214	1,890	699	2,589	744
1995	0.2567	48,700	12,500	1,890	745	2,635	676
1996	0.2292	9,600	2,200	1,890	868	2,758	632
1997	0.2046	0	0	1,990	960	2,950	604
1998	0.1827	0	0	1,990	1,062	3,052	558
1999	0.1631	0	0	1,990	1,168	3,158	515
2000	0.1456	0	0	1,990	1,285	3,275	477
2001	0.1300	0	0	1,990	1,408	3,398	442
2002	0.1161	0	0	1,990	1,542	3,532	410
2003	0.1037	0	0	1,990	1,688	3,678	381
2004	0.0926	0	0	1,990	1,843	3,833	355
2005	0.0826	0	0	1,990	2,008	3,998	330
2006	0.0738	0	0	1,990	2,008	3,998	295
2007	0.0659	0	0	1,990	2,008	3,998	263
SUB TOTAL		142,000	77,395	41,190	23,447	64,637	15,142
TOTAL							92,537

Table E-11 PRESENT WORTH CALCULATION <u>ALTERNATIVE-B</u>

DISCOUNT RATE 8.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST NET	CONSTRUCTION COST PRESENT WORTH	O&M PERSONNEL	O&M OPERATION	O&M TOTAL	O&M PRESENT WORTH
1983	1.0000	0	0	0	0	0	0
1984	0.9259	9,900	9,167	0	0	0	0
1985	0.8573	62,700	53,755	0	0	0	0
1986	0.7938	12,400	9,844	900	173	1,073	852
1987	0.7350	0	0	1,790	306	2,096	1,541
1988	0.6806	0	0	1,790	327	2,117	1,441
1989	0.6302	0	0	1,790	346	2,136	1,346
1990	0.5835	0	0	1,790	366	2,156	1,258
1991	0.5403	0	0	1,790	388	2,178	1,177
1992	0.5002	0	0	1,890	411	2,301	1,151
1993	0.4632	0	0	1,890	435	2,325	1,077
1994	0.4289	8,900	3,817	1,890	457	2,347	1,007
1995	0.3971	56,100	22,278	1,890	491	2,381	946
1996	0.3677	11,000	4,045	1,890	584	2,474	910
1997	0.3405	0	0	1,990	645	2,635	897
1998	0.3152	0	0	1,990	712	2,702	852
1999	0.2919	0	0	1,990	782	2,772	809
2000	0.2703	0	0	1,990	862	2,852	771
2001	0.2502	0	0	1,990	944	2,934	734
2002	0.2317	0	0	1,990	1,036	3,026	701
2003	0.2145	0	0	1,990	1,135	3,125	670
2004	0.1987	0	0	1,990	1,240	3,230	642
2005	0.1839	0	0	1,990	1,354	3,344	615
2006	0.1703	0	0	1,990	1,354	3,344	570
2007	0.1577	0	0	1,990	1,354	3,344	527
SUB TOTAL		161,000	102,906	41,190	15,702	56,892	20,494
TOTAL							123,400

Table E-12 PRESENT WORTH CALCULATION ALTERNATIVE-B

DISCOUNT RATE 12.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST		OPERATION AND MAINTENANCE COSTS			
		NET	PRESENT WORTH	PERSONNEL	OPERATION	TOTAL	PRESENT WORTH
1983	1.0000	0	0	0	0	0	0
1984	0.8929	9,900	8,839	0	0	0	0
1985	0.7972	62,700	49,984	0	0	0	0
1986	0.7118	12,400	8,826	900	173	1,073	764
1987	0.6355	0	0	1,790	306	2,096	1,332
1988	0.5674	0	0	1,790	327	2,117	1,201
1989	0.5066	0	0	1,790	346	2,136	1,082
1990	0.4523	0	0	1,790	366	2,156	975
1991	0.4039	0	0	1,790	388	2,178	880
1992	0.3606	0	0	1,890	411	2,301	830
1993	0.3220	0	0	1,890	435	2,325	749
1994	0.2875	8,900	2,559	1,890	457	2,347	675
1995	0.2567	56,100	14,399	1,890	491	2,381	611
1996	0.2292	11,000	2,521	1,890	584	2,474	567
1997	0.2046	0	0	1,990	645	2,635	539
1998	0.1827	0	0	1,990	712	2,702	494
1999	0.1631	0	0	1,990	782	2,772	452
2000	0.1456	0	0	1,990	862	2,852	415
2001	0.1300	0	0	1,990	944	2,934	382
2002	0.1161	0	0	1,990	1,036	3,026	351
2003	0.1037	0	0	1,990	1,135	3,125	324
2004	0.0926	0	0	1,990	1,240	3,230	299
2005	0.0826	0	0	1,990	1,354	3,344	276
2006	0.0738	0	0	1,990	1,354	3,344	247
2007	0.0659	0	0	1,990	1,354	3,344	220
SUB TOTAL		161,000	87,128	41,190	15,702	56,892	13,665
TOTAL							100,793

Table E-13 PRESENT WORTH CALCULATION ALTERNATIVE-C

DISCOUNT RATE 8.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST NET	CONSTRUCTION COST PRESENT WORTH	OPERATION AND MAINTENANCE COSTS PERSONNEL	OPERATION	TOTAL	PRESENT WORTH
1983	1.0000	34,000	34,000	0	0	0	0
1984	0.9259	31,900	29,537	0	0	0	0
1985	0.8573	236,600	202,846	0	0	0	0
1986	0.7938	44,500	35,326	1,490	620	2,110	1,675
1987	0.7350	0	0	2,970	1,301	4,271	3,139
1988	0.6806	0	0	2,970	1,398	4,368	2,973
1989	0.6302	0	0	2,970	1,501	4,471	2,817
1990	0.5835	0	0	2,970	1,615	4,585	2,675
1991	0.5403	0	0	2,970	1,735	4,705	2,542
1992	0.5002	0	0	3,080	1,865	4,945	2,474
1993	0.4632	31,000	14,359	3,080	2,008	5,088	2,357
1994	0.4289	29,100	12,480	3,080	2,161	5,241	2,248
1995	0.3971	215,500	85,578	3,080	2,359	5,439	2,160
1996	0.3677	40,400	14,855	3,080	2,614	5,694	2,094
1997	0.3405	0	0	3,190	2,785	5,975	2,034
1998	0.3152	0	0	3,190	2,966	6,156	1,941
1999	0.2919	0	0	3,190	3,160	6,350	1,854
2000	0.2703	0	0	3,190	3,375	6,565	1,774
2001	0.2502	0	0	3,190	3,595	6,785	1,698
2002	0.2317	0	0	3,190	3,835	7,025	1,628
2003	0.2145	0	0	3,190	4,092	7,282	1,562
2004	0.1987	0	0	3,190	4,369	7,559	1,502
2005	0.1839	0	0	3,300	4,665	7,965	1,465
2006	0.1703	0	0	3,300	4,665	7,965	1,357
2007	0.1577	0	0	3,300	4,665	7,965	1,256
SUB TOTAL		663,000	428,981	67,160	61,349	128,509	45,225
TOTAL							474,206

Table E-14 PRESENT WORTH CALCULATION <u>ALTERNATIVE-C</u>

DISCOUNT RATE 12.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST NET	CONSTRUCTION COST PRESENT WORTH	O&M COSTS PERSONNEL	O&M COSTS OPERATION	O&M COSTS TOTAL	O&M COSTS PRESENT WORTH
1983	1.0000	34,000	34,000	0	0	0	0
1984	0.8929	31,900	28,482	0	0	0	0
1985	0.7972	236,600	188,616	0	0	0	0
1986	0.7118	44,500	31,674	1,490	620	2,110	1,502
1987	0.6355	0	0	2,970	1,301	4,271	2,714
1988	0.5674	0	0	2,970	1,398	4,368	2,479
1989	0.5066	0	0	2,970	1,501	4,471	2,265
1990	0.4523	0	0	2,970	1,615	4,585	2,074
1991	0.4039	0	0	2,970	1,735	4,705	1,900
1992	0.3606	0	0	3,080	1,865	4,945	1,783
1993	0.3220	31,000	9,981	3,080	2,008	5,088	1,638
1994	0.2875	29,100	8,366	3,080	2,161	5,241	1,507
1995	0.2567	215,500	55,313	3,080	2,359	5,439	1,396
1996	0.2292	40,400	9,259	3,080	2,614	5,694	1,305
1997	0.2046	0	0	3,190	2,785	5,975	1,223
1998	0.1827	0	0	3,190	2,966	6,156	1,125
1999	0.1631	0	0	3,190	3,160	6,350	1,036
2000	0.1456	0	0	3,190	3,375	6,565	956
2001	0.1300	0	0	3,190	3,595	6,785	882
2002	0.1161	0	0	3,190	3,835	7,025	816
2003	0.1037	0	0	3,190	4,092	7,282	755
2004	0.0926	0	0	3,190	4,369	7,559	700
2005	0.0826	0	0	3,300	4,665	7,965	658
2006	0.0738	0	0	3,300	4,665	7,965	588
2007	0.0659	0	0	3,300	4,665	7,965	525
SUB TOTAL		663,000	365,691	67,160	61,349	128,509	29,827
TOTAL							395,518

Table E-15 PRESENT WORTH CALCULATION <u>ALTERNATIVE-D</u>

DISCOUNT RATE 8.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST NET	CONSTRUCTION COST PRESENT WORTH	OPERATION AND MAINTENANCE COSTS PERSONNEL	OPERATION	TOTAL	PRESENT WORTH
1983	1.0000	33,900	33,900	0	0	0	0
1984	0.9259	31,800	29,444	0	0	0	0
1985	0.8573	236,000	202,332	0	0	0	0
1986	0.7938	44,300	35,167	2,000	624	2,624	2,083
1987	0.7350	0	0	4,000	1,311	5,311	3,904
1988	0.6806	0	0	4,000	1,407	5,407	3,680
1989	0.6302	0	0	4,000	1,512	5,512	3,473
1990	0.5835	0	0	4,000	1,627	5,627	3,283
1991	0.5403	0	0	4,000	1,746	5,746	3,104
1992	0.5002	0	0	4,150	1,879	6,029	3,016
1993	0.4632	29,900	13,849	4,150	2,023	6,173	2,859
1994	0.4289	28,100	12,052	4,150	2,177	6,327	2,714
1995	0.3971	208,000	82,600	4,150	2,373	6,523	2,590
1996	0.3677	39,000	14,340	4,150	2,633	6,783	2,494
1997	0.3405	0	0	4,300	2,801	7,101	2,418
1998	0.3152	0	0	4,300	2,985	7,285	2,297
1999	0.2919	0	0	4,300	3,181	7,481	2,184
2000	0.2703	0	0	4,300	3,396	7,696	2,080
2001	0.2502	0	0	4,300	3,620	7,920	1,982
2002	0.2317	0	0	4,300	3,860	8,160	1,891
2003	0.2145	0	0	4,300	4,119	8,419	1,806
2004	0.1987	0	0	4,300	4,398	8,698	1,728
2005	0.1839	0	0	4,440	4,697	9,137	1,681
2006	0.1703	0	0	4,440	4,697	9,137	1,556
2007	0.1577	0	0	4,440	4,697	9,137	1,441
SUB TOTAL		651,000	423,684	90,470	61,763	152,233	54,264
TOTAL							477,948

Table E-16 PRESENT WORTH CALCULATION ALTERNATIVE-D

DISCOUNT RATE 12.00 %

YEAR	DISCOUNT FACTOR	CONSTRUCTION COST		OPERATION AND MAINTENANCE COSTS			
		NET	PRESENT WORTH	PERSONNEL	OPERATION	TOTAL	PRESENT WORTH
1983	1.0000	33,900	33,900	0	0	0	0
1984	0.8929	31,800	28,393	0	0	0	0
1985	0.7972	236,000	188,138	0	0	0	0
1986	0.7118	44,300	31,532	2,000	624	2,624	1,868
1987	0.6355	0	0	4,000	1,311	5,311	3,375
1988	0.5674	0	0	4,000	1,407	5,407	3,068
1989	0.5066	0	0	4,000	1,512	5,512	2,793
1990	0.4523	0	0	4,000	1,627	5,627	2,545
1991	0.4039	0	0	4,000	1,746	5,746	2,321
1992	0.3606	0	0	4,150	1,879	6,029	2,174
1993	0.3220	29,900	9,627	4,150	2,023	6,173	1,988
1994	0.2875	28,100	8,078	4,150	2,177	6,327	1,819
1995	0.2567	208,000	53,388	4,150	2,373	6,523	1,674
1996	0.2292	39,000	8,938	4,150	2,633	6,783	1,554
1997	0.2046	0	0	4,300	2,801	7,101	1,453
1998	0.1827	0	0	4,300	2,985	7,285	1,331
1999	0.1631	0	0	4,300	3,181	7,481	1,220
2000	0.1456	0	0	4,300	3,396	7,696	1,121
2001	0.1300	0	0	4,300	3,620	7,920	1,030
2002	0.1161	0	0	4,300	3,860	8,160	947
2003	0.1037	0	0	4,300	4,119	8,419	873
2004	0.0926	0	0	4,300	4,398	8,698	805
2005	0.0826	0	0	4,440	4,697	9,137	755
2006	0.0738	0	0	4,440	4,697	9,137	674
2007	0.0659	0	0	4,440	4,697	9,137	602
SUB TOTAL		651,000	361,994	90,470	61,763	152,233	35,990
TOTAL							397,984

5. Breakdown of Cost Estimates

Table E-17 Breakdown of Project Cost Estimates for Stage I Program

Unit: Rs 1,000

Items (Intake/Treatment Flow Rate)	Amparai Area (5,300 m^3/d)			Coastal Area (22,100 m^3/d)			Total (27,400 m^3/d)		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
A. INTAKE FACILITIES									
1. Intake bay	-	420	420	-	720	720	-	1,140	1,140
2. Raw water pump	2,760	320	3,080	3,810	430	4,240	6,570	750	7,320
3. Raw water main	570	100	670	2,480	300	2,780	3,050	400	3,450
Sub-Total (A)	3,330	840	4,170	6,290	1,450	7,740	9,620	2,290	11,940
B. TREATMENT FACILITIES									
1. Receiving and mixing well	200	350	550	240	410	650	440	760	1,200
2. Flocculation and Sedimentation basin	940	6,610	7,550	1,410	11,970	13,380	2,350	18,580	20,930
3. Rapid sand filter	5,900	1,920	7,820	20,050	6,380	26,430	25,950	8,300	34,250
4. Slow sand filter	80	3,870	3,950	-	-	-	80	3,870	3,950
5. Clear water reservoir	160	3,970	4,130	350	8,550	8,900	510	12,520	13,030
6. Administration building	1,380	1,650	3,030	2,000	2,390	4,390	3,380	4,040	7,420
7. Chemical feeding facility	1,530	80	1,610	2,770	150	2,920	4,300	230	4,530
8. Pipelaying work in plant premises	1,120	270	1,390	4,660	1,100	5,760	5,780	1,370	7,150
Sub-Total (B)	11,310	18,720	30,030	31,480	30,950	62,430	42,790	49,670	92,460
C. TRANSMISSION FACILITIES									
1. Pump house	-	80	80	-	360	360	-	440	440
2. Transmission pump	1,860	190	2,050	8,940	890	9,830	10,800	1,080	11,810
3. Transmission main	4,620	690	5,310	51,980	6,570	58,550	56,600	7,260	63,860
Sub-Total (C)	6,480	960	7,440	60,920	7,820	68,740	67,400	8,780	76,180
D. DISTRIBUTION FACILITIES									
1. Elevated tower	180	950	1,130	1,830	9,660	11,490	2,010	10,610	12,620
2. Distribution pipe	4,540	1,320	5,860	26,220	10,430	36,650	30,760	11,750	42,510
3. Service water meter	470	-	470	3,310	-	3,310	3,780	-	3,780
4. Stand post	-	30	30	-	560	560	-	590	590
5. Rehabilitation	980	330	1,310	-	-	-	980	330	1,310
Sub-Total (D)	6,170	2,630	8,800	31,360	20,650	52,010	37,530	23,280	60,810
E. MATERIALS (cement, reinforcement bar) (E)	6,340	-6,340	0	12,870	-12,870	0	19,210	-12,910	0
TOTAL (A+B+C+D+E)	33,630	16,810	50,440	142,920	48,000	190,920	176,550	64,810	241,360
F. LAND AQUISITION COST	-	-	-	-	60	60	-	60	60
G. ENGINEERING COST	-	-	-	55,000	2,500	57,500	55,000	2,500	57,500
H. DUTIES AND TAXES	-	10,000	10,000	-	36,660	36,660	-	46,660	46,660
I. PHYSICAL CONTINGENCY	3,430	2,680	6,110	19,730	8,730	28,460	23,160	11,410	34,570
J. PRICE CONTINGENCY	2,940	6,510	9,450	15,350	18,050	33,400	18,290	24,560	42,850
TOTAL	40,000	36,000	76,000	233,000	114,000	347,000	273,000	150,000	423,000

Table E-18 Breakdown of Project Cost Estimates for Stage II Program

Unit: Rs 1,000

Items (Intake/Treatment Flow Rates)	Amparai Area (4,300m^3/d)			Coastal Area (22,200m^3/d)			Total (26,500m^3/d)		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
A. INTAKE FACILITIES									
1. Intake bay	-	-	-	-	-	-	-	-	-
2. Raw water pump	1,380	170	1,550	3,810	200	4,010	5,190	370	5,560
3. Raw water main	570	100	670	2,480	300	2,780	3,050	400	3,450
Sub-Total (A)	1,950	270	2,220	6,290	500	6,790	8,240	770	9,010
B. TREATMENT FACILITIES									
1. Receiving and mixing well	-	-	-	-	-	-	-	-	-
2. Flocculation and Sedimentation basin	940	6,610	7,550	1,410	11,970	13,380	2,350	18,580	20,930
3. Rapid sand filter	3,570	1,160	4,730	16,960	5,470	22,430	20,530	6,630	27,160
4. Slow sand filter	240	10,320	10,560	-	-	-	240	10,320	10,560
5. Clear water reservoir	140	3,400	3,540	360	8,780	9,140	500	12,180	12,680
6. Administration building	-	-	-	-	-	-	-	-	-
7. Chemical feeding facility	1,390	70	1,460	2,780	150	2,930	4,170	220	4,390
8. Pipelaying work in plant premises	910	220	1,130	4,670	1,110	5,780	5,580	1,320	6,910
Sub-Total (B)	7,190	21,780	28,970	26,180	27,480	53,660	33,370	49,260	82,630
C. TRANSMISSION FACILITIES									
1. Pump house	-	50	50	-	150	150	-	200	200
2. Transmission pump	1,860	190	2,050	6,430	640	7,070	8,290	830	9,120
3. Transmission main	4,620	690	5,310	51,980	6,570	58,550	56,600	7,260	63,860
Sub-Total (C)	6,480	930	7,410	58,410	7,360	65,770	64,890	8,290	73,180
D. DISTRIBUTION FACILITIES									
1. Elevated tower	460	2,420	2,880	2,770	14,600	17,370	3,230	17,020	20,250
2. Distribution pipe	2,440	970	3,410	19,560	7,630	27,190	22,000	8,600	30,600
3. Service water meter	730	-	730	5,440	-	5,440	6,170	-	6,170
4. Stand post	-	30	30	-	270	270	-	300	300
5. Rihabilitation	-	-	-	-	-	-	-	-	-
Sub-Total (D)	3,630	3,420	7,050	27,770	22,500	50,270	31,400	25,920	57,320
E. MATERIALS (cement, reinforcement bar) (E)	7,680	-7,680	-	13,110	-13,110	-	20,790	-20,790	-
Total (A+B+C+D+E)	26,930	18,720	45,650	131,760	44,730	176,490	158,690	63,450	222,140
F. LAND AQUISITION COST	-	-	-	-	-	-	-	-	-
G. ENGINEERING COST	-	-	-	44,000	4,000	48,000	44,000	4,000	48,000
H. DUTIES AND TAXES	-	6,800	6,800	-	33,540	33,540	-	40,340	40,340
I. PHYSICAL CONTINGENCY	2,690	2,550	5,240	17,580	8,230	25,810	20,270	10,780	31,050
J. PRICE CONTINGENCY	2,380	5,930	8,310	13,660	17,500	32,160	16,040	23,430	39,470
TOTAL	32,000	34,000	66,000	207,000	108,000	315,000	239,000	142,000	381,000

Note: (m^3/d) shows Max. daily demand to be increased in Stage-II.

Table E-19 Breakdown of Cost Estimates for Transmission and Distribution Pipes for Stage I Program

(Unit: Rs 1,000)

Items	Amparai Area			Coastal Area			Total		
	F/C	L/C	Total	F/C	L/C	Total	F/C	L/C	Total
1. Transmission Main									
DIP ø600	-	-	-	6,380	680	7,060	6,380	680	7,060
DIP ø500	-	-	-	4,230	510	4,740	4,230	510	4,740
DIP ø400	-	-	-	4,690	610	5,300	4,690	610	5,300
DIP ø350	1,480	190	1,670	31,670	4,010	35,680	33,150	4,200	37,350
DIP ø300	-	-	-	2,450	340	2,790	2,450	340	2,790
PVC ø250	3,140	500	3,640	2,310	370	2,680	5,450	870	6,320
PVC ø200	-	-	-	250	50	300	250	50	300
Sub-Total	4,620	690	5,310	51,980	6,570	58,550	56,600	7,260	63,860
2. Distribution Pipe									
DIP ø350	-	-	-	160	20	180	160	20	180
DIP ø300	130	20	150	770	110	880	900	130	1,030
PVC ø250	180	30	210	1,570	250	1,820	1,750	280	2,030
PVC ø200	1,790	340	2,130	5,550	1,070	6,620	7,340	1,410	8,750
PVC ø150	1,850	550	2,400	7,720	2,320	10,040	9,570	2,870	12,440
PVC ø100	140	60	200	2,390	980	3,370	2,530	1,040	3,570
PVC ø 75	180	90	270	3,370	1,700	5,070	3,550	1,790	5,340
PVC ø 50	270	230	500	4,690	3,980	8,670	4,960	4,210	9,170
Sub-Total	4,540	1,320	5,860	26,220	10,430	36,650	30,760	11,750	42,510
3. Duties and Taxes	-	780	780	-	13,920	13,920	-	14,700	14,700
Total	9,160	2,790	11,950	78,200	30,920	109,120	87,360	33,710	121,070