However, the result and/or planning parameters of the ADB funded UFW improvement program will need to be considered in the review of the water demand in future.

4.6.6 Future Water Demands

Future water demand defined as the connected demand is calculated from the full development demand multiplied by the progress percentage from the year assumed for commissioning and the special demands added.

Tables 4.18 and 4.19 shows a summary of the projection of the water consumption and the water demand including water loss, respectively.

Table 4.18 Projected Water Consumption (Daily Average)

Service Area	Total Water Consumption (m^3/d)			
	1995	2000	2010	2020
COLOMBO DISTRICT				
Colombo M.C.	132,363	149,880	175,258	194,727
Dehiwala M.C.	38,480	45,100	49,957	55,267
Kotte U.C.	24,790	28,251	34,510	40,972
Moratuwa U.C.	21,168	23,129	29,331	35,167
Kolonnawa U.C.	6,892	8,336	10,687	13,376
Koti/Mulleriyawa P.S.	12,738	16,924	20,789	24,893
Homagama P.S. (part)	0	2,762	8,239	13,765
Kaduwela P.S.	0	5,792	20,647	38,901
Kesbewa P.S.	0	2,627	16,279	33,673
Maharagama P.S.	5,706	9,537	16,294	22,018
GAMPAHA DISTRICT				
Ja Ela U.C.	0	243	4,483	6,671
Peliyagoda U.C.	5,887	6,903	7,171	8,359
Seeduwa Katunayake U.C.	0	0	0	0
Wattala Mabole U.C.	4,106	5,308	6,517	8,525
Biyagama P.S. (incl. Biyagama EPZ)	6,489	12,207	22,378	30,217
Ja Ela P.S.	0	840	14,569	23,182
Katana P.S. (incl. Katunayake EPZ)	0	159	2,646	5,128
Kelaniya P.S.	16,503	22,035	28,822	34,357
Mahara P.S. (part)	0	442	5,768	11,075
Sithawaka P.S. (Padukka)	0	0	0	650
Watala P.S.	0	624	10,520	16,031
KALUTARA DISTRICT				
Horana U.C.	1,583	1,781	2,520	3,451
Panadura U.C.	4,578	5,555	6,421	7,516
Bandaragama P.S.(part)	0	0	0	2,001
Horana P.S. (part)	0	0	0	0
Panadura P.S.	0	1,082	5,260	9,951
Total	281,283	349,517	499,066	645,698

Table 4.19 Projected Water Demand (Daily Average)

Service Area	Total Water Demand (m^3/d) (Consumption + Loss)			
	1995	2000	2010	2020
COLOMBO DISTRICT				
Colombo M.C.	220,605	230,585	269,628	277,581
Dehiwala M.C.	54,972	60,133	66,609	69,084
Kotte U.C.	35,414	37,668	46,014	51,215
Moratuwa U.C.	30,240	30,839	39,108	43,959
Kolonnawa U.C.	9,846	11,115	14,250	16,720
Koti/Mulleriyawa P.S.	18,198	21,049	27,719	31,116
Homagama P.S. (part)	0	3,241	10,127	17,565
Kaduwela P.S.	0	6,582	24,580	48,627
Kesbewa P.S.	0	2,940	19,085	41,449
Maharagama P.S.	6,340	10,838	19,398	27,523
GAMPAHA DISTRICT				
Ja Ela U.C.	0	277	5,337	8,339
Peliyagoda U.C.	8,410	8,503	9,561	10,449
Seeduwa Katunayake U.C.	0	0	0	0
Wattala Mabole U.C.	5,866	6,588	8,690	10,656
Biyagama P.S. (incl. Biyagama EPZ)	7,210	13,871	26,641	37,771
Ja Ela P.S.	0	955	17,345	28,978
Katana P.S. (incl. Katunayake EPZ)	0	180	3,149	13,690
Kelaniya P.S.	23,576	27,416	38,429	41,946
Mahara P.S. (part)	0	485	6,629	13,427
Sithawaka P.S. (Padukka)	0	0	0	813
Watala P.S.	0	697	12,406	19,739
KALUTARA DISTRICT				
Horana U.C.	2,261	2,374	3,360	4,314
Panadura U.C.	6,540	7,407	8,562	9,395
Bandaragama P.S.(part)	0	0	1,394	5,207
Horana P.S. (part)	0	0	0	0
Panadura P.S.	403	1,653	6,701	12,808
Total	429,879	485,395	684,718	842,372

In details, water demands are calculated by node in the transmission model to facilitate the planning of transmission system in the later stage of this study. Each sub-division is connected to one transmission node in the model. The result of this allocation is summarized in Supporting Report (Volume III).

4.6.7 Set up of Peak Factor

Water supply facilities should be designed to satisfy everyday water demand at least until the target year. In order to meet this requirement, the maximum day demand is used for determining the capacity of water supply facilities. The maximum day demand is generally computed by conducting 'Peak Factor' which is defined as the ratio of the maximum day demand to the average day demand.

In the course of determining the peak factor, water consumption records through at least ten years would be requested. The daily water consumption is generally obtainable from the records of water production at water treatment plants, or readings on bulk water meters installed on transmission lines and/or at service reservoirs and water meters at house connections. Should they be not available, estimation of flow rate by the pump operation time would be utilized instead of these records for a minimum access.

In this study, water production records at Labugama, Kalatuwawa and Ambatale water treatment plants together with the bulk meter reading on the transmission mains previously collected in the Master Plan Update have been analyzed.

In the case of the Labugama water treatment plant, detailed production records being measured constantly are collected. Daily water production records from 1990 to 1993 are given in Supporting Report (Volume III). In compliance with these daily records, the relationships between daily maximum and minimum values and monthly average values have been summarized as given in Figure 4.4. It is identified that extraordinary fluctuation on water production occurred during 1991 and 1992 was exerted by severe drought in the south western part of Sri Lanka. During this drought period, it was reported that the Kalatuwawa water treatment plants were suffered from water deficit in the reservoirs resulting in less water production. Meanwhile, serious problem did not occur on water quantity at the Labugama reservoir because of less water production capacity in the treatment works. Consequently, large amount of treated water, in excess of designed capacity, was produced to supplement the production of Kalatuwawa treatment plant by means of a bypass line.

For the determination of peak factor, daily water supply in 1990, omitting other fluctuated data from 1990 to 1992, has been analyzed by means of frequency curve as shown in Figure 4.5.

It is identified that 40 percent of the days are in excess of yearly average and that peak factor should be considered in compliance with this excessive values. Although a couple of percent of the days show higher peak factor, however, this will be negligible in design purpose.

As a conclusion, an appropriate peak factor has been accessed to be situated within 1.10 to 1.15 so far as the data of Labugama water works is concerned.

Meanwhile, water production records at Kalatuwawa and Ambatale unfortunately have not been successively measured at daily base due to lack of bulk meters or precise flow measurement devices. Therefore, monthly records have been utilized instead and analyzed as described hereinafter.

The water production records at the Kalatuwawa water treatment works through 1986 to 1993 are collected as given in Data Report (Volume IV). Tables give monthly average, maximum and minimum water productions together with the ratio of monthly maximum to monthly average. The records at Kalatuwawa are measured by an orifice installed right after filtration facilities. It has been identified that accuracy as the factual water production is some what problematic. The computation of an average ratio of monthly maximum to monthly average gives 1.20. However, large values appear occasionally, especially during the drought period. Therefore, optimal peak factor is assessed to be situated less than 1.20.

The water production record at Ambatale water treatment plant as one of the most significant data among others is collected as given in Data Report (Volume IV). However, due to lack of water meters to be facilitated at the outlet of clear water reservoirs, the data is indeed a compilation of estimated values by pump operation occasionally measured. An estimated value for peak factor has been resulted in 1.16.

Meanwhile, the records of bulk water meter have also been partially gained, however, the frequency of records measured and locations installed are limited in number, so that it will be inappropriate for the analysis of peak factor.

Existing amounts of water production, however, include the suppressed condition at a time of drought period resulting in larger fluctuation than ordinary years. It is envisaged that the peak factor will be further stable with less figures than above described in the condition of usual climate which is identified by less temperature variation in the Greater Colombo area. Taking into account the production records at three water treatment plants and their estimated peak factors, it is considered most appropriate to adopt a value 1.15 in this study.

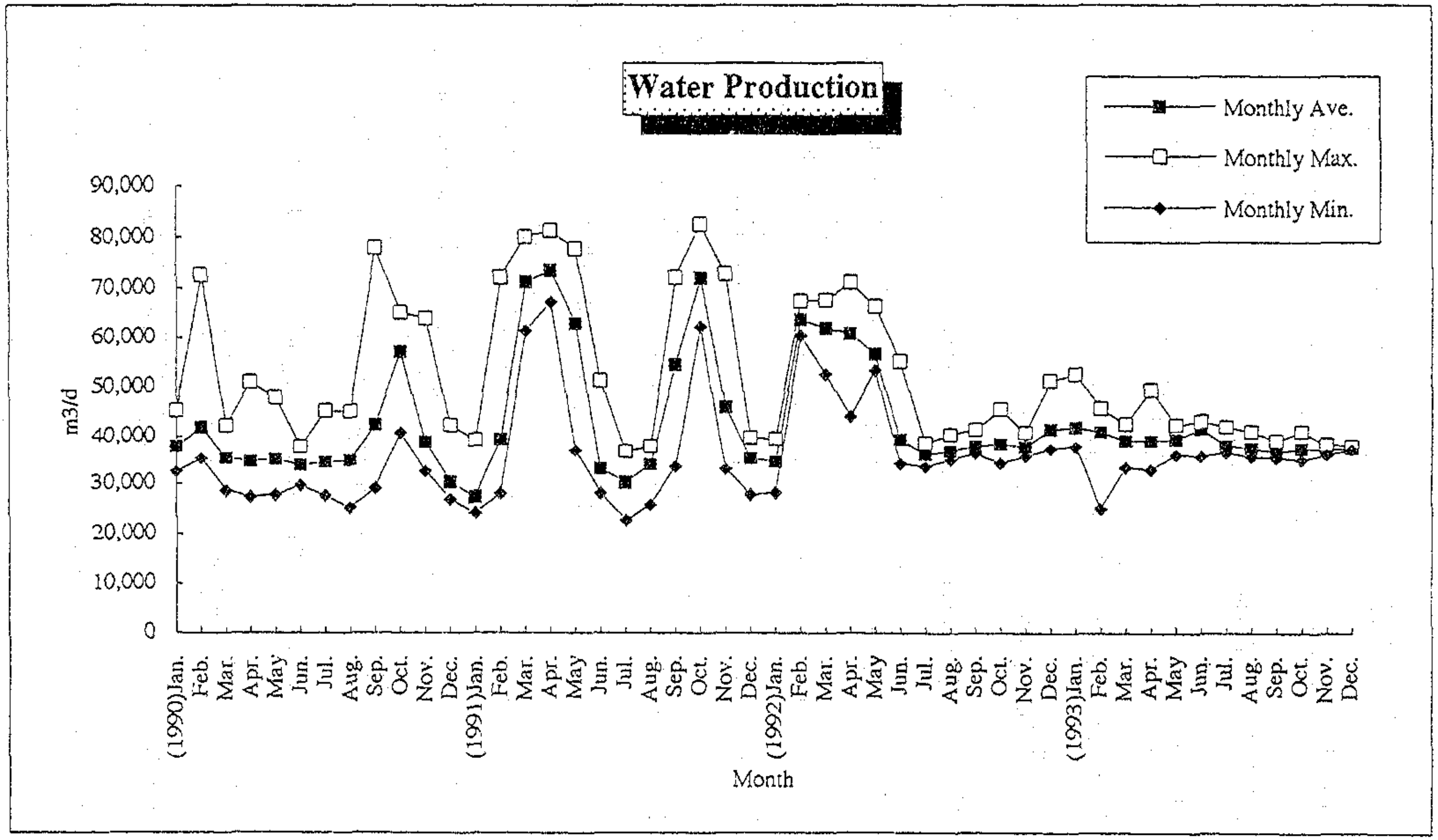


Figure 4.4 Water Production at Labugama Water Treatment Plant

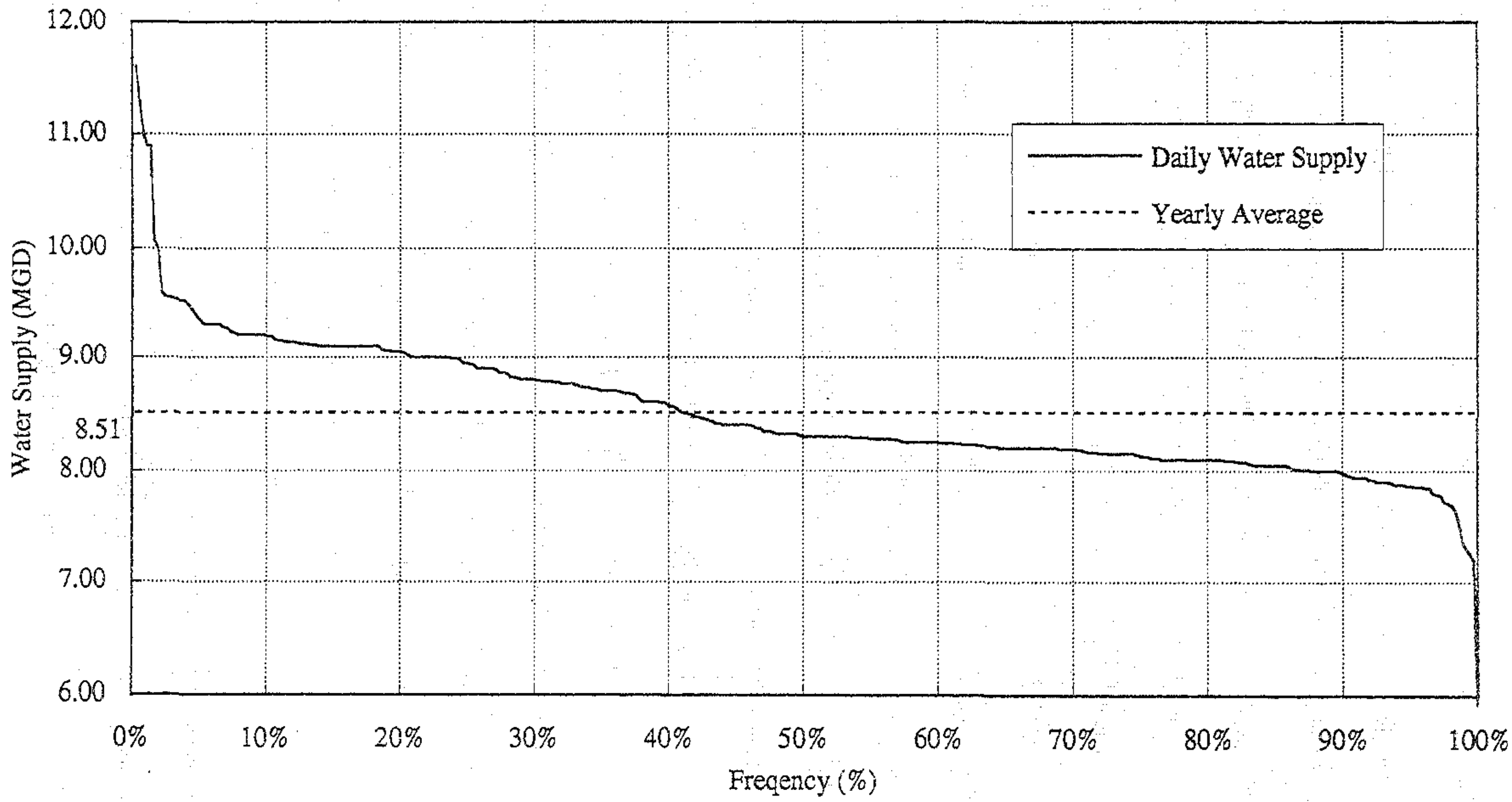


Figure 4.5 Frequency Curve for Water Supply at Labugama Water Treatment Plant (1993)

4.7 Required Size of the Kalu Ganga Project

A required capacity of the proposed Kalu Ganga Project is calculated from the total peak demand and the capacity of the existing treatment facilities. As discussed in Chapter 3, the water production capacity of the existing treatment plants are evaluated as below:

1) Ambatale Plant

   63 mgd at the old plant + 40 mgd at the new plant
   = total 103 mgd = 468,650 m^3/d

2) Kalatuwawa Plant

   90 percent of 20 mgd = 18 mgd = 81,900 m^3/d

3) Labugama Plant

   90 percent of 13 mgd = 11.7 mgd = 53,200 m^3/d

4) Total Existing Capacity

   132.7 mgd = 604,000 m^3/d

Demand exceeding the existing capacity should be supplied by the Kalu Ganga Project as shown in Table 4.20 From this table, the size of the Kalu Ganga Project to be planned is recommended as:

For 2010 182,000 m^3/d (40.0 mgd) as treatment production capacity

For 2020 364,000 m^3/d (80.0 mgd) as treatment production capacity

Table 4.20 Connected Demand and Required Water Production Capacity

Service Area Category	Division	Node No.	Connected Water Demand (m3/d) 1990	1995	2000	2005	2010	2015	2020	2025	2030
Towns East Area	Kaduwela	281	0	0	1,775	4,138	6,630	9,985	13,546	15,666	18,877
	Panagoda	402	0	0	0	0	0	0	0	0	0
	Pannipitiya	411	0	0	1,733	3,657	5,386	6,859	8,231	8,637	8,942
	Madiwela/Kotte	528	0	1,905	2,349	2,722	3,097	3,501	3,926	3,959	3,983
	Madiwela/Kotte	529	0	4,435	5,485	6,374	7,263	8,218	9,222	9,303	9,363
	Maharagama	552	0	0	2,759	5,716	8,301	10,790	13,202	13,854	14,343
	Batta. (High Zone)	563	0	0	4,180	9,743	15,609	22,075	29,058	30,493	31,570
	Batta. (Low Zone)	568	0	0	627	1,461	2,341	3,311	4,359	4,574	4,735
	Batta/Remote Zone	574	0	0	480	1,015	1,499	2,744	3,940	4,584	5,135
	Total Towns East		0	6,340	19,387	34,627	50,125	67,483	85,484	92,070	96,947
Towns South Area	Homagama	498	0	0	1,273	2,695	3,979	6,270	8,231	10,402	12,020
	Panadura (Keselwatta)	496	0	0	1,214	3,959	6,181	8,353	10,326	11,302	11,864
	Kesbewa (Exis. Maharagama)	529-A	0	0	907	3,377	5,688	8,701	11,612	12,478	12,956
	Kesbewa (Piliyandala)	542	0	0	1,479	5,507	9,600	16,117	22,741	26,619	29,296
	Kesbewa (from Kalatuwawa)	552	0	0	554	2,064	3,598	5,317	7,096	7,625	7,917
	Panadura P.S.	494	0	403	440	478	520	1,587	2,483	3,077	3,597
	Total Towns South		0	403	5,866	18,081	29,765	46,344	62,488	71,503	77,650
Towns North Area	Wattala South	122	0	0	748	6,937	11,995	16,311	20,353	22,736	24,004
	Mahara South	132	0	0	0	0	0	612	1,163	3,312	4,822
	Mahara North	141	0	0	260	2,068	3,547	5,138	6,562	11,414	14,445
	Ragama	145	0	0	325	3,823	6,239	7,957	10,015	10,641	11,266
	Welisara, Kandana	156	0	0	513	5,821	9,643	12,312	15,355	16,405	17,319
	Ja Ela U.C.	161	0	0	492	5,325	8,848	11,636	14,717	17,307	19,141
	Wattala North	165	0	0	256	2,900	4,594	5,682	6,970	8,566	9,778
	Katana P.S. (south)	166	0	0	0	0	0	929	1,759	5,909	8,793
	Katunayake EPZ	170	0	0	0	0	0	7,280	7,280	7,280	7,280
	Katunayake U.C. North	174	0	0	0	0	0	0	0	98	163
	Katana P.S. (north)	183	0	0	0	0	0	0	0	4,181	6,969
	Total Towns North		0	0	2,594	26,876	44,866	67,856	84,173	107,851	123,980
Biyagama	Biyagama (incl. EPZ)	127	6,000	7,210	9,979	12,745	15,532	15,832	16,165	16,165	16,165
		121	0	0	3,263	6,262	9,312	13,113	16,953	18,121	18,856
		132	0	0	629	1,208	1,796	3,250	4,653	5,844	6,722
	Total Biyagama		6,000	7,210	13,871	20,215	26,641	32,195	37,771	40,130	41,742
Area Far South	Sitawaka (Padukka Town)	428	0	0	0	0	0	413	813	1,073	1,301
	Bandaragama P.S. (West)	494	0	0	0	0	0	944	1,823	3,416	4,600
	Bandaragama P.S. (East)	497	0	0	0	714	1,394	2,338	3,385	4,268	4,781
	Horana P.S	1000	0	0	0	0	0	0	0	1,975	3,292
	Total of Area Far South		0	0	0	714	1,394	3,695	6,020	10,733	13,974
Total of New Area			6,000	13,952	41,719	100,712	152,791	217,572	275,936	322,286	354,293
Total of Existing Area Demand			343,163	415,927	443,676	483,650	531,927	549,829	566,436	575,674	581,675
Total Day Average Demand (m3/d)			349,163	429,879	485,395	584,362	684,718	767,401	842,372	897,961	935,968
Total Daily Peak Demand		Peak f = 1.15	401,537	494,361	558,204	672,016	787,426	882,511	968,727	1,032,655	1,076,363
Treatment Plant Capacity		Max.									
	Ambatale (Old)	63 mgd	286,700	286,700	286,700	286,700	286,700	286,700	286,700	286,700	286,700
	Ambatale (New)	40 mgd	182,000	182,000	182,000	182,000	182,000	182,000	182,000	182,000	182,000
	Kalatuwawa (Max. x 90%)	18 mgd	81,900	81,900	81,900	81,900	81,900	81,900	81,900	81,900	81,900
	Labugama (Max. x 90%)	11.75 mgd	53,200	53,200	53,200	53,200	53,200	53,200	53,200	53,200	53,200
	Horana	0.33 mgd	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Required => Additional Source			0	0	0	66,800	182,000	277,000	364,000	427,000	471,000
						(14.7mgd)	(40.0mgd)	(60.9mgd)	(80.0mgd)	(93.8mgd)	(103.5mgd)
Total Capacity			605,300	605,300	605,300	672,100	787,300	882,300	969,300	1,032,300	1,076,300

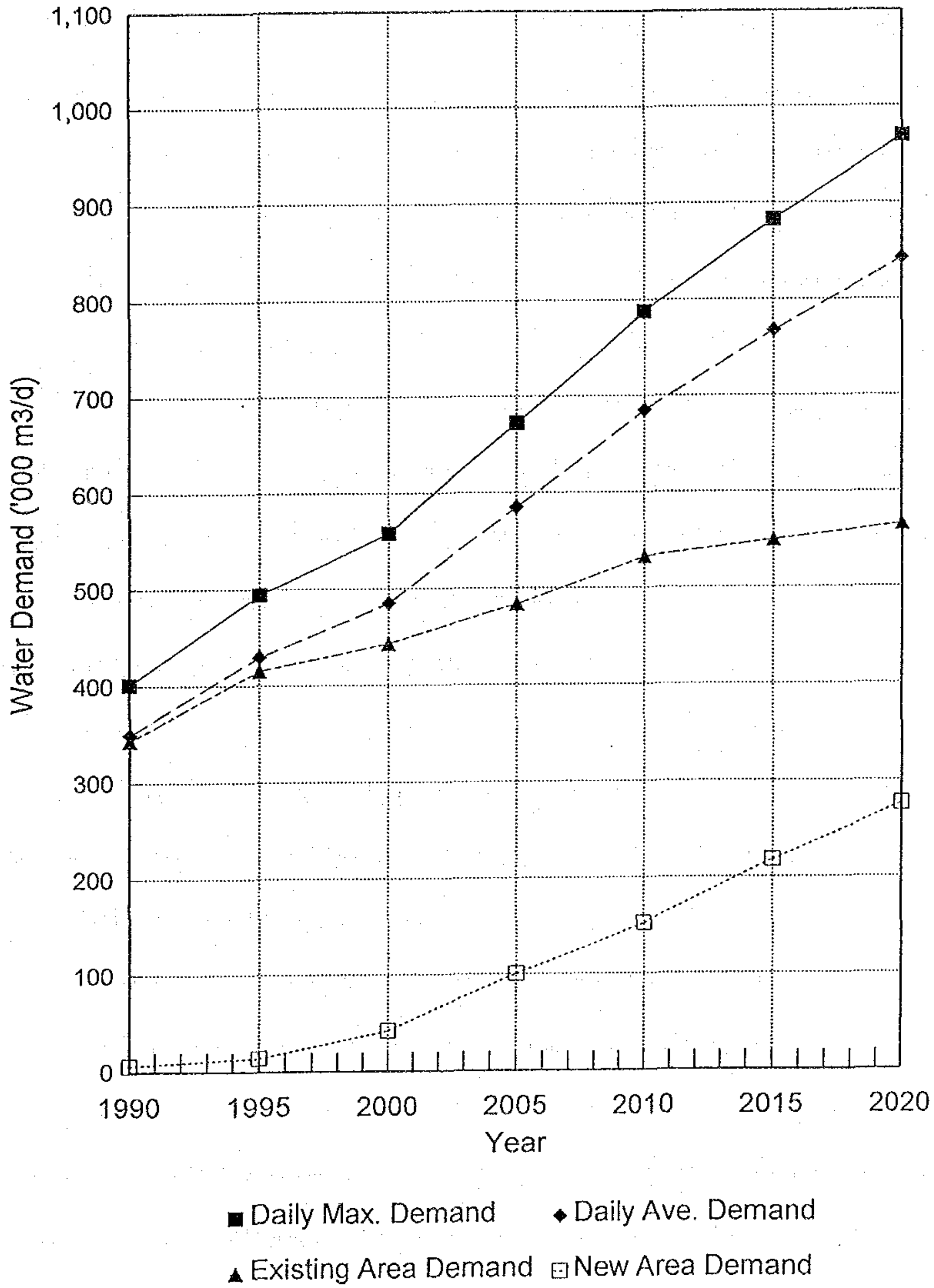


Figure 4.6 Water Demand Projection

CHAPTER 5

WATER DEMAND FOR THE KALU GANGA BY OTHER PROJECTS

5. WATER DEMAND FOR THE KALU GANGA BY OTHER PROJECTS

5.1 Kalutara Water Supply

Demand for water use in future in the area south of Greater Colombo will be for Kalutara District. For domestic water supply, largest consumption will arise at the Kalutara Water Supply Scheme. The development plan for this scheme has been prepared in 1968 for the 1998 demand in which daily average demand in 1998 was projected as 5.83 mgd (26,500 m^3/d). Present water production does not reach this maximum capacity since only a half of the planned facilities has been constructed although augmentation in water production capacity is being demanded to cater for the water use at the resort facilities along the coast. The projected water demand should therefore be considered to exist as potential demand which will come true when the remaining half of the water treatment plant will soon be constructed.

For estimating the future water demand at Kalutara, a full capacity of the plant will have to be taken into account. Future population growth should also be considered over that. The planning study of the Kalutara Water Supply Scheme assume that about 70 percent of population in the feasibility study area will be served by water supply scheme. Overall per capita consumption including non-domestic consumption was estimated as 32 gallon per day (145 L/cap/d) in 1998. Future demand is then estimated as follows:

- o Population data in 1980 for the same area as specified by the 1968 study was taken from the census record. Estimated growth rate of about 1 percent per annum for 1989 population assumed by A.G.A. Office are applied on 1980 population to make 1989 population.
- o Population growth rate after 1989 is assumed as 1.2 percent per annum for Kalutara District as described in Chapter 4.
- o Growth rate of overall per capita consumption is assumed as 1.0 percent per annum
- o To provide allowance in projection, estimated population in the area is used for water demand projection assuming

.From the assumption above, water demand for Kalutara Water Supply was projected to be 55,000 and 68,000 m^3/d for 2010 and 2020, respectively as shown in Table 5.1 below.

Table 5.1 Water Demand Projection for Kalutara Water Supply Scheme

Year	Original Study (1968)		Population Record and Estimate	Overall Per Capita Consumption (L/cap/d)	Planned Water Demand	
	Population in the Area	Served Population			(m^3/d)	(mgd)
Original Study (1968)						
1977	147,000	101600		114	11,600	2.5
1980			232,000			
1982	165,000	113,600		123	14,000	3.1
1987	186,000	128,300		132	16,900	3.7
1989			260,000			
1993	218,000	150,100		141	21,200	4.7
1998	263,000	181,400		146	26,400	5.8
Future Projection						
2000			296,000	149	44,000	9.7
2010			334,000	164	55,000	12.1
2020			376,000	181	68,000	14.9

5.2 Other Water Use

Other than the water demand for Kalutara Water Supply Scheme, industrial water use should be taken into account. As describe in Chapter 4, there are some plans for industrial estate development around Greater Colombo. Among these plans, those which will require water source from the Kalu Ganga are listed in Table 5.2.

Table 5.2 Industrial Estate Development Plan and Water Demand

Development Plan	Location	Estimated Water Requirement	
		(gallon/d)	(m^3/d)
Lagos Estate/Air-Strip	Kalutara	1,000,000	4,550
Clyde Estate	Dodangoda	130,000	590
New Chattle Estate Kobewelawatta	Bulathseinhala	520,000	2,370
Halwattagodella	Madurawala	80,000	364
Total		1,730,000	approx. 7,900

5.3 Total Water Demand

The planned figures described above are taken from the scheduled plans. There will likely be more development schemes arisen in future in particular by industrial sectors due to the restriction of development in the C.M.C. area. For reserving an allowance in the projection to cope with such future development, the water demand required for industrial estate development should be larger, maybe by two or three times, than that for the demand presently planned.

The total water demand to be taken from the Kalu Ganga in the area south of Greater Colombo is then estimated as follows:

Table 5.3 Estimated Water Demand in the Area South of Greater Colombo

Year	Kalutara Water Supply Scheme	Industrial Estate		Total
		(Scheduled)	(Recommended)	
	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)
2010	55,000	7,900	25,000	80,000
2020	68,000	7,900	25,000	93,000

For the purpose of studying the safe yield of the Kalu Ganga, it may be practical to say that approximately 100,000 m^3/d (1.2 m^3/s) of water be reserved for areas of Dodangoda, Bulathseinhala, Madurawala, and the service area of Kalutara Water Supply Scheme.

CHAPTER 6

KALU GANGA WATER SOURCE

6 KALU GANGA WATER SOURCE

6.1 Need for Kalu Ganga Development as Water Source

The Master Plan Update suggested that the Kalu Ganga will have to be considered as a water source for future development of water supply for Greater Colombo after 2000. With commissioning of the 40 mgd new Ambatale treatment plant in January 1994, the maximum treatment capacity of the Ambatale plant is now augmented to 103 mgd (469,000 m^3/d). With the increased treatment capacity, salinity intrusion in the Kelani Ganga is becoming a major concern since the Ambatale plant has experienced stoppages of water intake due to salinity in 1991 drought. It is feared that salinity intrusion will occur more frequently when the 103 mgd plant is in full operation.

As shown in regard to the water demand projection in Chapter 4, the existing system will not be able to satisfy the demand for 2005 which includes the demand for the scheduled expansion in the east, south and north of Greater Colombo. Water shortage will likely occur sometime after 2000. Expansion of water supply is, however, called for in many areas to improve the present inconvenient and unsanitary living conditions due to lack of piped water supply. To implement the water supply expansion, the water production capacity must definitely be immediately increased considering the time required for implementation.

Increasing the existing capacity of the Ambatale plant in substantial amount will however not likely considering the salinity problem. At Kalatuwawa and Labugama, the water production capacity will not be increased above the present level due to the limitation in the capacity of the impounding reservoirs.

Under the present circumstances and for achieving the stable water supply meeting the future demand, it is inevitable that new water sources stable both in quantity and quality be planned and developed.

The Kalu Ganga is the most promising option as a new water source for the Greater Colombo water supply from the aspects such as safe yield, water quality and location. Not only as an additional water source, having two sources will bring the water supply system a great reliability at the time of emergency. By provision of interconnected transmission system, either of sources will be able to supply water in case the other sources be shut down or face lack of raw water.

From these points of view, the Kalu Ganga is proposed as an additional water source for the Greater Colombo Water Supply System.

6.2 General Description of the Kalu Ganga

6.2.1 Authorities Responsible for River Management

The authorities responsible for river management in Sri Lanka are not clearly prescribed by the law. With regard to the sand exploitation from the Kalu Ganga, the Divisional Secretariat Office at Kalutara under the Ministry of Public Administration is the responsible agency. Anyone who intends to excavate sand from the Kalu Ganga should be registered at this office.

As to the features of environment, the Central Environmental Authority is the responsible authority for certain development projects. According to the National Environmental Act No.47 of 1980 as amended by the Act No.56 of 1988, it is determined that the projects and undertakings set out in the Schedule as projects and undertakings shall obtain approval under the provisions of Part IV of the Act, enforced on 18 June 1993. (Source : Gazette of the Democratic Socialist Republic of Sri Lanka).

The Schedule consists of Part I, Part II and Part III. Part I consists of 31 items including:

(1) All river basin development and irrigation projects excluding minor irrigation works (as defined by the Irrigation Ordinance Chapter 453).

(13) Water Supply

All groundwater extraction projects of capacity exceeding 1/2 million m^3/d

Construction of water treatment plants of capacity exceeding 1/2 million m^3/d.

Part II consists of items of (32) to (52) including:

(32) All projects and undertakings listed in Part I irrespective of their magnitudes and irrespective of whether they are located in the coastal zone or not, if located wholly or partly within the areas specified in Part III of the Schedule.

Among the specifications of Part III, those related to the water supply project are as follows;

1) Within 100 m from the boundaries of or within any area declared under the National Heritage Wilderness Act No.3 of 1988.

the Forest Ordinance (Chapter 451)

whether or not such areas are wholly or partly within the Coastal Zone as defined in the Coast Conservation Act, No.57 of 1981.

2) Within the following areas whether or not the area wholly or partly within the Coastal Zone:

Any erodable area declared under the Soil Conservation Act (Chapter Zone)

Any Flood Area declared under the Flood Protection Ordinance (Chapter 449) and any flood protection area declared under the Sri Lanka Land Reclamation and Development Corporation Act, No.15 of 1968 as amended by Act, No.52 of 1982.

Sixty meters from the bank of a public stream as defined in the Crown Lands Ordinance (Chapter 454) and having a width of more than 25 m at any point of its course.

6.2.2 Other Agencies Related to the Use of the River Water

The Department of Irrigation is the authority to manage the irrigation schemes. For the irrigation purposes, the Department of Irrigation conducts the measurement of river flow and rainfall in the basin.

The Department of Industry is the authority to manage the industrial development schemes. Some industrial schemes need water directly from a river.

Presently when the NWSDB plans to take water from a certain river for any development scheme, it usually goes to the Department of Irrigation to see if the plan is not going to infringe the existing water rights of irrigation schemes, nor contend with any irrigation plans taking water from the river.

6.2.3 Basin and River

The Kalu Ganga is located in Kalutara and Ratnapura districts in the southwestern part of Sri Lanka. The catchment area is estimated at 2,719 km^2. The Kalu Ganga originates from Adams Peak and flows through Ratnapura. Weganga which is a tributary of the Kalu Ganga joins the Kalu Ganga at Ratnapura. The Kalu Ganga still flows down to west and some tributaries join from north and south, and afterwards passes the Ellagawa gauging station.

The river then flows down west and after joining of the Mahayak Oya coming from north, curves southeast, and after joining the Kuda Ganga which originates on the Tangamale Plains joins the Kalu Ganga, passes the Putupaula gauging station at about 20 km upstream of the Kalutara bridge. After passing the Putupaula gauging station, it meanders north and south, and discharges to the Indian Ocean at Kalutara town.

The northeastern and southeastern areas near the basin boundary is covered by the forest but the other areas are mainly covered by paddy field and rubber plantations.

Width of the river is about 45 m at the Ellagawa gauging site and about 100 m at the Putupaula gauging site. Length of the river is about 124 km with the elevation difference of 450 m between the river-shed and the river-mouth.

The river mouth is located on the south western coast of Sri Lanka where the force of littoral drift is rather active. A large sand bar has been developed from north to south at the river mouth. Due to this active littoral drift, the river mouth is now located about 2.6 km downstream of the Kalutara bridge largely bending south. At the river mouth, the width of the opening is only about 20 m when the tide is low while the width of the river in the upstream reaches of the Kalutara bridge is about 100 m. A large lagoon is developed between the river mouth and the Kalutara bridge.

6.2.4 Rainfall

(1) Rainfall Gauging Station

In and around the basin of the Kalu Ganga, there are more than 30 rainfall gauging stations. Some of them are under the management of the Department of Irrigation while some are under tee estates. The other stations are placed under the Department of Meteorology.

Among those, daily rainfall records for the period of 1983 to 1992 were collected at the five rainfall gauging stations under the management of the Department of Meteorology as listed in Table 6.1.

Table 6.1 Rainfall Gauging Stations

Name	Location	Elevation
Clyde Estate	6°-35'-20"N - 80°-02'-10"E	+24 m MSL
Horagoda	6°-30'-00"N - 80°-14'-55"E	+20 m MSL
Rayigama	6°-46'-25"N - 80°-10'-40"E	+20 m MSL
Wellandura	6°-54'-20"N - 80°-54'-00"E	+282 m MSL
Ratnapura	6°-40'-49"N - 80°-23'-29"E	+34 m MSL

The locations of these stations are shown in Figure 6.1.

(2) Annual Rainfall

The mean annual rainfall in the period of 1983 to 1992 at these stations are as follows;

Clyde Estate	2,850 mm
Horagoda	3,419 mm
Rayigama	4,270 mm
Wellandura	2,562 mm
Ratnapura	3,659 mm

(3) Numbers of Non-Rainy Days

From the daily rainfall records at Clyde Estate located at the closest place to the alternative intake sites, the mean numbers of non-rainy days in these ten years are listed as follows;

Table 6.2 Number of Non-Rainy Days at Clyde Estate Gauging Station

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
26	24	23	17	10	8	19	18	13	14	17	22

6.2.5 River Flow

(1) River Flow Gauging Station

River flow gauging stations are under the management of the Department of Irrigation. Table 6.3 shows the summary of river gauging stations in the basin of the Kalu Ganga. Locations are shown in Figure 6.2.

Table 6.3 River Gauging Stations

Name	Location	Elevation (+m MSL)	Basin Area (km^2)	Period of Record
Ellagawa	N-6°-43'-52" E-80°-13'-00"	4	1393	1956 - to date
Millakanda	N-6°-37'-25" E-80°-10'-25"	17	769	1950 - to date
Putupaula	N-6°-36'-40" E-80°-03'-55"	2	2598	1943 - to date
Kukulegama	N-6°-33'-20" E-80°-20'-30"	200	334	1972 - to date
Dela	N-6°-37'-20" E-80°-27'-10"	29	220	1956 - to date
Ratnapura	N-6°-40'-30" E-80°-24'-00"	14	604	1976 - to date

Among the daily discharge records at the gauging stations above, records at the Putupaula and Ellagawa gauging stations were collected.

The Putupaula gauging station is located about 20 km upstream from the Kalutara Bridge which is located about 2.6 km upstream from the river mouth. The river water level has been measured at Putupaula since 1943. At first, the river water level was recorded twice a day by using a staff gauge. Since 1958, reading the water level had been conducted 12 times in a day time. Since 1985, continuous 24 times every hour reading has been conducted. The hourly water levels have been averaged on a daily basis. The daily water levels have then been converted to daily discharges by the Department of Irrigation.

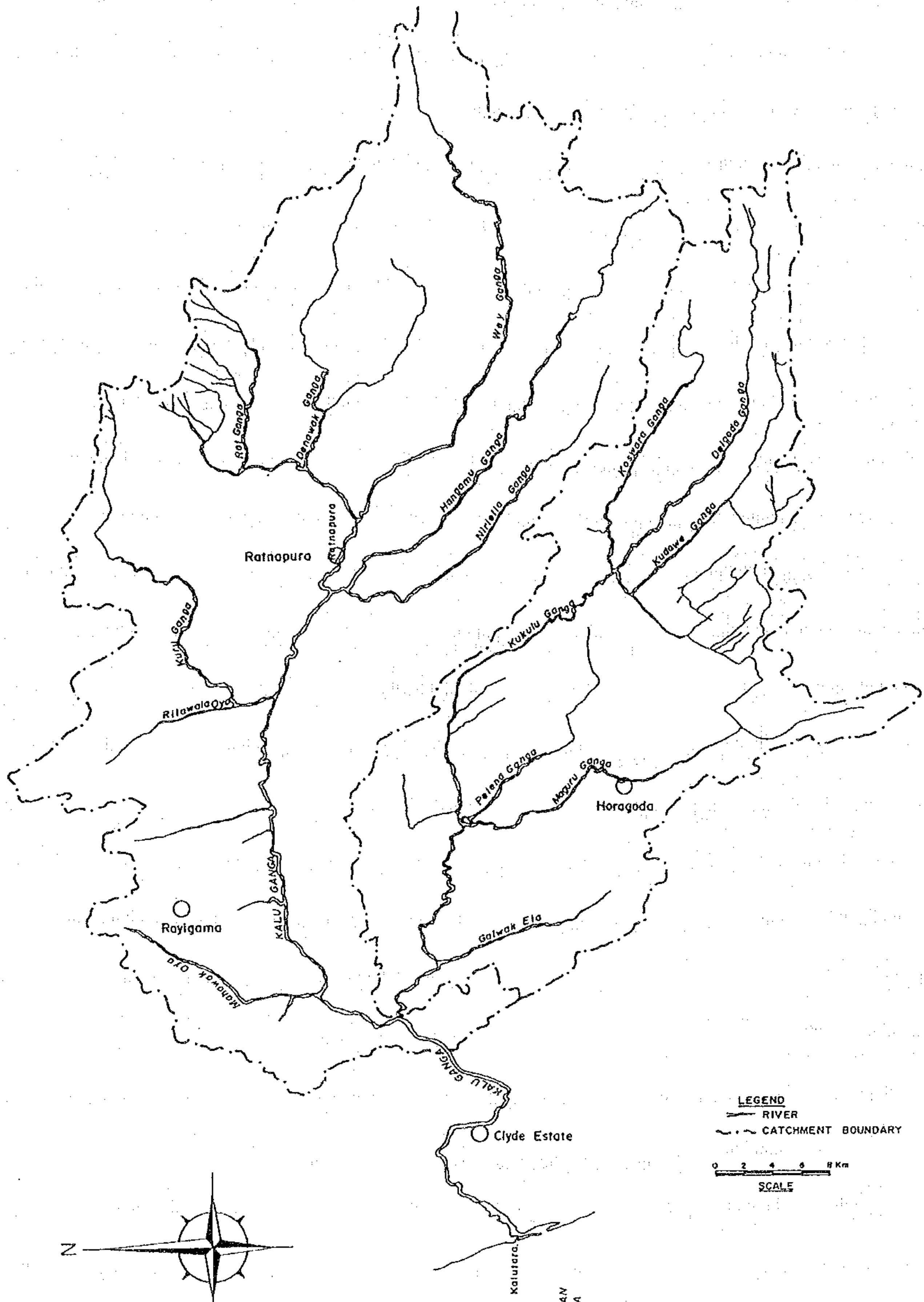


Figure 6.1 Locations of Rainfall Gauging Stations

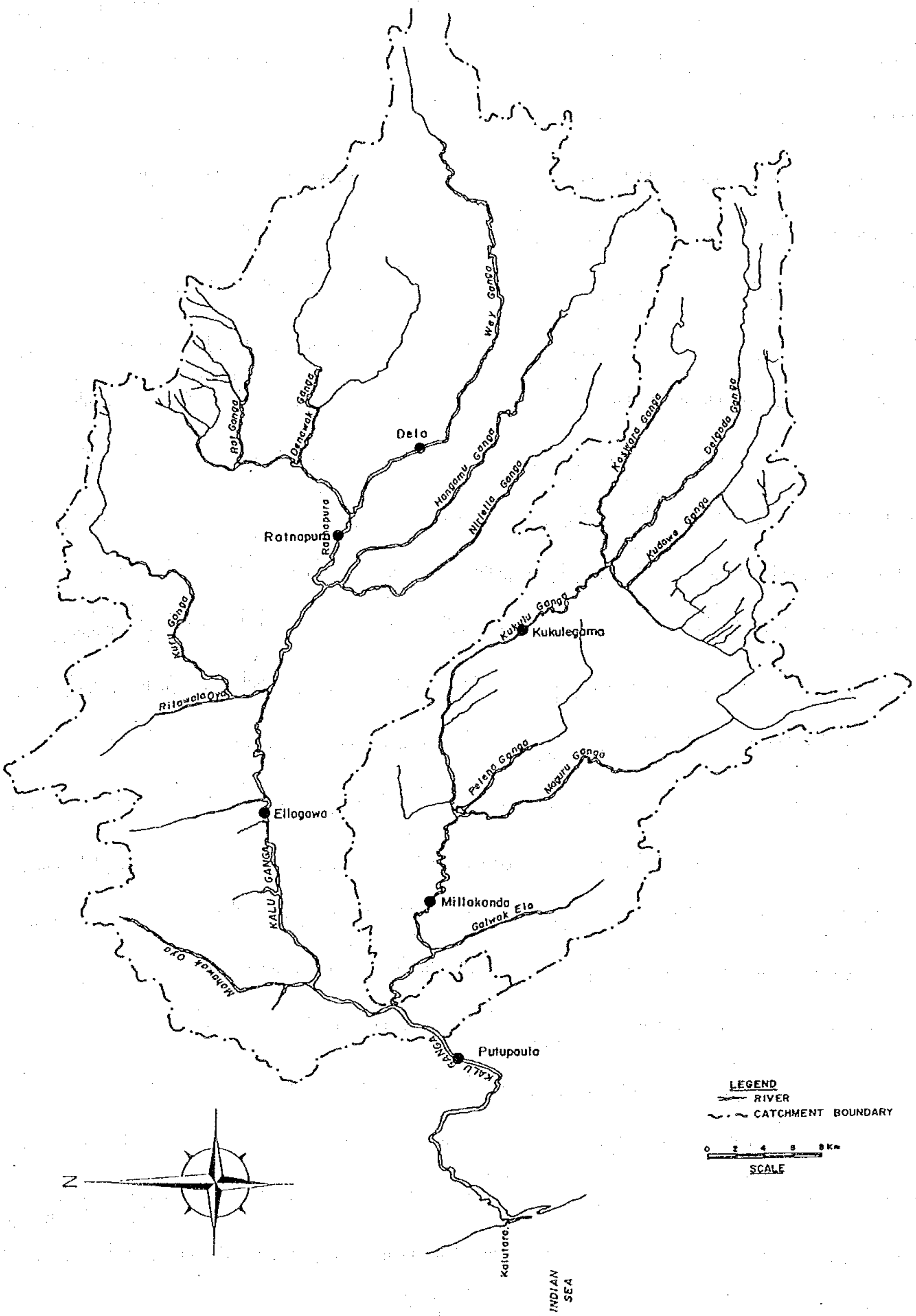


Figure 6.2 Locations of River Flow Gauging Stations

The Ellagawa gauging station is located approximately 28 km upstream from the Putupaula gauging station. The river water levels have been measured at Ellagawa since 1956. The daily water levels measured are converted to daily river flows by the Department of Irrigation in the same manner as for the Putupaula records.

(2) Discharge Rating Curve

Discharge rating curves at the gauging stations of Putupaula and Ellagawa are shown in Figures 6.3 and 6.4. The discharge rating curve at Putupaula in the period since 1988 to date is given in the equation as:

$$Q = 76.05 \cdot (H + 0.4)^{1.49}$$

where,

H : water level of the river (m)

(Source : Department of Irrigation, Hydrology Section)

In the field work of this study, discharge measurement at the both stations were conducted by the Study Team for examining the discharge rating curves used by the Department of Irrigation. Measured data are plotted on Figures 6.3 and 6.4, respectively. As seen in these Figures, the existing discharge rating curves at the both gauging stations have quite good accordance with the measured data by the Study Team.

(3) Flood Level

Annual maximum floods experienced at the Putupaula gauging station are shown in Table 6.4 and Figure 6.5 (Source : Department of Irrigation, Hydrology Section). According to Figure 6.5, the flood discharge over 1500 m^3/s occurred 6 times before the year 1960 in the period of 17 years, but since then that scale flood never occurred in the period of 33 years. This is, as the phenomenon of nature, rather strange. Accordingly it is concluded that the probability analysis of flood peak at Putupaula should be made based on the data since 1960.

In addition, the flood peak discharges at Putupaula gauging station are estimated by using the discharge rating curve based on the experienced flood peak water-levels. But actual situation of flood at Putupaula is that, due to insufficient discharge carrying capacity of the Kalu Ganga in the reaches upstream of Putupaula gauging station, considerable part of flood discharge coming from the upstream overflows the embankment on the both sides before reaching the gauging station. Accordingly the probability analysis of flood peak is conducted in terms of the water-level.

Probable annual maximum floods at the station are analyzed and presented below and shown in Figure 6.6 by Gumbel Method.

Table 6.4 Probable Annual Peak Floods

Return Period (Year)	Probable Annual Peak Floods (m MSL)
2	4.97
5	5.61
10	6.03
50	6.97
100	7.36

6.2.6 Present Use of River Water

Present major use of river water of the Kalu Ganga are summarized as follows:

Location:	about 13 km upstream of the Putupaula gauging station
Name:	Horana Intake
Amount	1,300 m^3/day(=0.015 m^3/s)
Location	about 500 m downstream of the Putupaula gauging station
Name	Putupaula Rubber Estate
Amount	about 1,000 gallons per day (= 4.5 m^3/day = 0.00005 m^3/s)
Location	about 500 m upstream of the existing Kethhena intake site
Name	Associated Motorways Group
Amount	30,000 gallons per day (=136 m^3/day = 0.0016 m^3/s)
Location	about 100 m upstream of the Narthupana Bridge
Name	Ceymac Rubber Co., Ltd.
Amount	60,000 gallons per day (=273 m^3/day = 0.0032 m^3/s)
Location	about 200 m upstream of the Narthupana Bridge
Name	Hayles-ADC Textile Ltd.
Amount	500,000 gallons per day (=2273 m^3/day = 0.026 m^3/s) (planning figure to be implemented within one year as of February 1994)
Location	about 15 km upstream of the Kalutara Bridge
Name	Kethhena Intake
Amount	5.8 million gallons per day (=26,367 m^3/day = 0.305 m^3/s)

According to the Department of Irrigation, there is no irrigation scheme at present along the Kalu Ganga.

6.2.7 Existing Development Plans for the Kalu Ganga

Presently no development is proposed by the related agencies except for ones described in Section 6.3. The Department of Industry is said to have a plan to move the industrial zone from the Colombo area to the Kalutara area near the river-mouth of the Kalu Ganga. But no definite plan was established yet.

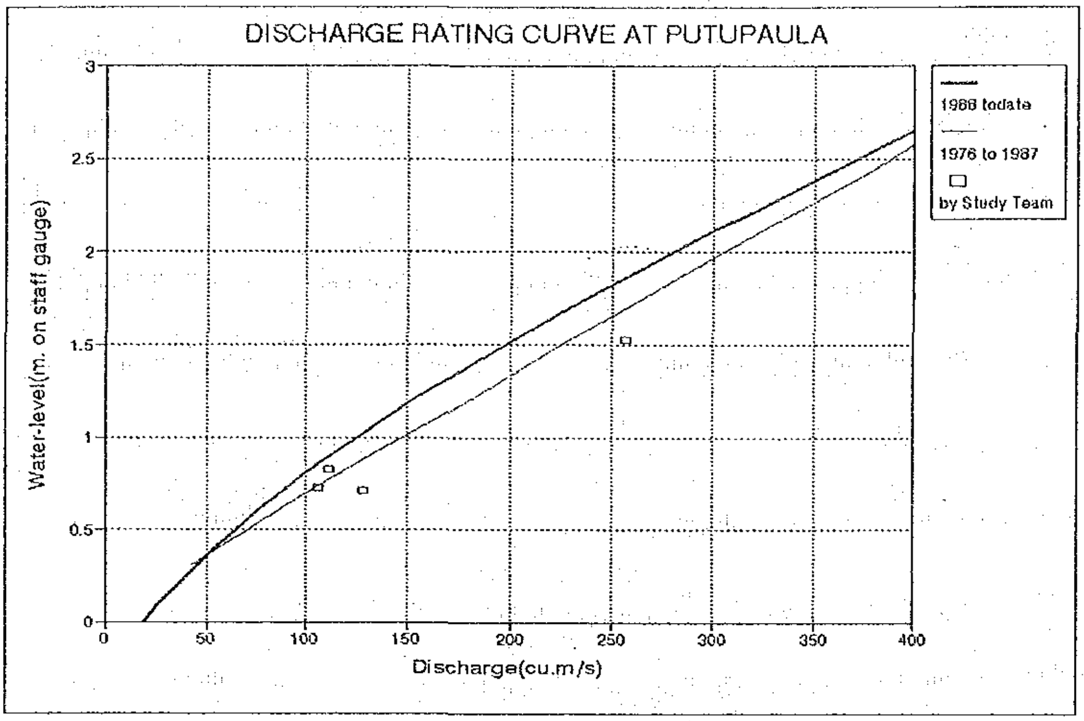


Figure 6.3 Discharge Rating Curves at Putupaula

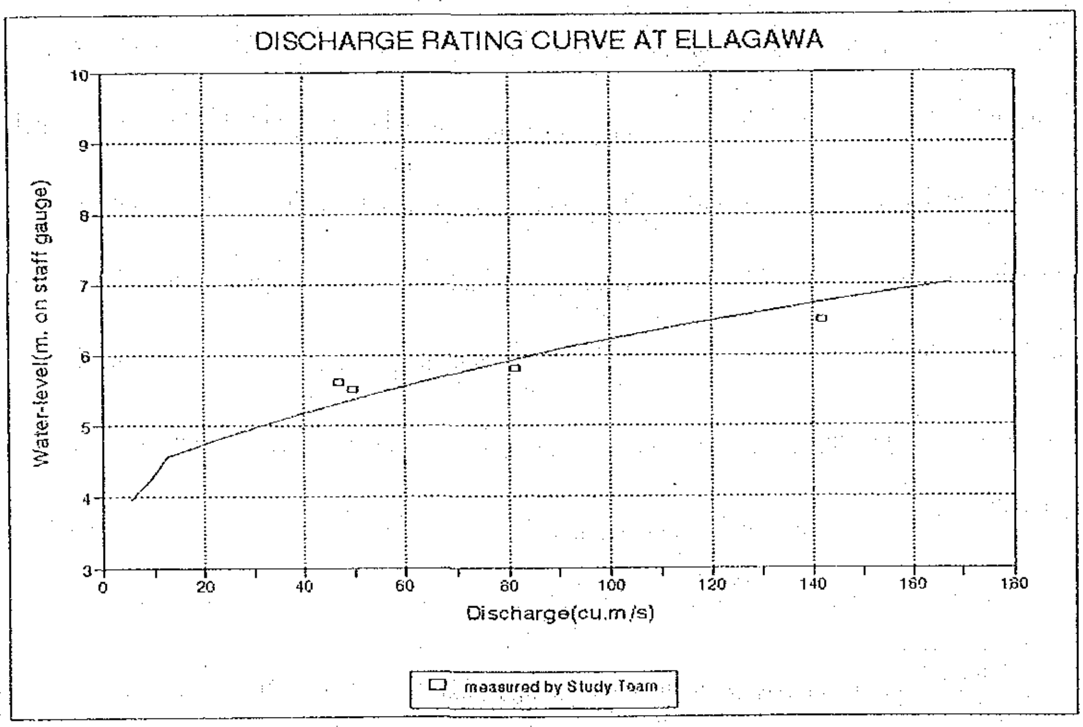


Figure 6.4 Discharge Rating Curve at Ellagawa

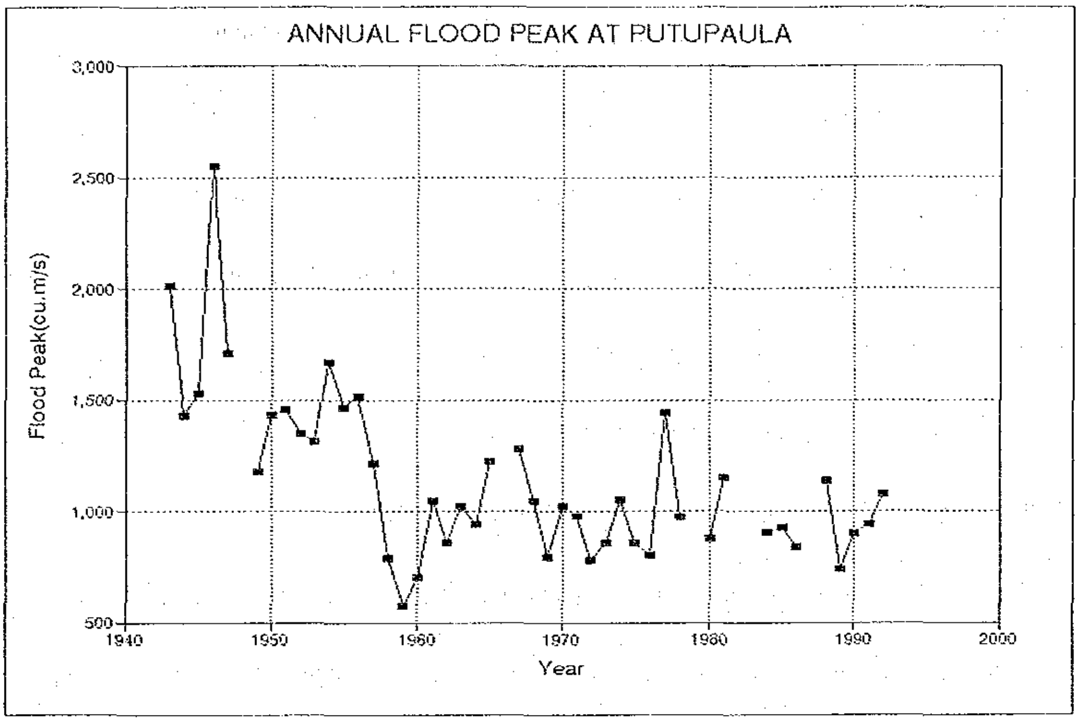


Figure 6.5 Past Flooding Level at Putupaula

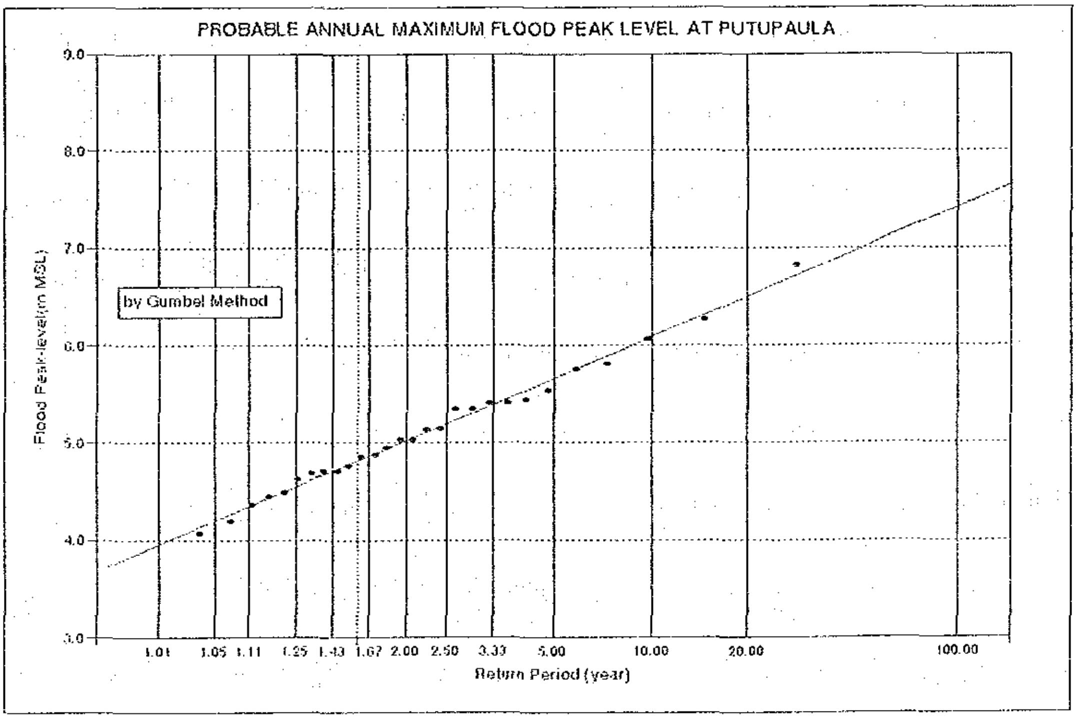


Figure 6.6 Annual Maximum Flow at Putupaula by Gumbel Method

6.3 Other Projects Planned for the Kalu Ganga

6.3.1 Gem Mining Project

Colombo Sapphire Pvt. Ltd., propose to mechanically dredge the Kalu Ganga river bed to extract gemstones. They have selected a site near the Urugala Bridge which is about 20 to 25 km upstream of the two proposed water intakes for the water supply.

The Board of Investment granted approval for a pilot scale project but the exact location has yet to be agreed. Considerable media attention has been focused on this project with a number of articles both for and against being published in the newspapers in recent months. Objections to the scheme are based on dangers to the environment and adverse effects on people currently employed in the gem industry. Support for the scheme is based on commercial factors.

An eight member Presidential Committee was formed on 1st December 1993 to investigate the controversy and recommended a ban on mechanized gem mining until detailed studies have proved that no damage to the environment will be caused by such activities. It also recommended that the pilot scheme should be banned in the present socio-political context. The President, D.B.Wijetunga is reported to have told the Committee that their recommendations would be implemented on obtaining Cabinet approval. Cabinet approval was announced on 19th January 1994.

It therefore appears unlikely that dredge gem mining will be carried out in the short to medium term, if at all. Should a detailed environmental assessment prove that no significant adverse effects will occur, then it must be assumed that the water quality at the proposed treatment works intakes will not deteriorate. Logic dictates that considerable quantities of suspended solids will be introduced into the river water at the mining site and the river bed level will be lowered. However, the distance between the mining site and the treatment works intake would be more than adequate to ensure almost total settlement of suspended matter. The mining site is also far enough up the Kalu Ganga that the lowering of the bed level would not increase the possibility of saline intrusion.

An Environmental Impact Assessment report has been prepared for this project but has yet to be made available.

6.3.2 Kukule Ganga Hydropower Project

There is no large scale water related development program under the governmental authorities or private sectors on the upper reaches of the Kalu Ganga other than the Kukule Ganga hydropower project organized by the Ceylon Electricity Board. The followings are the brief summary of the project configuration and, in addition, an effect on the Kalu Ganga water supply scheme is given.

(1) Physical Condition of the Project Site

The Kukule Ganga Hydropower Project site is located south-east of Colombo at about 70 km air-distance in Karawana division of the Ratunapura district. The project is set up on the Kukule Ganga, a tributary of the Kalu Ganga which is the second largest river in Sri Lanka, draining a mean annual flow of about 280 m^3/s with high rainfall averaging between 3,000 mm and 5,000 mm annually across the basin area of about 2,600 km^2. While the Kukule Ganga at the project site drains annual mean flow of 30.4 m^3/s, receiving average annual rainfall of 3,750 mm with a basin area of 312 km^2. Dominant climatic feature in the catchment area is the south-west monsoon (May/June) and inter-monsoon rainy period (September/November).

Regarding the process of this hydropower project, the prefeasibility study was carried out in 1988/1989 under UNDP financing. The study proposed single purpose development for hydropower with a dam construction on the Kukule river. Thereafter, the Government of Sri Lanka received funding from IDA under the Power Distribution and Transmission Project for the feasibility study and the study was completed on August 1992.

The principle feature of the project is that full supply level is determined at 206 m above MSL as a results of backwater analysis with regard to effect of inundation upstream especially at flood times, while the minimum operation level is set at 204 m above MSL as the possible lowest level to allow proper functioning of the intake and desilting facilities. With this drawdown of 2 m a regulating of 1.67 million m^3 is attained which is sufficient for daily peaking operation of the plant.

The water of the Kukule Ganga will be diverted through the intake into desilting basin, from which the water enters into the headrace tunnel to the power cavern where two Francis unit of 35 MW each will be installed then the water returns back into the Kukule Ganga itself through tailrace tunnel.

The electricity is transmitted to the existing Matugama substation through a 132 kV line.

(2) Principal Features of the Project and Implementation Schedule

Features of the project proposed are shown as follows:

1) Diversion Facilities

Type	Run-off-river
Catchment area	312 km^2
Mean stream flow	30.4 m^3/s

Full supply level	206 m MSL
Maximum operating level	204 m MSL
Regulation storage	1.67 million m^3
1,000 year flood	2,000 m^3/s
Sediment yield	250 $m^3/km^2/yr$

2) Power Plant

Headrace tunnel, D/L	4.8 m/5,650 m
High pressure tunnel, D/L	4.8-3.9 m/206 m
Tailrace tunnel, D/L	4.8 m/1,600 m
Powerhouse	Underground
Installed capacity	2 x 35 MW
Tailwater level	21.0 m MSL

3) Performance

Peak power discharge	47.5 m^3/s
Annual average energy production	317 GWh

4) Inundation effect

Land affected by headpond	about 65 ha
Land submerged in headpond	about 19 ha
Population	about 100 (20 households including 10 in the peripheral zones of the ponds

An implementation schedule for the construction has been proposed with the commencement at early month of 1995 and commissioning in the beginning of 2000.

(3) Hydrological Effect on the Kalu Ganga Water Supply Scheme

It is envisaged that the water use for the hydropower purpose conducting run-of-river type will not bring about any water shortage to the down reaches so far as the quantity is concerned.

6.4 Extent of Salinity Intrusion

6.4.1 Past Studies

Regarding the salinity intrusion in the Kalu Ganga, no study has ever been conducted.

6.4.2 Investigation Results and Analysis

(1) Saline Water Measurement

Saline water measurement along the Kalu Ganga was conducted by the Study Team on 31 January, 9 February and 4 March, 1994. The measurement was conducted starting from the low tide time to the high tide time. The results are shown in Figure 6.7. As seen in these Figures, the saline water reached the points about 5 km, 2 km and 8 km upstream of the Kalutara bridge at the high tide time for the peak discharge of 60, 90 and 40 m^3/s on the day respectively.

(2) River Profile

The topographical survey around the river bank of the Kalu Ganga has ever been carried out in 1960's and amended in 1970's. The results are kept at the Department of Survey. In this topographic survey, only the elevations of the river-bed near the river bank were surveyed. Since then, longitudinal and cross-sectional profiles of the Kalu Ganga have been surveyed by Irrigation Department in 1989. In this survey, 16 cross-sections have been surveyed in the reaches downstream of the confluence of the Kuda Ganga. But the elevation of the river-bed was surveyed at only one point in the low-water channel.

On the occasions of saline water measurement, water depth along the Kalu Ganga was taken measure at around the center line of the river. And at the same time, hourly water-levels at the Kalutara bridge and Putupaula gauging station were also taken measure. Other than these occasions, water depth measurement in further upstream reaches was conducted on 15th and 20th of June 1994.

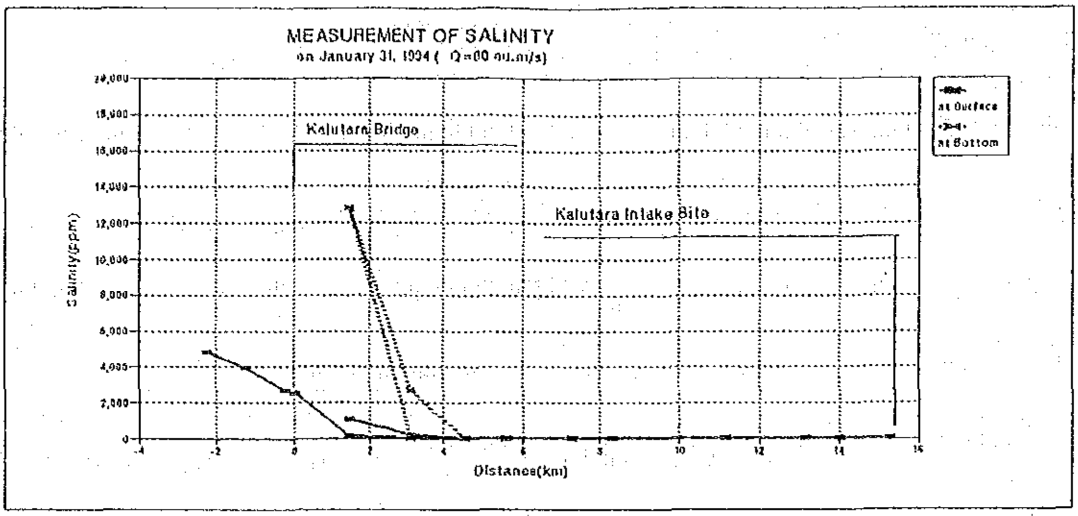
By using these data, river-bed elevations of the Kalu Ganga are provisionally estimated in the reaches. The average elevation of river-bed in the reaches downstream of the proposed water intake site is around 4 m below the mean sea level.

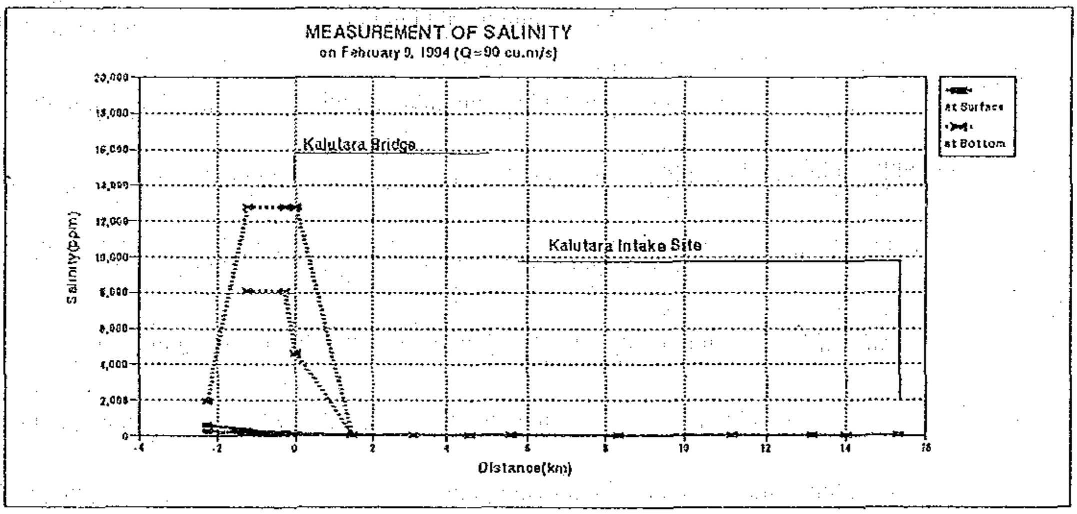
Based on these old and present data on the elevations of river-bed and the river bank, longitudinal profile of the Kalu Ganga in the reaches downstream of the confluence of the Kuda Ganga is prepared for the analysis of saline water intrusion.

(3) Tide at the River-Mouth

The water-levels at the Kalutara bridge located at about 2.6 km upstream of the river-mouth measured on the occasion of salinity measurement are compared with the tide at the Colombo Port as shown in Figure **Error! Reference source not found.**.8. The water-level at the Kalutara bridge varies periodically due to the tide at the river-mouth and is about one hour behind the tide at the Colombo Port. The elevation of water-level at the Kalutara bridge goes up when the discharge of the Kalu Ganga goes up. It is tentatively concluded that the tide at the river-mouth of the Kalu Ganga has the same elevation with that of the tide at the Colombo Port.

(Note: the tide at the Colombo Port here is the estimate of the tide by the harmonic analysis since the tide chart in this period has not been abstracted. The validity of the estimate is confirmed by the past data.)





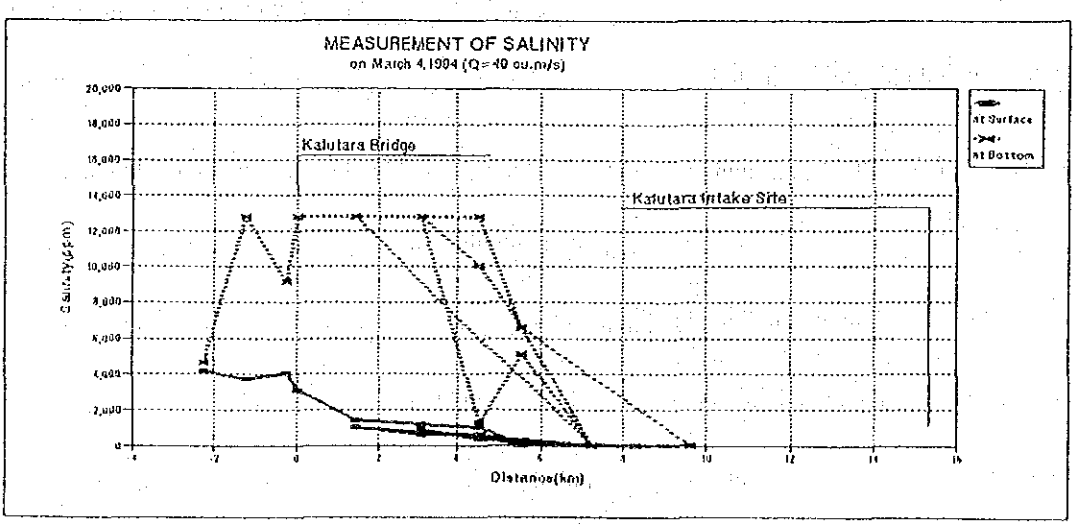


Figure 6.7 Result of Saline Water Measurement

(4) Saline Water Intrusion

The provisional analysis of sea water intrusion for the occasion of design drought of the river has been conducted by using the above-mentioned river-profile and the measured salt wedge lengths.

The analysis has been conducted by using the "Farmer-Morgan" formula. The formula is;

1) Length of salt wedge

$$\lambda K F_{i0}^2 = n_2^{*2}(3 - 2n_2^*) / 6 - F_{i0}^2 \{ n_2^* / (1 - n_2^*) + ln(1 - n_2^*) \}$$

$$\lambda = L_i / h_0 , \quad K = t_i / r_2 U_0^2 \quad n_2^* = h_2^* / h_0$$

$$F_{i0} = U_0 / \sqrt{\varepsilon g h_0} \quad \varepsilon = (r_2 - r_1) / r_2$$

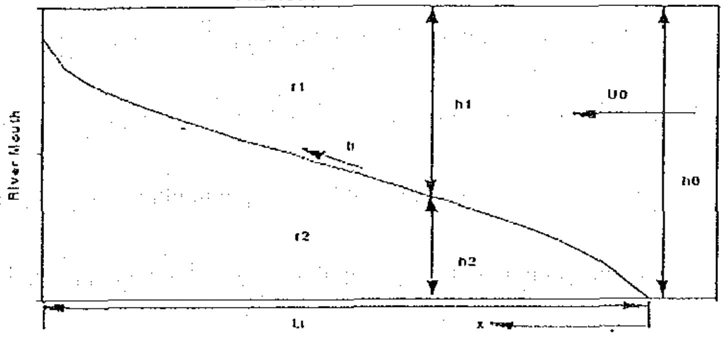
2) Profile of salt wedge

$$\chi / L_i = (n_2 / n_2^*)^2 (3 - 2n_2 / n_2^*) \quad n_2 = h_2 / h_0$$

where,

Li	: length of salt wedge
K	: non-dimensional resistance coefficient between two layers
t_i	: shearing stress between two layers
r_2	: density of sea water
r_1	: density of river water
U_0	: mean velocity of river water at the front of salt wedge
h_0	: total depth ($= h_1 + h_2$)
h_1	: depth of river water layer
h_2	: depth of salt wedge layer

PROFILE OF SALT WEDGE



The profiles of salt wedge are calculated for the following three cases of discharges and two cases of tide (high tide and low tide);

$Q_1 = 14.4\ m^3/s$ (Q_1 = 10 year drought without water intake for the Project)
$Q_2 = 12.2\ m^3/s$ ($Q_2 = Q_1$ – water intake for the 2010 demand)
$Q_3 = 10.0\ m^3/s$ ($Q_3 = Q_1$ – water intake for the 2020 demand)

high tide : elevation of tide = + 0.32 m MSL
low tide : elevation of tide = – 0.18 m MSL

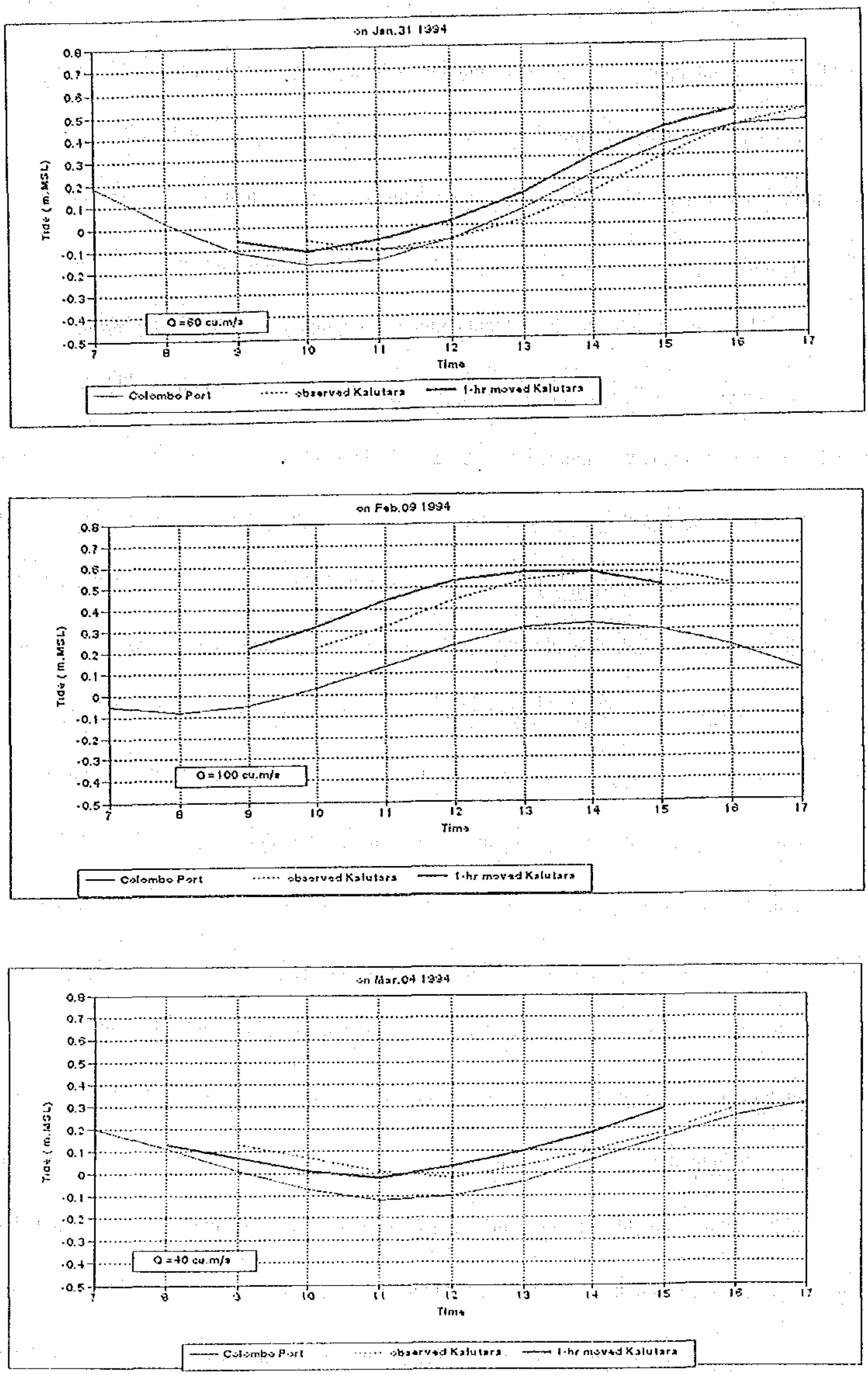


Figure 6.8 Water Level at Kalutara Bridge

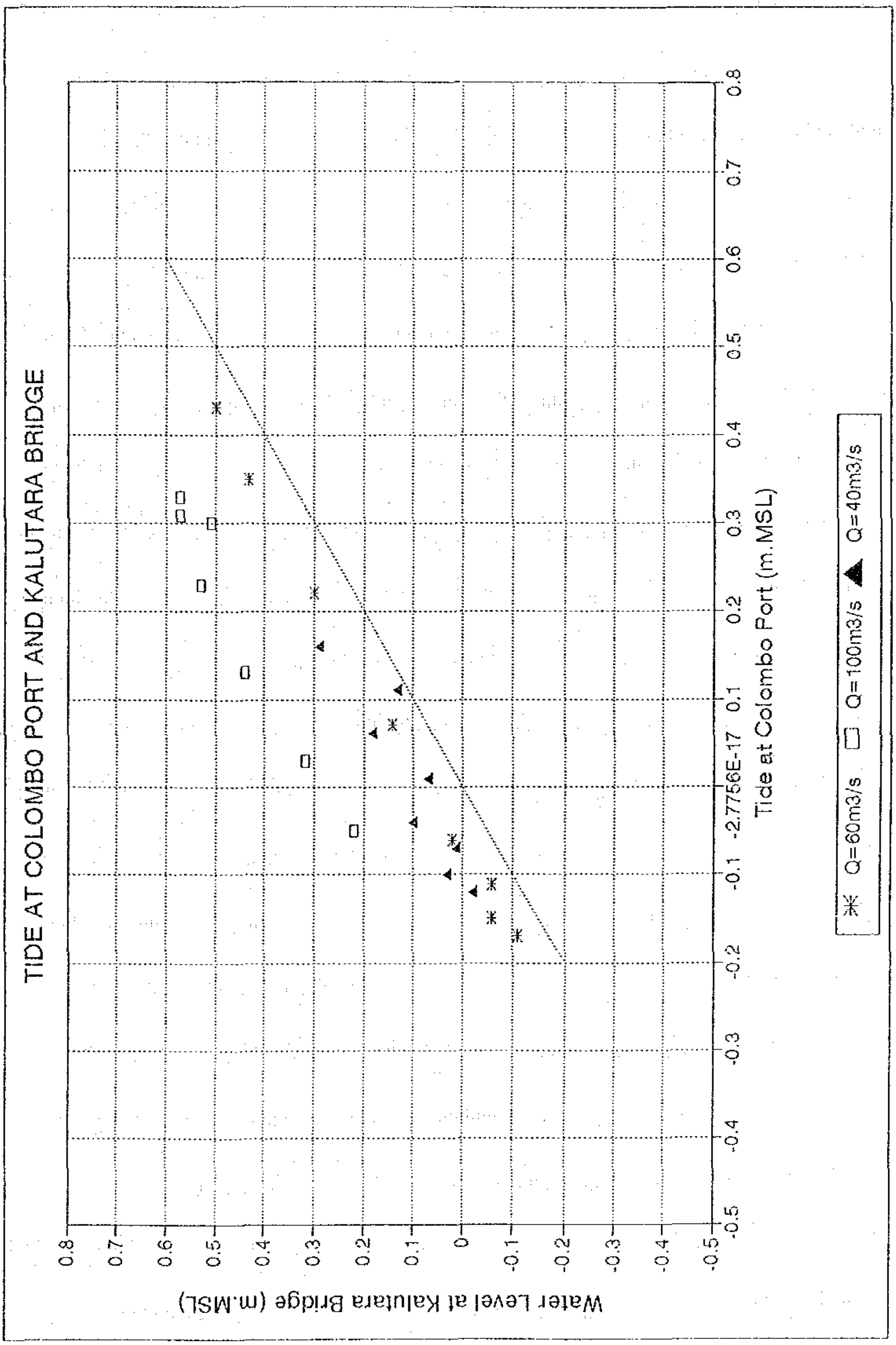


Figure 6.9 Tide at Colombo Port and Kalutara Bridge

The profiles are shown in Figures 6.10 (1) and (2). As seen in these Figures, the salt wedge reaches more upstream of the proposed water intake site for the case of high tide and the discharge of 10.0 m^3/s. For the other cases the saline water intrusion seems to be interrupted by the rather high river-bed in the reaches upstream of Kalutara intake. But this situation is not so definite as seen in the Figure. The reasons are as follows;

- River-bed elevations are measured only at around the center of the low-water channel and the measured river-bed are not always the mean elevation of the river-bed.
- River-bed elevations are not always the fixed ones. They will vary in the course of the time especially depending on the activities of sand mining that is now very active in the reaches downstream of the Kalutara intake. They also may vary if some flood control facilities are constructed in the downstream reaches in future.
- The river-mouth of the Kalu Ganga also changes its location depending on the movement of the littoral drift. According to the topographic map in 1980's, the location of the river-mouth was much closer to the Kalutara bridge. The present saline water intrusion analysis is made based on the present location of the river-mouth.
- The calculation model used for the analysis is a provisional one that is for rectangular cross-section, for the steady state and for the level river-bed.
- The high tide that is used for the analysis as the mean daily high tide in the past for the period of about 30 years, may higher in the actual situation of drought of 10-year return period.

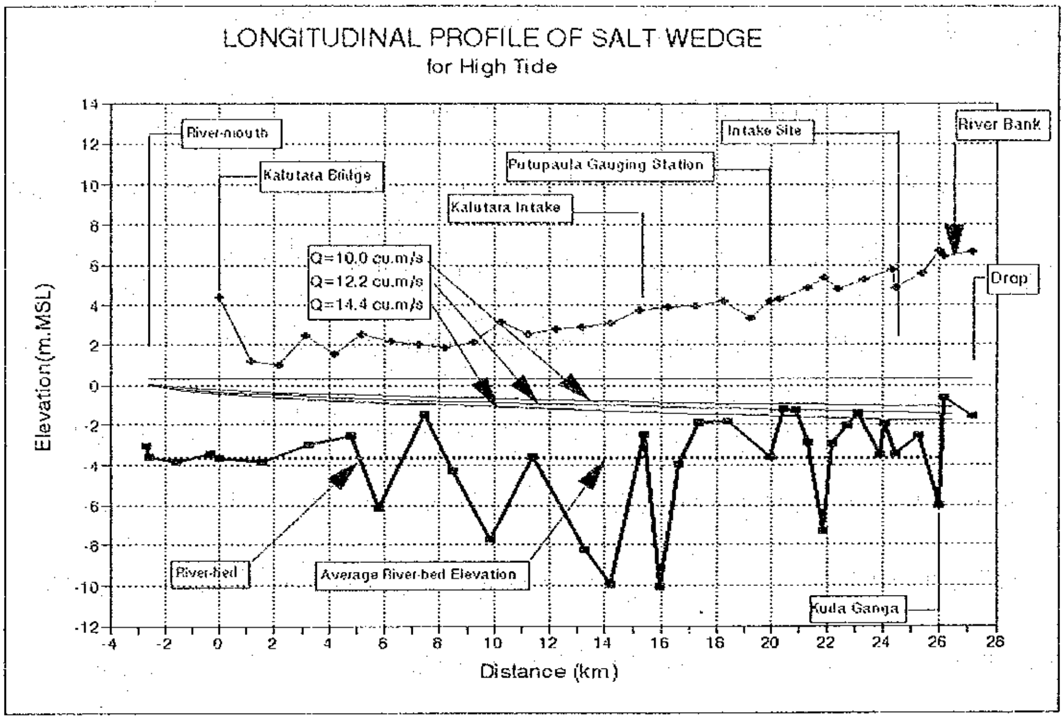
The elevations of salt wedge surface at the proposed water intake site are, on the assumption that the saline water intrusion will not be interrupted by the present river-bed situation, as follows;

for high tide

River flow after intake (minimum flow of 10 year return period)	Elevation of salt wedge surface
Q_1 = 14.4 m^3/s (no intake)	– 1.73 m MSL
Q_2 = 12.2 m^3/s (intake for 2010 demand)	– 1.38 m MSL
Q_3 = 10.0 m^3/s (intake for 2020 demand)	– 1.06 m MSL

for low tide

River flow after intake (minimum flow of 10 year return period)	Elevation of salt wedge surface
Q_1 = 14.4 m^3/s (no intake)	– 2.66 m MSL
Q_2 = 12.2 m^3/s (intake for 2010 demand)	– 2.17 m MSL
Q_3 = 10.0 m^3/s (intake for 2020 demand)	– 1.76 m MSL



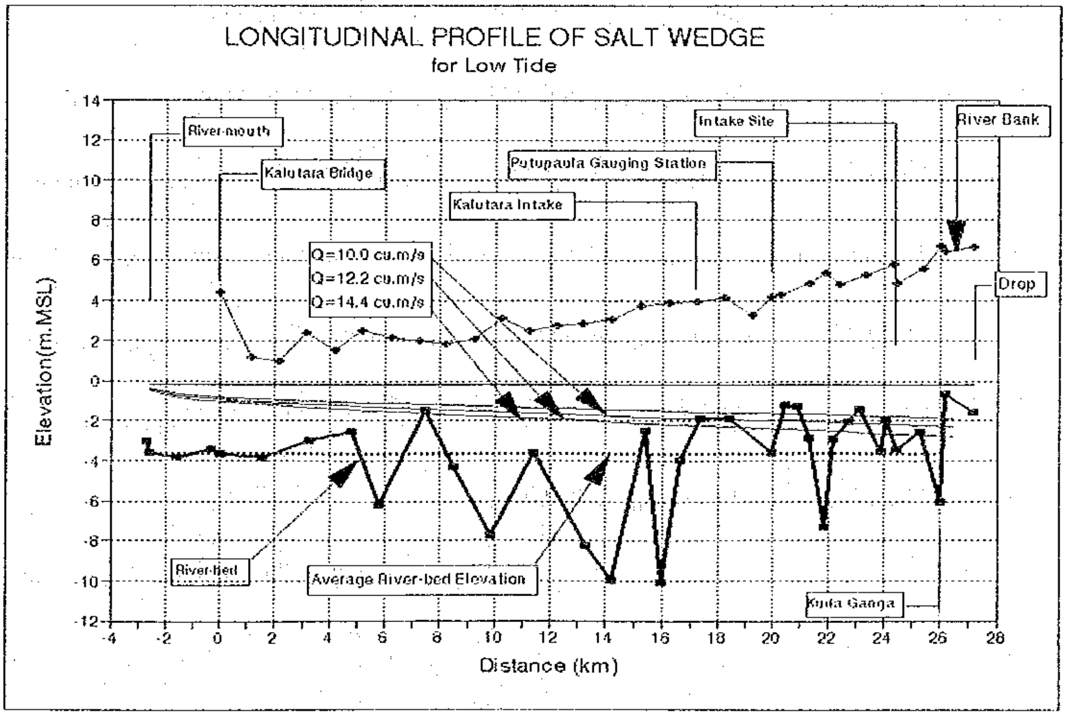


Figure 6.10 Longitudinal Profile of Salt Wedge

6.4.3 Recommendation for Future Study

The present analysis on the salt wedge is a provisional one, since the analysis is made on the assumption that the salt wedge is formed in a steady state in a river with a uniform width and level river-bed elevation, due to the insufficiency of necessary data on such as longitudinal and cross-sectional river profiles, hourly change of salt wedge profile and others.

For future study on the sea water intrusion in more detail, the existing conditions of the longitudinal and cross-sectional river profiles and hourly change of salt wedge profile should be surveyed. In addition, data on tide at the river mouth of the Kalu Ganga, the extent of sand mining in the downstream reaches of the Kalu Ganga at present and in the future, future flood control scheme in the downstream reaches including the treatment of river mouth against river mouth closure, etc. should be collected. And two-layer hydraulic model for unsteady flow condition should be constructed for analyzing the future situation on the saline water intrusion in the Kalu Ganga.

6.5 Safe Yield

6.5.1 Past Records at Putupaula Gauging Station

In the vicinity of the proposed intake points of the Kalu Ganga, the river water levels have been measured at Putupaula since 1943. Based on the daily discharges at Putupaula, the annual minimum flows from 1944 to 1986 were selected with replacement of some anomalous figures by reference to records at the Ellagawa gauging station by the previous study i.e., Greater Colombo Water Supply System Master Plan Update. These are shown in Table 6.5 and Figure 6.11. According to these Table and Figure, the annual minimum flows have been drastically changed in 1980's from 1970's. The reason for this change in the annual minimum flows was examined from the features of the rainfall, the discharges at upstream gauging stations and other factors as described in the following sub-section.

6.5.2 Discharges at Gauging Stations Upstream

The annual minimum flows at the Ellagawa gauging station are shown in Table 6.5 and in Figure 6.11. As shown in Figure 6.11, the annual minimum flows at the Ellagawa gauging station do not always show the same tendency with that of the Putupaula station.

Mean monthly discharges at the Putupaula, Ellagawa and Millakanda stations are shown in Data Report (Volume IV). Correlation of mean monthly discharges between Putupaula and Ellagawa, and Ellagawa and Millakanda are shown in Figures 6.12 and 6.13, respectively. correlations appear fairly meaningful. The basin ratios correspond to the ratio of monthly discharges between the two in the respective cases. The basin areas of the Putupaula, Ellagawa and Millakanda stations are 2,598 km^2, 1,393 km^2 and 769 km^2, respectively.

The basin rainfalls at Putupaula and Ellagawa are shown in Data Report (Volume IV). Correlation between the two is shown in Figure 6.14. As shown in Figure 6.14, the basin rainfalls of the two stations are nearly the same and this means that the mean monthly discharges of the two should be corresponding to the basin area. This view is also supported by the fact that the correlation of the mean monthly discharges at Ellagawa and Millakanda is fairly good and the ratio of the mean monthly discharges is corresponding to the ratio of the two basin areas. The Millakanda gauging station is located along the Kuda Ganga that is one of the main tributaries of the Kalu Ganga.

Notwithstanding these facts, only the annual minimum flows at Putupaula do not show the same tendency with that of Ellagawa. As seen in data of the daily flows at Putupaula and Ellagawa, even when the daily flows continuously receded at Ellagawa, those at Putupaula did not always recede. The record shows that the flow at Putupaula sometimes increased when the flow at Ellagawa receded. This phenomena must be derived from the tidal fluctuation in the ocean as described in the following sub-section.

6.5.3 Tidal Influence

The daily flows at the gauging stations of the Kalu Ganga are calculated from the daily water levels and the discharge rating curves. The daily water levels are calculated based on the hourly water levels. As one of the typical cases, the hourly water levels in the period of early 10 days in February 1987 are shown in Figure 6.15. As shown in Figure 6.15, the hourly water levels at Putupaula go up and down with two peaks a day just like a tidal movement even in the period of continuous flow recession at the Ellagawa station and of no rainfall in the basin. The tidal levels in this period at the Colombo Port recorded by the Ports Authority are also shown in Figure 6.15. Though the amplitude of the water level fluctuation is much different, the fluctuation movements in the tidal levels and the river water levels are same. This should be the only reason why the daily flow at Putupaula fluctuates on daily basis even when the daily flow at Ellagawa continuously recedes with no rainfall in the both basins. This occurs only during the very low flow. Accordingly this does not contribute to the accordance of the ratio of the monthly discharge between Putupaula and Ellagawa and the basin ratio with the nearly same basin rainfall.

Table 6.5 Annual Minimum Flow at Putupaula and Ellagawa

No .	Year	Q_{Min}* Putupaula (m^3/s)	Q_{Min} Ellagawa (m^3/s)	Q_{Min}** Putupaula (m^3/s)	No .	Year	Q_{Min}* Putupaula (m^3/s)	Q_{Min} Ellagawa (m^3/s)	Q_{Min}** Putupaula (m^3/s)
1	1944	34			26	1969	70	14	26
2	1945	48			27	1970	57	19	35
3	1946	46			28	1971	80	17	32
4	1947	25			29	1972	69	9	17
5	1948	15			30	1973	69	9	17
6	1949	40			31	1974	36	8	15
7	1950	49			32	1975	25	15	28
8	1951	27			33	1976	18	9	17
9	1952	44			34	1975	15	10	19
10	1953	38			35	1978	25	12	22
11	1954	46			36	1979	19	8	15
12	1955	60			37	1980	18	12	22
13	1956	29			38	1981	22	13	24
14	1957	32			39	1982	13	12	22
15	1958	40			40	1983	12	11	21
16	1959	45			41	1984	20	13	24
17	1960	35			42	1985	14	13	24
18	1961	11			43	1986		21	39
19	1962	71			44	1987		11	21
20	1963	84			45	1988		6	11
21	1964	75			46	1989		10	19
22	1965	70			47	1990		12	22
23	1966	75	19	35	48	1991		7	13
24	1967	71	17	32	49	1992		10	19
25	1968	65	19	35	50	1993		13	24

Note: * Estimates in Master Plan Update
** Estimates in this study

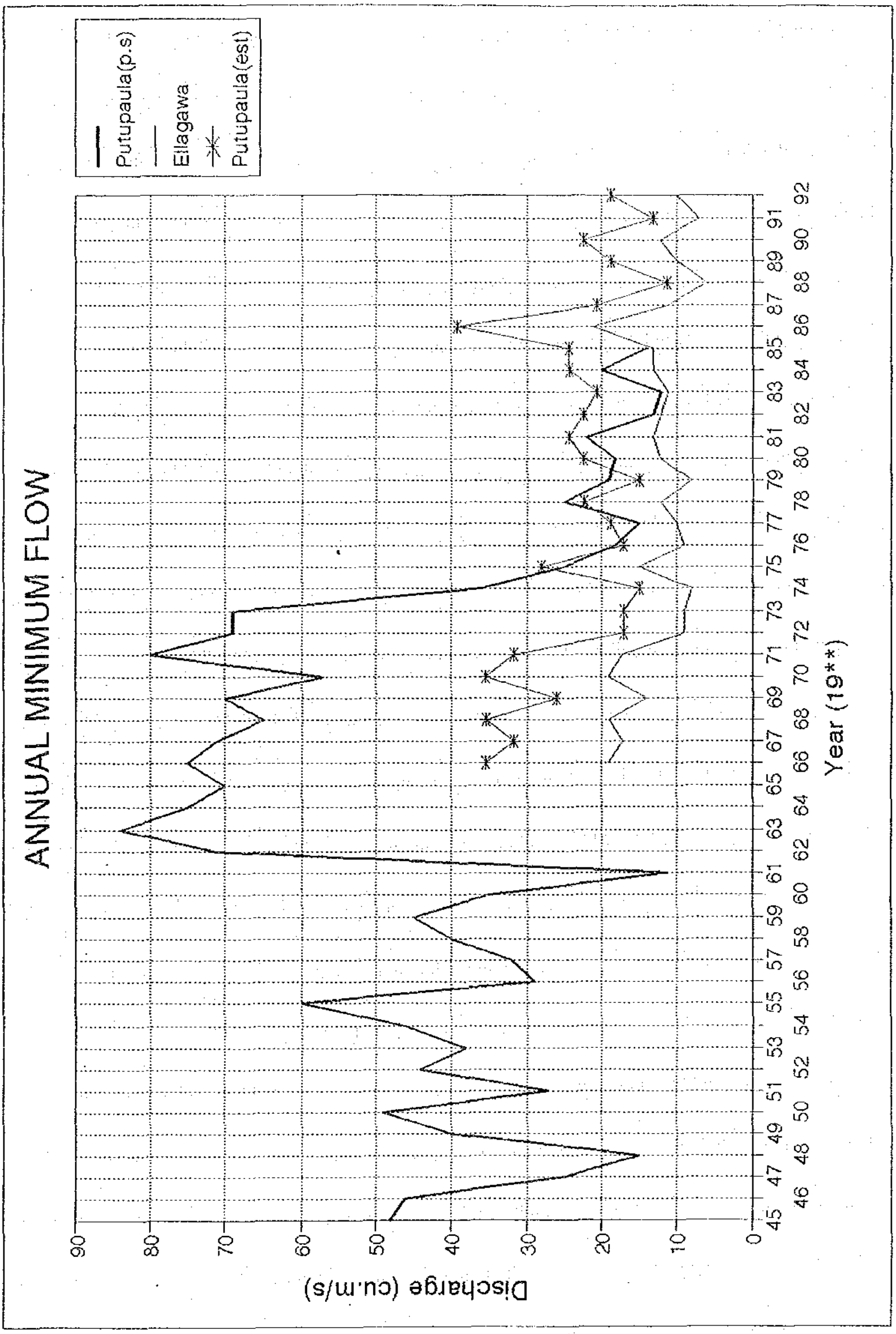


Figure 6.11 Annual Minimum Flow at Putupaula and Ellagawa

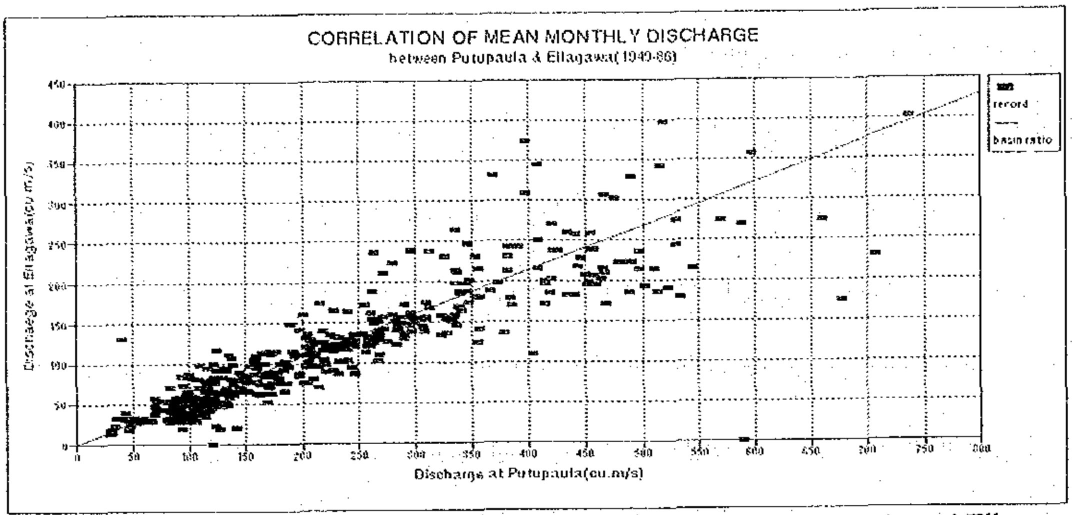


Figure 6.12 Correlation of Mean Monthly Discharges between Putupaula and Ellagawa

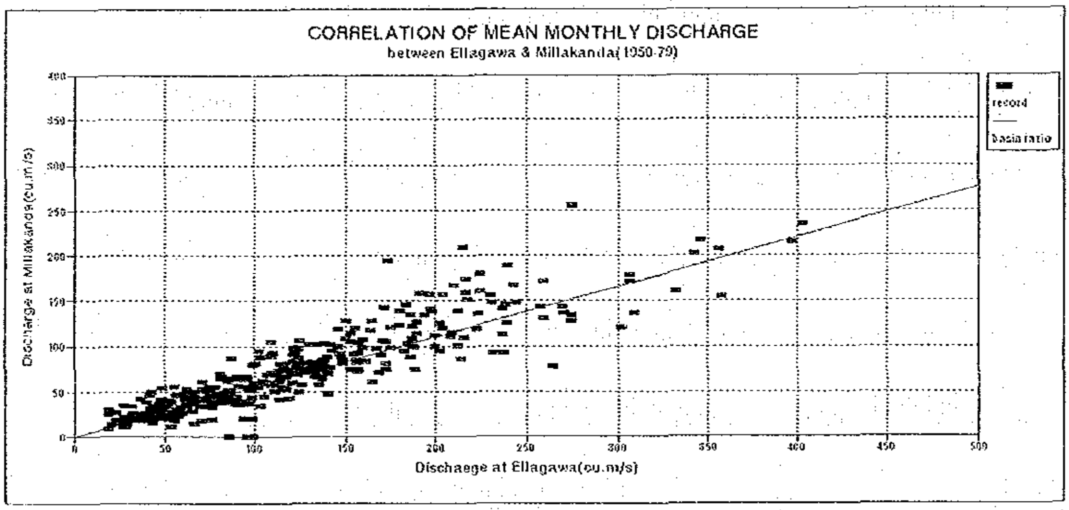


Figure 6.13 Correlation of Mean Monthly Discharges between Ellagawa and Millakanda

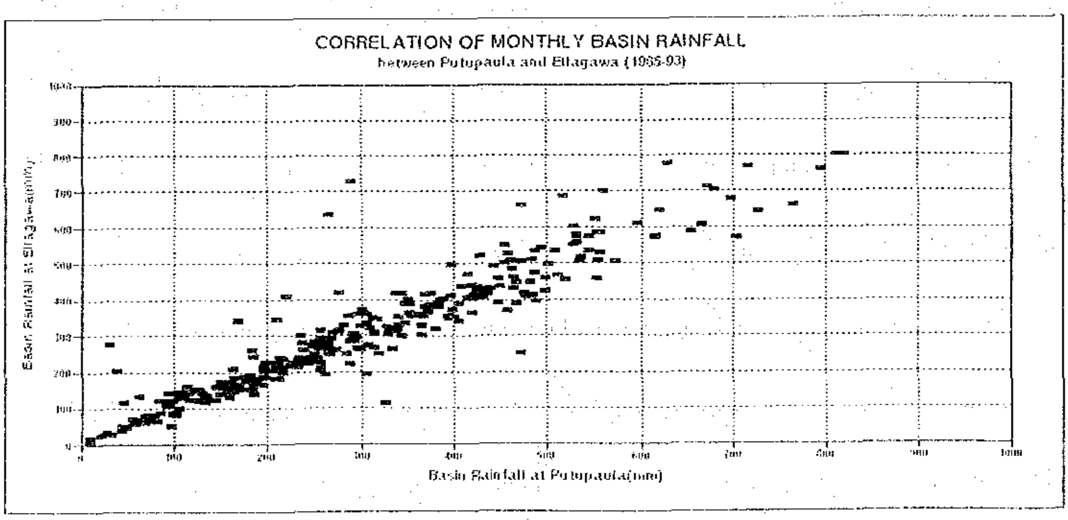


Figure 6.14 Correlation of Rainfall between Putupaula and Ellagawa

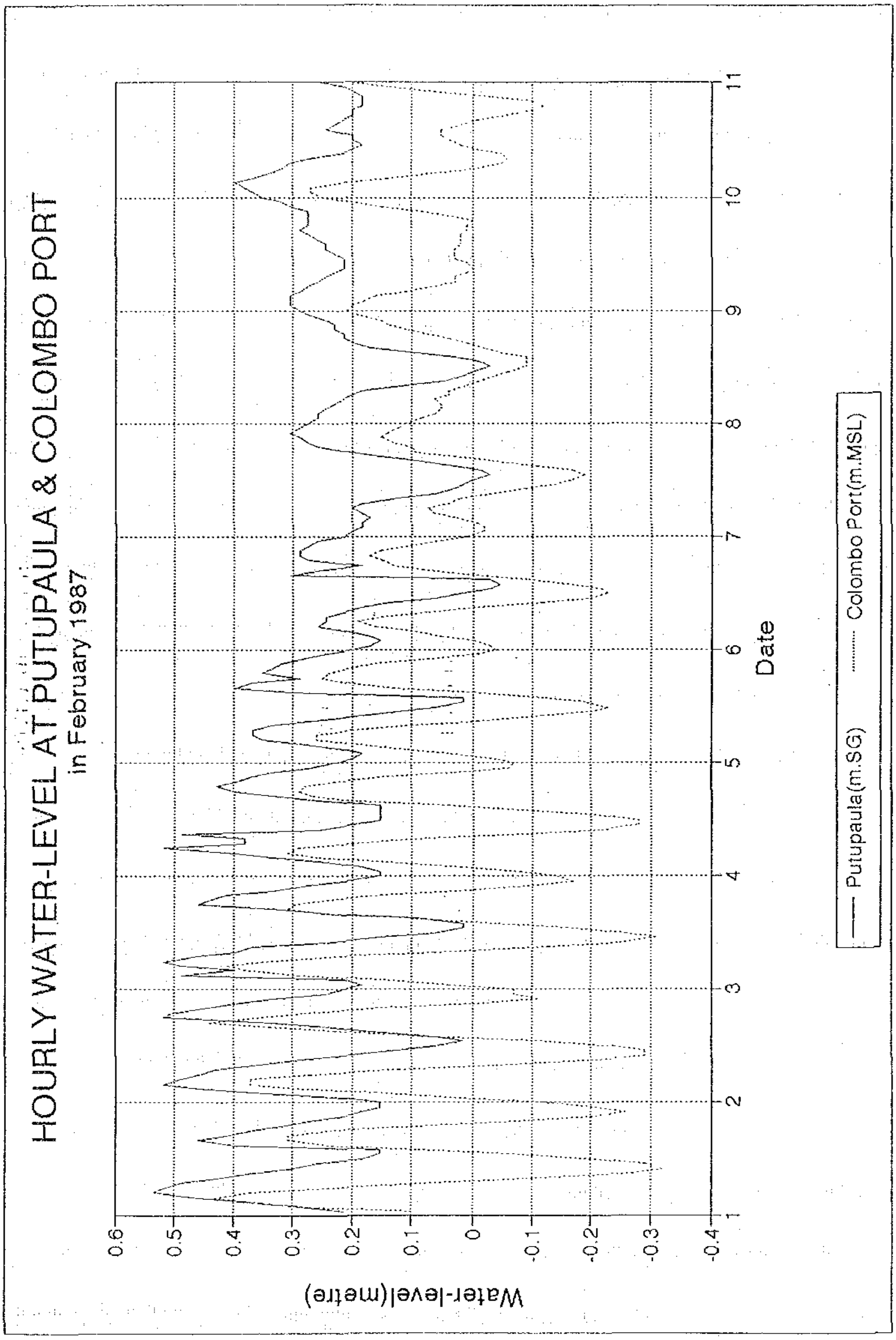


Figure 6.15 Hourly Water Levels (February 1987)

6.5.4 Annual Minimum Flow at Putupaula

With the above mentioned consideration, the annual minimum flows at the Putupaula station are calculated by multiplying the basin ratio between the Putupaula and Ellagawa stations to the annual minimum flows at the Ellagawa station. Thus estimated annual minimum flows at the Putupaula gauging station are shown in Table 6.5 and Figure 6.11 in Section 6.5.1.

6.5.5 Probable Annual Minimum Flow at Putupaula

Probability analysis on the annual minimum flows at the Putupaula gauging station is conducted by using the log-normal method and Gumbel method. These are shown in Figures 6.16 and 6.6, respectively. As seen in these Figures, Gumbel method shows rather good accordance with the non-exceeding probability of annual minimum flow at Putupaula. The summary of the probable annual minimum flows at Putupaula is shown in Table 6.6.

Table 6.6 Summary of Probable Minimum Flow at Putupaula

Return Period (year)	Probable Annual Minimum Flow by Gumbel Method (m^3/s)
5	16.7
10	14.4
20	12.7
30	11.9

6.5.6 Existing Water Use

Existing water use along the Kalu Ganga in the objective reaches are the industrial use rather than water supply. The total amount is estimated as about 0.35 m^3/s.

Other than these, in the reaches downstream of the Narthupana Bridge, the water transport seems active as many ferry facilities are found.

The other use was not presently observed. No major future use of the river water is proposed other than the Kukulegama Power Generation Project as discussed in the previous section.

6.5.7 River Maintenance Flow

For any development plan of river water use, river maintenance flow should be taken into consideration. At present, no river law nor any regulation on the river maintenance flow other than the environmental acts are in force for the Kalu Ganga.

The river maintenance flow should generally be determined on the basis of the factors such as water transportation, fishery, natural view, protection of saline water intrusion, protection of river mouth closure, protection of river facilities, maintenance of underground water table, protection of flora and fauna, maintenance of water quality, existing water use, etc. The main factor affecting the river water level during the low flow period is not an amount of discharge itself but is a tidal level.

One of major factors for the river maintenance flow is possibility of river mouth closure. River mouth closure is a combined phenomena related to low discharge and littoral drift along the sea shore. Presently the river mouth of the Kalu Ganga is much influenced by the littoral drift. The river mouth is rather small in the dry season even though the basin is wide. Even now the river mouth has to be dredged to widen by the Department of Irrigation prior to coming rainy seasons.

Another important purpose of keeping the river maintenance flow is the maintenance of water quality from the view point of environment and the maintenance of flora and fauna in the river. Presently, however there is no standard on the river water quality in the form of a regulation or law.

6.5.8 Available Water of the Kalu Ganga

Regarding the quantity, the discharge of the Kalu Ganga is estimated at 14.4 m^3/s for the drought of which the return period is 10 years. The return period of a drought on which the water supply plan should be based on, may need to be discussed in consideration of the social welfare situation and from the view point of social service. Although there still remains the issue on the river maintenance flow, the determination of necessary maintenance flow has to wait for further study.

For quality in particular on the saline water intrusion, further detail study is needed. But as discussed in a previous section, according to the provisional analysis, the salt water wedge may reach rather far in the downstream reaches of the Kalu Ganga for the low flow for the return period of 10 years.

The elevations of salt water wedge at the proposed intake site are estimated as follows:

Case No.	Q	High Tide (+0.32 m MSL)	Low Tide (-0.18 m MSL)
1	14.4 m^3/s	H = 1.73 m MSL	H = 2.66 m MSL
2	12.2 m^3/s	H = 1.38 m MSL	H = 2.17 m MSL
3	10.0 m^3/s	H = 1.06 m MSL	H = 1.76 m MSL

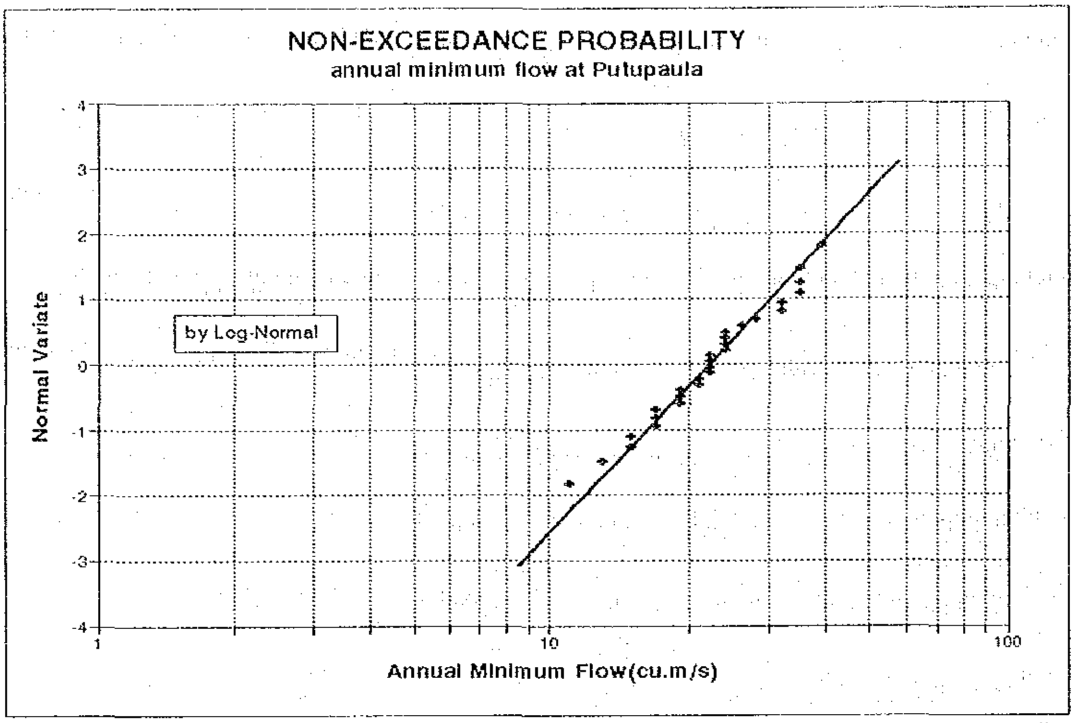


Figure 6.16 Annual Minimum Flow Probability Analysis (Log-Normal Method)

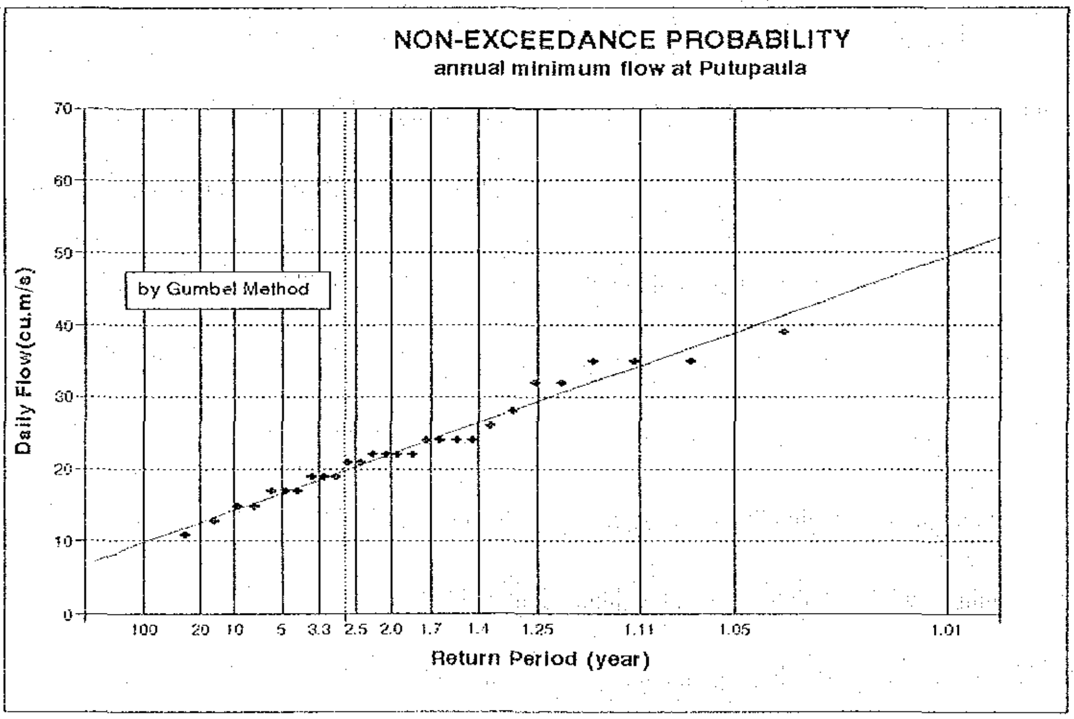
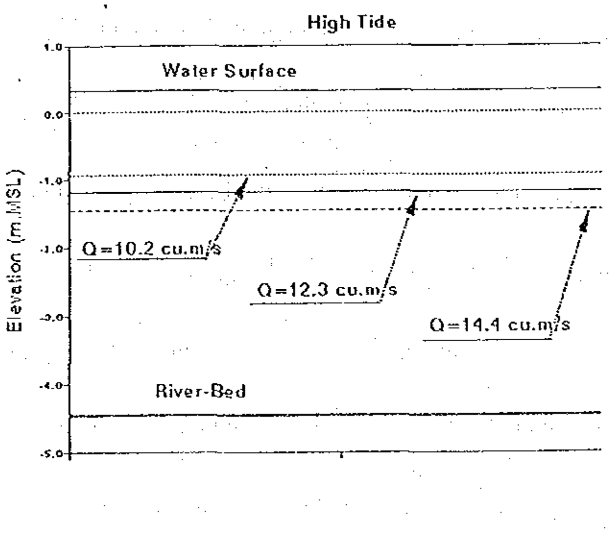


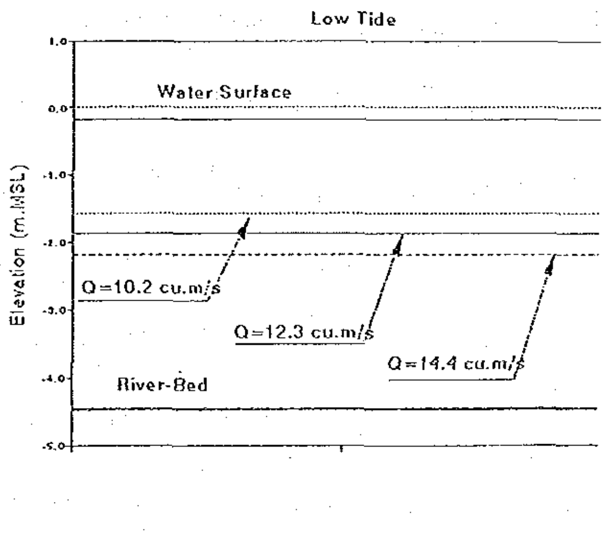
Figure 6.17 Annual Minimum Flow Probability Analysis (Gumbel Method)

Here Case 1 corresponds to the case without any water withdrawal, Case 2 corresponds to the low flow for the water withdrawal in the year 2010 and Case 3 corresponds to that in the year 2020, and H is the elevation of salt wedge for the respective case.

The above situation is shown below schematically. As seen in the below diagram, even in Case 3, the surface of salt wedge at the time of low tide is still lower than that of case without any water withdrawal at the time of high tide.

At the proposed intake site, the depth of a layer of fresh water is estimated at approximately 1.4 m on the saline water wedge with the river discharge of 10.0 m^3/s after the water intake (14.4 m^3/s minus 4.4 m^3/s withdrawal for 2020 demand) and at the time of the high tide. This may suggest that the proposed water withdrawal at the proposed intake site be still possible without such serious influence of saline water.





In consideration of various unknown mechanism and factors on the functions of river maintenance flow of the Kalu Ganga at present, it might be suggested that the water withdrawal in the downstream reaches be tentatively limited within the range that the minimum flow after water withdrawal for the return period of 10 years is more than the past minimum flow of 11 m^3/s. This can be understood that the plan would not worsen the situation in the past natural situation.

In consideration of the above view point, the fact that the accuracy of low flow at Putupaula is rather limited due to the procedure of the estimate of low flow as discussed in previous section, and the fact that the accuracy of the saline water intrusion analysis is rather limited as discussed in previous section, the water withdrawal from the Kalu Ganga could not exceed the proposed one in the year 2020 that may lead to the minimum flow of the Kalu Ganga in the downstream reaches at 10.0 m^3/s for the return period of 10 years.

But this view might be updated in the future with further sufficient data on the related aspects.

6.6 Water Quality

6.6.1 Historical Data

Only a limited amount of historical data has been found relating to water quality in the Kalu Ganga. Fragmented records are available from 1967 but cover very few parameters. These are summarized in Table 6.7. The widest range of parameters was examined on four separate days; 8th January 1990, 17th December 1990, 5th February 1991 and 23rd May 1991. These results are presented in Table 6.8.

The data for 1967 and 1968 were obtained from the files at the NWSDB Central Laboratory and from the log books since 1985 at the Kalutara Treatment Plant. The accuracy of the log book data is considered to be suspect with regard to the pH values, conversations with various people indicated that the pH measuring instrument was rarely calibrated and the probe was found to be defective. Recent pH determinations have been carried out using a comparator. The turbidity figures on the other hand were judged to be realistic.

The 1967/68 data and the data (turbidity and pH) from the Kalutara Treatment Plant log book are presented in tabular and graphical form in Data Report (Volume IV).

The turbidity data shows that, for periods of up to two months, the turbidity of the Kalu Ganga can be below the Sri Lankan maximum permissible drinking water standard of 8 JTU (equivalent to 8 NTU), and this situation generally occurs in January and February. Figures below 5 NTU are common for weeks at a time. Turbidities above 70 NTU occur infrequently and only for a very short period, sometimes only hours. High figures generally occur in the months of April to June and from October to December. The average of all the recorded values from the Kalutara log books is 20.5 NTU, though monthly average values vary between 2.4 and 52.1 NTU. 1992 was a particularly dry year with an average turbidity of 12.6 NTU, and 1993 had more normal rainfall with an average turbidity of 19.3 NTU.

The pH values quoted in the Kalutara Treatment Plant log books are mostly around the neutral point of 7.0 pH units. The overall recorded range lies between 5.89 and 7.9 pH units. Waters with naturally occurring pH values as low as 5.89 are not common and are almost always very soft waters originating from peat moorlands. In such cases the pH values are consistently low. One possible explanation (aside from defective equipment) is that acid waste from a rubber factory had been discharged to the river upstream of the treatment plant intake. The river water has a very low buffering capacity and it's pH could be significantly affected by such an event.

From the data in Table 6.8, the 08/01/90 figures would suggest that some degree of saline intrusion may have been present at the plant intake. The sets of data for the other three days are reasonably consistent, showing the river water to have variable but low turbidity, to be soft, low in color, alkalinity, dissolved solids and chlorides. The iron figures appear to be high but they are for total iron. Tests carried out during the study period showed that the majority of the iron is in suspension, not in solution and will be readily removed by a conventional water treatment plant.

A few color values are presented in the 1986 data, ranging from 50 to 100. No units are quoted but it must be assumed they are equivalent to degrees Hazen. The values given in the data from 1990/91 show the color to be below 5 degrees Hazen in all cases. The 1986 color values increase with turbidity and therefore were most likely measured as 'apparent' color which would explain their high values. The 1990/91 would have been measured as 'true' color i.e. after filtration through a 0.45 micron membrane filter.

Table 6.7 Summary of Available Analytical Data

Year	Months for which Data is Available												Parameter					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	pH	Turbidity	EC	Alk	Sal	Iron
'67										x	x	x	x	x	x		x	x
'68	x	x											x	x	x		x	x
'85												x	x	x		x		
'86	x				x								x	x		x		
'87												x	x					
'88					x	x	x	x	x		x			x				
'88	x	x	x	x	x	x	x	x	x		x		x					
'89					x	x	x	x	x	x	x	x		x				
'90	x													x				
'91								x	x	x	x	x	x	x				
'92	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
'93	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
'94	x												x	x				

Table 6.8 Raw Water Quality of the Kalu Ganga at the Kalutara Water Plant

Parameter	8 Jan. '90	17 Dec. '90	5 Feb. '91	23 May '91
Appearance	Clear	Turbid	Slightly Turbid	Clear
Turbidity: Unsettled (NTU)	7.9	22	9.4	0.9
pH	7.9	7	7.1	7.6
Electrical Conductivity (μS/cm)	270	38	50	85
Chlorides (as Cl)	48	10	9	10
Total Alkalinity (as $CaCO_3$)	104	29	24	42
Total Hardness (as $CaCO_3$)	78	26	19	42
Total Dissolved Solids	180	25	30	55
Nitrites (as N)	Trace	Trace	Trace	Trace
Nitrates (as N)	0.06	Minute Trace	0.02	Minute Trace
Iron Total (as Fe)	1	1.8	1.4	0.08
Color (Hazen Scale)	Less than 5	Less than 5	Less than 5	Less than 5

6.6.2 Investigation Results and Evaluation

(1) Sampling and Results.

To confirm the existing data and to extend the range of parameters, four sampling exercises were carried out during the study period. Two during the dry season and two during the wet. It was unfortunate however that a considerable amount of rain fell during the dry season and the river water quality was not truly representative of dry weather flow.

In the dry season, samples were taken using a depth sampler at points about 1 m above the river bed. In the wet season the flow in the river was too strong and the depth sampler could not be used. The turbulent condition of the river during this time would however have made the samples representative of the average water quality. The suspended solids load close to the river bed may well have been much higher with scoured sand and silt.

On all four occasions samples were taken at the same two locations, at Narthupana bridge and from a point close to the bridge near Pahala Naragala. The dates of sampling were January 24th and 28th and June 10th and 25th 1994. The sample point locations are given in Figure 6.18.

With the exception of the analyses for mercury, arsenic and anionic surfactants, which were performed by the laboratory of the NBRO, the analyses were carried out by the Central Laboratory of the NWSDB. The results are presented in Table 6.9.

Additional surface samples were taken by the study team and analyzed using a Hach DR 2000 portable laboratory. The results of these analyses are given in Table 6.10.

(2) Evaluation.

Examination of the data presented in Tables 6.9 and 6.10 show little meaningful variation in the values of the various parameters. With the exception of the bacteriological figures, some of the turbidity and ammonia figures and one nitrite figure, all comply with the Sri Lankan maximum permissible levels for drinking water (see Table 6.11). The maximum desirable levels are exceeded in some cases by bacteria, pH (below a minimum of 7.0), color, turbidity, ammonia, nitrite, and iron. All of the exceedence values will be reduced to well below acceptable levels by conventional water treatment processes.

Comparison of the water quality data with the proposed Sri Lankan Water Quality Standards for Different Uses (Table 6.12) shows that the Kalu Ganga complies with the criteria for "Drinking Water, Conventional Treatment". The "E.C. Regulations - Characteristics of Surface Waters Intended for the Abstraction of Drinking Water", are reproduced as Table 6.13. This regulation places the Kalu Ganga water under category A2 which also signifies conventional treatment.

From the data in Tables 6.9 and 6.10, the Kalu Ganga river water can be characterized as having low to medium turbidity and color, soft, with low alkalinity, chlorides and dissolved solids. The relatively high sulphate figures which appear in some of the columns in Table 6.9 must be viewed with suspicion. Such figures cannot be correct as they exceed the dissolved solids/EC figures by a significant amount. No heavy metals were found to be present.

The nitrate and phosphate figures are high enough to support significant algal growth. This should not pose any problems provided the raw water is fed directly to the treatment process stages from the intake facility. Some algal growth will inevitably take place on channel and tank walls in the phototrophic zone, principally filamentous types. This should be cleaned off regularly to prevent interference with the operation of the plant.

Comparison with the analyses for the Kelani Ganga at Ambatale (Table 6.14) show that the rivers are broadly similar, though some of the Kelani Ganga EC values indicate the presence of saline water on occasions.

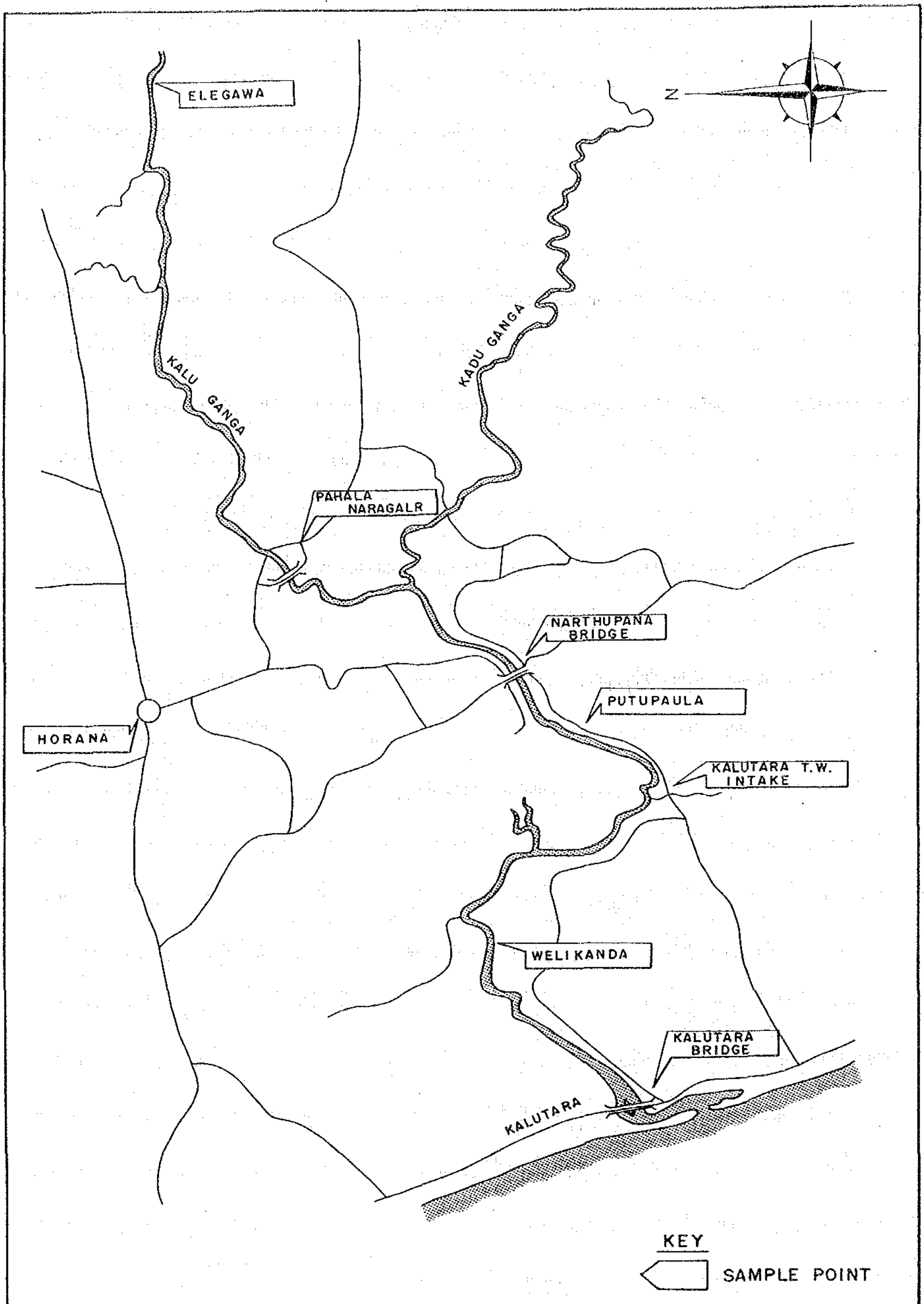


Figure 6.18 Sample Point Locations

Table 6.9 Kalu Ganga Water Analyses (NBRO Laboratory, 1994)

Parameter	Unit	Pahara Naragara				Narthupana Bridge			
		24 Jan.	28 Jan.	10 Jun.	25 Jun.	24 Jan.	28 Jan.	10 Jun.	25 Jun.
pH	pH unit	6.6	7.0	6.98	6.42	6.6	6.8	6.3	6.4
Temperature	°C	28.0	28.0	28.0	28.0	28.5	28.0	28.0	28.0
Odor	-	N-O	N-O	N-O	N-O	N-O	N-O	N-O	N-O
Color	°Hazen	30	5.0	10.0	5.0	10.0	10.0	5.0	5.0
Turbidity	NTU	30	7.0	20.0	7.0	17.7	7.5	10.0	4.5
Alkalinity	mg/l as $CaCO_3$	14	25.0	8.0	7.0	10.0	15.0	11.0	4.0
E.C.	μS/cm	48	60.0	44.6	45.2	40.0	44.0	43.4	53.4
Cadmium	mg/l as Cd	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium	mg/l as Mg	1.46	3.16	5.0	ND	1.22	1.22	ND	0.61
Sulphate	mg/l as SO_4	ND	70.0	ND	ND	50.0	70.0	ND	1.0
Ammonia	mg/l as N	0.15	0.07	0.12	0.06	0.15	ND	0.11	0.01
Nitrite	mg/l as N	0.006	MT	0.005	0.006	0.01	MT	0.001	0.03
Nitrate	mg/l as N	trace	trace	0.7	0.2	trace	trace	0.06	0.02
Chloride	mg/l as Cl	10.0	7.0	3.0	3.0	8.0	7.0	3.0	3.0
Cyanide		ND	ND	ND	ND	ND	ND	ND	ND
Mercury	mg/l as Hg	ND	ND	ND	ND	ND	ND	ND	ND
O-Phosphate	mg/l as PO_4	<0.04	<0.04	0.17	0.02	<0.04	<0.04	0.01	0.01
Copper	mg/l as Cu	ND	ND	ND	ND	ND	ND	ND	ND
T-Iron	mg/l as Fe	0.63	0.24	0.83	0.27	0.20	0.24	0.58	0.30
Selenium	mg/l as Se	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	mg/l as Mn	ND	ND	ND	ND	ND	ND	0.1	ND
Zinc	mg/l as Zn	ND	ND	ND	ND	ND	ND	ND	ND
Lead	mg/l as Pb	ND	ND	ND	ND	ND	ND	ND	ND
H-Chromium	mg/l as Cr	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	μg/l as As	ND	ND	ND	ND	ND	ND	ND	ND
Fluoride	mg/l as F	0.5	0.6	0.02	0.14	0.5	0.6	0.08	0.07
T-Hardness	mg/l as $CaCO_3$	18.0	8.0	11.0	4.0	14.0	17.0	9.0	5.0
T-Solids	mg/l	114.0	60.0	34.0	16.0	34.0	54.0	12.0	6.0
S-Solids	mg/l	89.0	20.0	5.0	5.0	9.0	34.0	2.0	2.0
D-Solids	mg/l	25.0	40.0	29.0	11.0	25.0	20.0	10.0	4.0
A-Surfactant	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
T-Coliforms	MPN	-	-	>1,100	75	>1,100*	-	>1,100	93
E-Coli	MPN	-	-	460*	nil	TNTC*	-	1,000	ND
$KMnO_4$ Value	mg/l	0.8	0.3	0.3	0.65	0.1	0.5	0.5	0.7

Key:

N-O	Non-Objectionable	ND	Not Detected
MT	Minute Trace	O	Organic
H	Hexa	T	Total
S	Suspended	D	Dissolved
A	Anionic	MPN	Most Probable Number
*	Sampled on 28/06/94		

Table 6.10 Kalu Ganga Water Analyses (HACH portable laboratory, 1994)

Parameter	Unit	Kalutara Bridge	Putupaula	Ellagawa	Narthupana Bridge	Pahara Naragala	Putupaula	Wellkanda	Narthupana Bridge
		31 Dec 93	19 Jun 94	19 Jan 94	28 Jan 94	28 Jan 94	28 Jan 94	31 Jan 94	03 Feb 94
Temp.	°C		26.2	26.0	26.4	26.2	26.3	29.1	27.5
pH	pH unit		6.56	6.76	7.02	7.13	7.00	7.17	7.51
Turbidity	NTU		-	-	-	-	-	-	-
Total Hardness	mg/l as $CaCO_3$	8.0	10.0	16.0	18	28			19
Total Alkalinity	mg/l as $CaCO_3$	4.0	7.0	11.0	17	25			18
Sulphate	mg/l as SO_4	1.0	ND	ND	ND	ND			ND
Chloride	mg/l as Cl	-	<4.0	4.0	-	3.0			5.0
Nitrate	mg/l as N	-	0.6	0.2	0.4	0.5			1.1
Phosphate	mg/l as PO_4	-	0.14	0.01	0.05	0.01			0.01
Iron	mg/l as Fe	0.92+	0.22*	0.30*	0.38*	0.23*			ND
Manganese	mg/l as Mn	-	ND	ND	ND	ND			ND
E.C.	μS/cm	-	34.7	51.9	91.0	74.2	60.2	59.5	55.7
Langellier Index		-	-3.14	-2.74	-2.08	-1.77			-1.94

ND : Not Detected + : Total * : Settled

Table 6.11 Drinking Water Standard

Parameter	Units	Sri Lankan Standard		UK/EC	WHO
		MDL	MPL	MPL	Guideline
Color	deg. Hazen	5.0	30.0	20.0	15.0
Odor	-	N-O	N-O	-	N-O
Taste	-	N-O	N-O	-	N-O
Turbidity	JTU	2.0	8.0	4.0	5.0
pH	pH units	7.0-8.5	6.5-9.0	5.5-9.5	6.5-8.5
E.C.	micro S/cm	750	3,500	1,500	-
Chloride	mg/l Cl	200	1,200	400	250
Chlorine (free)	mg/l Cl_2	-	0.2	-	-
Alkalinity (T)	mg/l $CaCO_3$	200	400	30 (min)	-
Ammonia	mg/l N	-	0.06	0.39	-
Anionic detergents	mg/l	0.2	1.0	0.2	-
Phenolic compound	mg/l OH	0.001	0.002	0.5	-
Grease and oil	mg/l	-	1.0	-	-
Calcium	mg/l Ca	100	240	250	-
Magnesium	mg/l Mg	30	140	50	-
Albuminoid NH_3	mg/l N	-	0.15	-	-
Nitrate	mg/l N	-	10.0	-	-
Nitrite	mg/l N	-	0.01	0.03	-
Fluoride	mg/l F	0.6	1.5	1.5	1.5
Phosphate (T)	mg/l PO_4	-	2.0	2.2	-
Residues (T)	mg/l	500	2,000	1,500	1,000
Hardness (T)	mg/l $CaCO_3$	250	600	60 (min)	500
Iron (T)	mg/l Fe	0.3	1.0	0.2	0.3
Sulphate	mg/l SO_4	200	400	250	400
Copper	mg/l Cu	0.05	1.5	3.0	1.0
Manganese	mg/l Mn	0.05	0.5	0.05	0.1
Zinc	mg/l Zn	5.0	15.0	5.0	5.0
Aluminium	mg/l Al	-	0.2	0.2	0.2
Pesticide resid.	mg/l	-	as WHO	0.5	*
C.O.D.	mg/l O_2	-	10	5.0	-
Arsenic	mg/l As	-	0.05	0.05	0.05
Cadmium	mg/l Cd	-	0.005	0.005	0.005
Cyanide	mg/l CN	-	0.05	0.05	0.05
Lead	mg/l Pb	-	0.05	0.05	0.05
Mercury	mg/l Hg	-	0.001	0.001	0.001
Selenium	mg/l Se	-	0.01	0.01	0.01
Chromium	mg/l Cr	-	0.05	0.05	0.05

MDL : Maximum Desirable Level
MPL: Maximum Permissible Level
(T): Total
* WHO has a list of individual pesticide types but no overall figure.
Source: NWSDB and Department of the Environment, UK

Table 6.12 Sri Lankan Proposed Inland Water Quality Standards for Different Uses

Parameter	Unit Type of limit	Drinking water with simple treatment	Bathing	Fish and aquatic life	Drinking water convent. treatment	Minimum quality
Color	Hazen unit max.	5 des. 30 max.	-	-	3--	-
Odor		unobj.	unobj.	-	-	-
Taste		unobj.	-	-	-	-
Dissolved oxygen	mg/l, max.	6	5	6 mean [1)] 4 min. dly [2)]	4	3
BOD (5 days 20°C)	mg/l, max	2	-	-	3	4
pH		6.5-8.5	6-8.5	6-8.5	5.0-8.5	5.0-8.5
Total coliform	MPN/100 ml (P=80%)	50	5,000	20,000	5,000	-
Faecal coliform	MPN/100 ml (P=80%)	250 des. 600 max.	-	-	-	-
Nitrate (NO_3-N)	mg/l max.	-	-	-	-	-
Total ammonia (NH_3-N) pH<7.5 pH=8.0 pH=8.5	mg/l max.	- - -	- - -	0.94 0.59 0.22	- - -	9.1 4.9 1.6
Chloride (Cl)	mg/l max.	200 des. 1,200 max.	-	-	200 des. 1,200 max.	-
Cyanide (CN)	mg/l max.	-	-	0.005	-	0.005
Fluoride (FL)	mg/l max.	1.5	-	-	1.5	-
Total phosphate (PO_4)	mg/l max.	-	-	0.4 [3)]	-	0.7 [3)]
Sulphate (SO_4)	mg/l max.	400	-	-	4--	-
Total hardness	mg/l as $CaCO_3$	250 des. 600 max.	-	-	-	-
Total cadmium (Cd)	μg/l, max.	5	-	H Cd <60 0.2 60-120 0.8 120-180 1.3 >180 1.8	5	5
Total arsenic (As)	μg/l, max.	50	-	50	50	50
Total chromium (Cr)	μg/l, max.	50	-	2	50	50
Total copper (Cu)	μg/l, max.	-	-	H Cu <60 2 60-120 2 120-180 3 >180 4	-	100

Table 6.12 Sri Lankan Proposed Inland Water Quality Standards for Different Uses (Continued)

Parameter	Unit Type of limit	Drinking water with simple treatment	Bathing	Fish and aquatic life	Drinking water convent. treatment	Minimum quality
Iron (Fe)	μg/l, max.	0.3 des. 1.0 max.	-	300	2	-
Lead (Pb)	μg/l, max.	50	-	H Pb <60 1 60-120 2 120-180 4 >180 7	50	50
Manganese (Mg)	μg/l, max.	-	-	-	-	1,000
Mercury (Hg)	μg/l, max.	1	-	0.1	1	2
Nickel (Ni)	μg/l, max.	-	-	H Ni <60 2 60-120 2 120-180 3 >180 4	-	100
Selenium (Se)	μg/l, max.	10	-	1	10	-
Zinc (Zn)	μg/l, max.	-	-	30	-	1,000
Gross alpha radioact.	pC /l, max.	3	3	-	3	3
Gross beta radioact.	pC/l, max.	30	30	-	30	30
Phenolic comp. (C_6H_3OH)	μg/l, max.	2	5	1	5	5
Anionic deterg. as MBAS	μg/l, max.	200 des. 1,000 max.	1,000	-	200 des. 1,000 max.	-
Total pesticide	μg/l, max.	-	-	-	-	50
Aldrin	μg/l, max.	-	-	-	-	0.1
DDT	μg/l, max.	-	-	0.004	-	1
Dieldrin	μg/l, max.	-	-	-	-	0.1
Endrin	μg/l, max.	-	-	0.0023	-	-
Heptachlor & heptachlorepoxyde	μg/l, max.	-	-	0.01	-	0.2
α-heptachloro-cyclohexane	μg/l, max.	-	-	-	-	0.02
Other organic micro-pollutants		-	-	see Table S.2	-	-
Conductivity	dS/l, max.	-	-	-	-	-
Boron	mg/l, max.	-	-	-	-	-

H : Hardness ($CaCO_3$), mg/l
des. : desirable highest level
max. : maximum permissible level
P-80% : 80% of the samples give a value that is equal to or less than the indicated limit
\- : the minimum requirement is given in the column "Minimum quantity".
1) : mean-during longer period
2) : min. dly-average of daily waters
3) : prevention of eutrophication, excessive weed growth, etc., may require lower, site specific, limits for stagnant waters.

Table 6.13 E.C. Regulations - Characteristics of Surface Water Intended for the Abstraction of Drinking Water

	Parameter		A1G	A1I	A2G	A2I	A3G	A3I
1	pH		6.5-8.5		5.5-9.0		5.5-9.0	
2	Coloration (after simple filtration)	mg/l Pt scale	10	20 (O)	50	100 (O)	50	200 (O)
3	Total suspended solids	mg/l SS	25					
4	Temperature	°C	22	25 (O)	22	25 (O)	22	25 (O)
5	Conductivity	$\mu S/cm^{-1}$ at 20°C	1,000		1,000		1,000	
6	Odour (dilution factor at 25°C)		3		10		20	
7	Nitrates	mg/L NO_3	25	50 (O)		50 (O)		50 (O)
8	Fluorides	mg/l F	0.7-1	1.5	0.1-1.7			0.7-1.7
9	Total extractable organic chlorine	mg/l Cl						
10	Dissolved iron	mg/l Fe	0.1	0.3	1	5	1	5
11	Manganese	mg/l Mn	0.05		0.1		1	
12	Copper	mg/l Cu	0.02	0.05 (O)	0.05		1	
13	Zinc	mg/l Zn	0.5	3	1	5	1	5
14	Boron	mg/l B	1		1		1	
15	Beryllium	mg/l Be						
16	Cobalt	mg/l Co						
27	Nickel	mg/l Ni						
28	Vanadium	mg/l V						
29	Arsenic	mg/l As	0.01	0.05		0.05	0.05	0.1
20	Cadmium	mg/l Cd	0.001	0.005	0.001	0.005	0.001	0.005
21	Total chromium	mg/l Cr		0.05		0.05		0.05
22	Lead	mg/l Pb		0.05		0.05		0.05
23	Selenium	mg/l Se		0.01		0.1		0.01
24	Mercury	mg/l Hg	0.0005	0.001	0.0005	0.001	0.0005	0.001
25	Barium	mg/LBa		0.1		1		1
26	Cyanide	mg/lCn		0.05		0.05		0.05
27	Sulphates	mg/l SO_4	150	250	150	250 (O)	150	250 (O)
28	Chlorides	mg/l Cl	200		200		200	
29	Surfactants (reacting with methyl blue)	mg/l(laury lsulphate	0.2		0.2		0.5	
30	Phosphate	mg/l P_2O_5	0.4		0.7		0.7	
31	Phenols (phenol index) paranitra-niline 4 aminoantipyrine	mg/l C_6H_5OH		0.001	0.001	0.005	0.01	0.1
32	Dissolved or emulsified hydrocarbons (after extraction by petroleum ether)	mg/l		0.05		0.2	0.5	1
33	Polycyclic aromatic hydrocarbons	mg/l		0.0002		0.0002		0.001
34	Total pesticides (parathion, BHC, diedrin)	mg/l		0.001		0.0025		0.005
35	Chemical oxygen demand (COD)	mg/l O_2					30	
36	Dissolved oxygen saturation rate	% O_2	>70		>50		>30	
37	Biochemical oxygen demand (BOD_5) (at 20°C without nitrification)	mg/l O_2	<3		<5		<7	
38	Nitrogen by Kjeldhal method (except NO_3)	mg/l N	1		2		3	
39	Ammonia	mg/l NH_4	0.05		1	1.5	2	4 (O)
40	Substances extractable with chloroform	mg/l SEC	0.1		0.2		0.5	
41	Total organic carbon	mg/l						
42	Residual organic carbon after flocculation and membrane filtration (5 µ) TOC	mg/l C						
43	Total coliforms 37°C	/100 ml	50		5,000		50,000	
44	Faecal coliforms	/100 ml	20		2,000		20,000	
45	Faecal streptococci	/100 ml	20		1,000		10,000	
46	Salmonella		Not present in 5,000 ml		Not present in 1,000 ml			

I = mandatory O = exceptional climatic or geographical conditions G = guide

Category A1 : Simple physical treatment and disinfection, eg. rapid filtration and disinfection

Category A2: Normal physical treatment , chemical treatment and disinfection, e.g. preOchlorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination).

Category A3: Intensive physical and chemical treatment, extended treatment and disinfection, e.g. chlorination to break-point coagulation, flocculation, decantation, filtration, absorption (activated carbon), disinfection (ozone, final chlorination).

Source: Department of Environment, UK

Table 6.14 Kelani Ganga Raw Water Quality at Ambatale (1992/1993)

Date	02.03.92	02.03.92	04.03.93	06.07.92	22.07.92	04.08.92	26.08.92	14.10.92	26.10.92	23.10.92	02.11.92	23.11.92	02.12.92	28.01.93	02.03.93	31.03.93	29.04.93	14.05.93
Appearance	Clear	Clear	Turbid	Clear	Clear	Clear	Clear	Slightly Turbid	Turbid	Clear	Turbid & Coloured	Very Turbid	Clear	Slightly Turbid & Coloured	Slightly Turbid	Clear	Turbid	Slightly Turbid
Turbidity: Unsettled (N.T.U.)	1.5	3.9	9.5	4.8	7.5	2.8	3.0	36.0	17.0	1.4	31.0	54.0	7.3	7.3	4.2	2.7	22.0	25.0
pH	7.0	7.2	6.9	6.5	8.2	8.2	6.0	6.9	8.0	7.1	7.9	8.4	6.6	6.8	6.8	8.2	6.3	6.0
Electrical Conductivity (Microsiemens)	660	230	240	21	79	32	34	38	56	210	67	50	33	40	42	52	36	50
Chlorides (as Cl)	196	92	64	10	10	8	10	8	9	30	12	8	10	7	8	10	9	20
Total Alkalinity (as CaCO3)	26	32	36	20	42	50	18	30	44	50	52	36	18	24	22	53	16	10
Total Hardness (as CaCO3)	85	52	36	12	39	46	16	20	40	68	40	22	10	25	20	38	10	26
Total Dissolved Solids	440	155	160	15	50	20	25	25	40	140	45	35	20	25	28	35	25	35
Nitrates (as N)	Trace	Trace	Trace	Less than 0.1	Less than 0.1	Less than 0.1	Less than 0.1	Less than 0.1	Trace	0.6	Less than 0.1	Trace	Less than 0.1	Less than 0.1	Trace	Less than 0.1	Trace	Trace
Nitrites (as N)	Minute Trace	Minute Trace	Minute Trace	Less than 0.001	0.008	Less than 0.001	Less than 0.001	Less than 0.001	0.024	0.05	0.16	Minute Trace	Less than 0.001	Less than 0.001	0.002	Less than 0.001	Minute Trace	Minute Trace
Iron Total (as Fe)	0.72	0.56	0.32	0.72	1	1.8	0.48	9	2	0.08	2.4	15	0.32	0.4	0.32	2.2	6	1.6
Colour (Hazen scale)	Less than 5	Less than 5	15	5	5	5	5	10	10	5	40	15	5	5	5	10	10	10

Source: NWSDB

6.6.3 Treatment Implication of Raw Water Quality

There is no substitute for carrying out on-site treatability tests to determine the appropriate treatment processes and conditions. Only by such means can the type of coagulant, optimum coagulant dose, coagulation pH, rapid mix and flocculation conditions etc. be determined. However certain conclusions can be drawn from examining the water quality data:

1) Primarily the raw water analyses show which parameters exceed the drinking water standards and therefore must be reduced or removed by a treatment process.

2) The magnitude of the turbidity value (and by inference the suspended solids value) determines the advisability of using pre-setting basins and, to some extent, the type of sedimentation basin that is required.

3) The total alkalinity value defines the natural buffering capacity of the raw water. Primary coagulants, e.g. aluminum sulphate, are acidic and will significantly depress the pH of low buffered waters. In such cases on alkali such as hydrated lime must be added to maintain the optimum coagulation pH.

4) The nitrate and phosphate values indicate the amount of nutrients available for algal growth.

Reference to Table 6.8 demonstrates that turbidity and iron values can be in excess of the drinking water standard. Therefore the treatment plant processes should be selected to reduce these constituents to acceptable levels.

It should be noted however that for fairly long periods of time the raw river water complies with the maximum permissible levels i.e. turbidity less than 8 JTU and iron less 1.0 mg/l. Theoretically during these periods the water could be forwarded to distribution without any treatment but chlorination. This however is not recommended as a sudden increase in turbidity could not be accurately predicted and sedimentation basins cannot be rapidly brought into use. The water would also be aggressive.

Examination of the historical turbidity data shows that on only a very few occasions each year does it exceed 50 NTU. The highest recorded value appears to be 170 NTU. On this basis there is no need for any form of pre-setting basin.

Pre-setting basins may in fact make matters worse by providing ideal conditions for the growth of algae. Nitrate levels of 0.2 mg/l as N and phosphate levels of 0.005 mg/l as P have been shown to support concentrations of algae of such magnitude that they can block filters in one to two hours. Table 6.10 shows that the nitrate and phosphate levels can exceed these threshold limits.

6.6.4 Treatability Tests

A number of raw water treatability tests were carried out on the Kalu Ganga during August and September 1988 using coagulation jar tests. The results of these tests were obtained from the log book at the Kalutara Treatment Plant and are reproduced in Data Report (Volume IV).

The jar tests follow a set pattern with six jars dosed with 2.5 % alum solution in doses across the range of 0.2 ml to 1.2 ml in 0.2 ml steps. No details of the tests are given regarding the size of sample, stirring speeds or duration of the stirring period. On the assumption that one litre samples were used, the applied alum doses were equivalent to 5.0 mg/l to 30.0 mg/l in 5.0 mg/l steps, presumably as $Al_2(SO_4)_3 \cdot 18H_2O$.

Coagulation pH correction was carried out using 0.1% lime, but no attempt seems to have been made to identify the optimum coagulation pH. For the majority of the tests the pH of the samples was between 6.4 and 6.8 pH units.

The results are very varied with no clear indication as to the optimum conditions. However, reasonable results appear to have been achieved at a coagulation pH of 6.8, whereas at 6.4 no successful tests are found. Occasional acceptable results were achieved at a pH of6.6. In general, an alum dose of 10 to 15 mg/l gave satisfactory results regardless of raw water turbidity.

6.7 Recommendations for Water Quality Monitoring

Due to the limited amount of available water quality data for the Kalu Ganga, it is necessary to begin a comprehensive analytical program as soon as possible. The NWSDB has a well equipped laboratory suitable for this purpose and should be commissioned to carry out regular, frequent, comprehensive analyses to build up a database on Kalu Ganga water quality.

The recommended suite of analyses are given in Table 6.15. The 'flashy' nature of the river as indicated by the raw water turbidity figures presented in Section 6.6.1 suggests that for one week during the dry season and one week during the wet season, daily samples should be taken for full analysis. From then onwards sampling and analysis to be carried out as indicated in the Table 6.15.

Sampling should be carried out at a point 5.0 m from the right bank of the river at a depth of 1.0 m above the bed at the Narthupana Bridge.

Table 6.15 Proposed Kalu Ganga Sampling Program

Parameter	Daily	Weekly	Monthly
Temperature	x		
Turbidity	x		
Color(true)		x	
pH	x		
Total Hardness		x	
Calcium Hardness		x	
Alkalinity		x	
Iron (total)		x	
Iron (dissolved)		x	
Suspended Solids		x	
Phosphate		x	
Nitrate		x	
Sulphate		x	
Chloride		x	
Coliform bacteria			x

CHAPTER 7

PROPOSED LONG TERM DEVELOPMENT PLAN

7. PROPOSED LONG TERM DEVELOPMENT PLAN

7.1 Balance in Water Demand and Supply

7.1.1 Balance in Demand and Supply without the Kalu Ganga Source

There will be at least two scenarios in water supply expansion. One is without the Kalu Ganga and another is with the Kalu Ganga. Until the Kalu Ganga Water Supply Project is implemented, water supply for Greater Colombo will have to be managed with the existing water production facilities although the water supply expansion is needed in many areas for improvement of people's living condition as well as for promotion of the commercial and industrial activities. However, it will take considerable time until the Kalu Ganga Project will be completed even if the implementation commences immediately. The presently ongoing or committed projects consist of the Towns East and Towns South projects, expansion in Biyagama area and other small scale expansion for urban centers. Expansion of water supply to the towns north of Colombo is intended and awaited as a major expansion after the Towns South Project.

The strategy and constraints in the present development are summarized in Table 7.1. Water transmission for the demand in 2000 from the existing treatment plants is shown in Figure 7.1.

Table 7.1 Development Strategy in Minimum Development without the Kalu Ganga

<table>
<tr><th>Service Area</th><th>Strategy in Implementation</th><th>Constraints in Service</th></tr>
<tr><td>Existing Service Area</td><td>Assure 24 hour supply to the entire existing service area.
Extend connection to 100% of the planned service level.</td><td rowspan="5">Existing water source capacity will reach the daily average water demand in between 2000 to 2005.
In around 2005, water shortage will likely occur:
(i) at the time of daily peak demands, or
(ii) when the Kelani flow is too low for full amount intake.
Without augmentation of additional production and transmission capacity, water supply will have to be suppressed in some areas after 2005.</td></tr>
<tr><td>Towns East Area</td><td>Extend service to OECF Phase 1 area.
Withhold the Phase 2 Implementation</td></tr>
<tr><td>Towns South Area</td><td>Implement the OECF Project in full.</td></tr>
<tr><td>Biyagama Area</td><td>Expand service</td></tr>
<tr><td>Towns North Project</td><td>Extend supply to Ja Ela, Ragama, Welisara and Kandana (urban centers only). Funding arrangement has not been made.</td></tr>
</table>

Table 7.2 Water Demand Projection for Minimum Development without the Kalu Ganga Project

Service Area	Division	Node No.	Connected Water Demand (m^3/d) 1995	2000	2005	2010	2015	2020
Towns East Area	Kaduwela	281	0	1,775	4,138	6,630	9,985	13,546
	Panagoda	402	0	0	0	0	0	0
	Pannipitiya	411	0	1,733	3,657	5,386	6,859	8,231
	Madiwela/Kotte	528	1,905	2,349	2,722	3,097	3,501	3,926
	Madiwela/Kotte	529	4,435	5,485	6,374	7,263	8,218	9,222
	Maharagama	552	0	2,759	5,716	8,301	10,790	13,202
	Battaramulla (High)	563	0	4,180	9,743	15,609	22,075	29,058
	Battaramulla (Low)	568	0	627	1,461	2,341	3,311	4,359
	Batta. (Remote)	574	0	480	1,015	1,499	2,744	3,940
	Total Towns East		6,340	19,387	34,827	50,125	67,483	85,484
Towns South Area	Homagama	498	0	1,273	2,695	3,979	6,270	8,231
	Panadura (Keselwatte)	496	0	1,214	3,959	6,181	8,353	10,326
	Kesbewa (Exis. Maharagama)	529-A	0	907	3,377	5,888	8,701	11,612
	Kesbewa (Main Area)	542	0	1,557	5,801	10,112	16,874	23,751
	Kesbewa (Sub Area)	552	0	475	1,770	3,085	4,560	6,085
	Panadura P.S.	494	403	440	478	520	1,587	2,483
	Total Towns South		403	5,866	18,081	29,765	46,343	62,488
Towns North Area	Wattala South	122	0	748	6,937	11,995	16,311	20,353
	Mahara South	132	0	0	0	0	612	1,163
	Mahara North	141	0	260	2,068	3,547	5,138	6,562
	Ragama	145	0	325	3,823	6,239	7,957	10,015
	Welisala, kandana	156	0	513	5,821	9,643	12,312	15,355
	Ja Ela U.C.	161	0	492	5,325	8,843	11,636	14,717
	Wattala North	165	0	256	2,900	4,594	5,682	6,970
	Katana P.S. (South)	166	0	0	0	0	929	1,759
	Katunayake EPZ	170	0	0	0	0	7,280	7,280
	Katunayake U.C. North	174	0	0	0	0	0	0
	Katana P.S. (North)	183	0	0	0	0	0	0
	Total Towns North		0	2,594	26,876	44,866	67,856	84,173
Biyagama	Biyagama (include. EPZ)	127	7,210	9,979	12,745	15,532	15,832	16,165
	Biyagama	121	0	3,263	6,262	9,312	13,113	16,953
	Biyagama	132	0	629	1,208	1,796	3,250	4,653
	Total Biyagama		7,210	13,871	20,215	26,641	32,195	37,771
Area far South	Sitawaka (Padduka Town)	428	0	0	0	0	413	813
	Bandaragama P.S. (West)	494	0	0	0	0	944	1,823
	Bandaragama P.S. (East)	497	0	0	714	1,394	2,338	3,385
	Horana P.S.	1000	0	0	0	0	0	0
	Total Area far South		0	0	714	1,394	3,695	6,020
Total of New Area			13,952	41,719	100,712	152,791	217,572	275,935
Total of Existing Area Demand			415,900	443,600	483,600	531,900	549,800	566,400
Total Day Average Demand			429,800	485,400	584,300	684,700	767,400	842,300
Total Daily Maximum Demand (Peak factor = 1.15)			494,300	558,200	672,000	787,300	882,300	968,700
Water Production Capacity	(Max.)							
Ambatale (Old)	63 mgd		286,700	286,700	286,700	286,700	286,700	286,700
Ambatale (New)	40 mgd		182,000	182,000	182,000	182,000	182,000	182,000
Kalatuwawa (90% of Max.)	18 mgd		81,900	81,900	81,900	81,900	81,900	81,900
Labugama (90% of Max.)	11.75 mgd		53,200	53,200	53,200	53,200	53,200	53,200
Horana	0.33 mgd		1,500	1,500	1,500	1,500	1,500	1,500
Total Production Capacity			605,300	605,300	605,300	605,300	605,300	605,300
Surplus/Deficit in Production Capacity								
for Daily Maximum Demand			110,900	47,100	-66,700	-182,000	-277,000	-363,400
for Daily Average Demand			175,400	119,900	20,900	79,400	-162,100	-237,100

Node Nos. are referred to from the Transmission Models presented in the Master Plan Update 1991.

Transmission Diagram for 2000 Demand

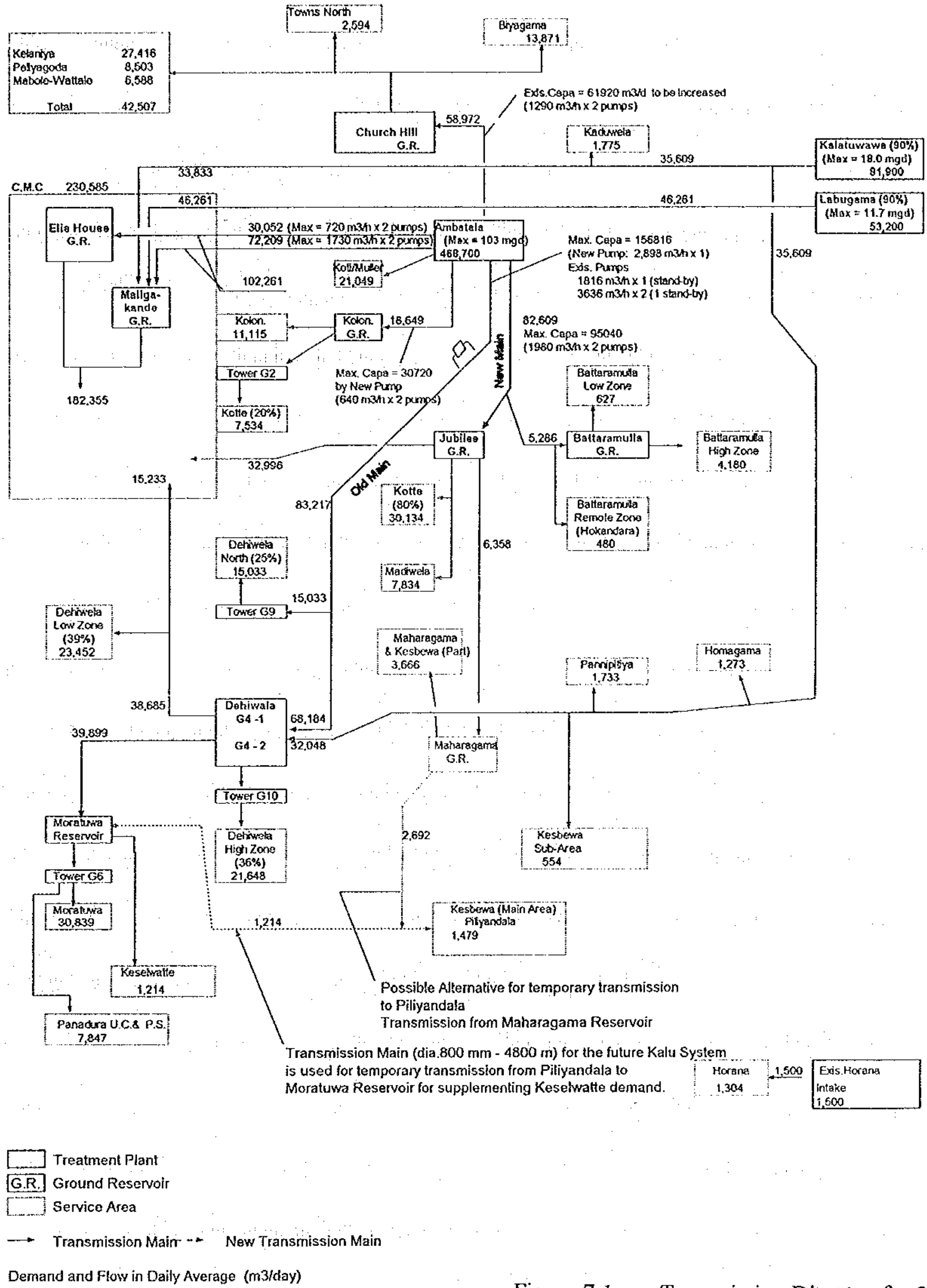


Figure 7.1 Transmission Diagram for 2000

To implement these expansion, balance in the water production capacity and the projected water demand should be carefully studied. The water demand projected as described in Chapter 5 is used for this purpose. The progress factor for housing connection is applied as well. The result of calculation is presented in Table 7.2. Figure 7.1 shows a transmission diagram for the demand in 2000 without the Kalu Ganga system (Figure 7.1 includes a proposed transmission main to Kesbewa and Keselwatte as described in Section 7.9).

As shown in Table 7.2, the existing treatment capacity will have a shortage against the daily maximum water demand. Treatment plants are normally designed to meet the daily maximum demand so that it could have an allowance in capacity for maintenance or repair work when the demand is lower than the peak day. In 2005, however, daily average demand will reach the capacity of the existing treatment plants so that they have to be operated almost in full capacity through a year.

It will be likely that in operating the existing treatment facilities with proper allowance for maintenance, the limit will come sometime between 2000 and 2005 taking into account the variation in actual progress in water demand. In such a case, water supply will have to be suppressed in some areas to balance with production capacity.

7.1.2 Balance in Demand and Supply with Kalu Ganga Source

To satisfy the needs for water supply expansion more than the area specified in Table 7.1 and the needs for the areas in Table 7.1 for years after 2005, it is inevitable to augment the treatment capacity to meet the additional water demand in future. Taking into consideration that the Kelani Ganga has a certain limitation in water use due to the salinity intrusion and safe yield, the Kalu Ganga Project should now be planned for implementation.

The water demand for development of the Kalu Ganga Project has been identified as described in Chapter 4 assuming the probable extent of expansion areas. The water intake, treatment and transmission system should then be planned to maintain a proper balance between the new and existing facilities. In particular, the transmission system should carefully be studied so that the transmission pipelines and pumping system will be used most effectively and economically to convey an amount of treated water to each service area.

To examine the water balance in transmission, the following strategy are established:

- o Ambatale water will be allocated to C.M.C. and northern areas.
- o Southern areas will be supplied from the Kalu source. A boundary of supply from Ambatale and Kalu will be dependent on the balance in each planning year.
- o Water from Labugama will be used mainly for the C.M.C. area.

- o Water conveyed by the Kalatuwawa - Dehiwala line will be used along the transmission route from upstream as much as possible so that the supply line will not cross each other and the hydraulic head in the line will be used efficiently.
- o Existing transmission mains will be used as much as possible either in the existing lines or for new transmission from the Kalu source.

Table 7.3 shows a proposed allocation of water demand and source to supply the water on the basis of the strategy stated above.

Figures 7.2 and 7.3 show the transmission diagrams proposed for the water demands in 2010 and 2020, respectively.

7.1.3 Alternative Transmission System Considered for 2020 Demand

To satisfy the 2020 demand, the existing transmission main between Ambatale and Dehiwala will need to have a considerable modification. This is due to the water balance from Ambatale and Kalu Ganga system. The upper part of the main (Ambatale to Jubilee) will not need to be used for normal transmission. Existing pumping system including the booster pumping station on the main will be left idle although they will be reserved for unusual transmission for emergency case. The lower part of this transmission main (Jubilee to Dehiwala) will be used for transmission from Dehiwala to Jubilee. For this reversed flow, a new pumping system will have to be installed at Dehiwala Reservoir.

From the view point of maximum usage of the existing facilities, the transmission system presented in Figure 7.3 may not be most appropriate. To avoid a major part of the existing facilities to be left idle or to be abandoned, an alternative as shown in Figure 7.4 is considered. This alternative suggests that additional 40 mgd will be supplied from Ambatale instead of from the Kalu Ganga.

With this scheme, the following advantages come up:

- o An additional transmission main from Horana to Dehiwala (1200 to 1100 mm) will not be needed.
- o The existing Ambatale to Dehiwala transmission main and the existing pumping system will be kept used.

However, to adopt this system, proper countermeasures against salinity intrusion should be provided for increase in water intake from the Kelani Ganga at the Ambatale treatment plant. Construction of a salinity barrier in the Kelani Ganga, if considered, should be studied taking into account a cost and economic comparison between two systems shown in Figures 7.3 and 7.4.

Table 7.3 Water Demand and Supply Balance for the Kalu Ganga Project (Year 2000)

Service Area/Division	Node No.	Demand in 2000		Water Supply Source					
		Daily Ave.	Daily Max. (f=1.15)	Existing					New Kalu Ganga
				Amba-tale	Kalatuwawa (90%) North Line	Kalatuwawa (90%) South Line	Labu-gama (90%)	Horana	
		443,676 m^3/d	558,204 m^3/d	468,700 m^3/d	40,950 m^3/d	40,950 m^3/d	53,200 m^3/d	1,500 m^3/d	0 m^3/d
Existing Service Area									
Colombo M.C.		230,585	265,173	173,064	38,908		53,200		
Dehiwala/Mt.Lavinia M.C.		60,133	69,153	32,214		36,939			
Kotte U.C.		37,668	43,318	43,318					
Kolonnawa U.C.		11,115	12,783	12,783					
Moratuwa U.C.		30,839	35,465	35,465					
Kotti/Mulleriyawa P.S.		21,049	24,206	24,206					
Peliyagoda U.C.		8,503	9,778	9,778					
Wattala Mabole U.C.		6,588	7,576	7,576					
Kelaniya P.S.		27,416	31,528	31,528					
Panadura U.C.		7,407	8,518	8,518					
Horana U.C.		2,374	2,730	2,730				1,500	
Sub-Total		443,676	510,227	378,450	38,908	36,939	53,200	1,500	0
New Service Area									
Towns East Kaduwela	281	1,775	2,042		2,042				
Panagoda	402	0	0						
Pannipitiya	411	1,733	1,993			1,993			
Madiwela/Kotte	528	2,349	2,701	2,701					
Madiwela/Kotte	529	5,485	6,308	6,308					
Maharagama	552	2,759	3,173	3,173					
Battaramulla (High)	563	4,180	4,807	4,807					
Battaramulla (Low)	568	627	721	721					
Batta. (Remote)	574	480	552	552					
Total Towns East		19,387	22,295	18,261	2,042	1,993	0	0	0
Towns South Homagama	498	1,273	1,464			1,464			
Panadura (Keselwatte)	496	1,214	1,396	1,396					
Kesbewa (exis. Maharagama)	529A	907	1,043	1,043					
Kesbewa (Main)	542	1,557	1,700	1,700					
Kesbewa (Sub Area)	552	475	637			637			
Panadura P.S.	494	440	506	506					
Total Towns South		5,866	6,746	4,645	0	2,019	0	0	0
Towns North Wattala South	122	748	861	861					
Mahara South	132	0	0	0					
Mahara North	141	260	299	299					
Ragama	145	325	374	374					
Welisala, kandana	156	513	590	590					
Ja Ela U.C.	161	492	566	566					
Wattala North	165	256	294	294					
Katana P.S. (South)	166	0	0	0					
Katunayake EPZ	170	0	0	0					
Katunayake U.C. North	174	0	0	0					
Katana P.S. (North)	183	0	0	0					
Total Towns North		2,594	2,983	2,983	0	0	0	0	0
Biyagama Biyagama (incl. EPZ)	127	9,979	11,476	11,476					
Biyagama	121	3,263	3,752	3,752					
Biyagama	132	629	724	724					
Total Biyagama		13,871	15,952	15,952	0	0	0	0	0
Far South Sitawaka (Padduka)	428	0	0	0					
Bandaragama (West)	494	0	0	0					
Bandaragama (East)	497	0	0	0					
Horana P.S.	1000	0	0	0					
Total Area Far South		0	0	0					
Total of New Service Area		41,719	47,977	41,841	2,042	4,011	0	0	0
Total Service Area		485,395	558,204	420,291	40,950	40,950	53,200	1,500	0

Table 7.3 (cont'd) Water Demand and Supply Balance for the Kalu Ganga Project (Year 2010)

Service Area/Division	Node No.	Demand in 2010		Water Supply Source					
		Daily Ave.	Daily Max. (f=1.15)	Existing					New Kalu Ganga
				Amba-tale	Kalatuwawa (90%) North Line	Kalatuwawa (90%) South Line	Labu. (90%)	Horana	
		684,718 m³/d	787,426 m³/d	468,700 m³/d	40,950 m³/d	40,950 m³/d	53,200 m³/d	1,500 m³/d	182,000 m³/d
Existing Service Area									
Colombo M.C.		269,628	310,072	169,510	33,326		53,200		54,037
Dehiwala/Mt.Lavinia M.C.		66,609	76,600			26,043			50,557
Kotte U.C.		46,014	52,916	52,916					
Kolonnawa U.C.		14,250	16,387	16,387					
Moratuwa U.C.		39,108	44,974						44,974
Kotti/Mulleriyawa P.S.		27,719	31,876	31,876					
Peliyagoda U.C.		9,561	10,995	10,995					
Wattala Mabole U.C.		8,690	9,993	9,993					
Kelaniya P.S.		38,429	44,193	44,193					
Panadura U.C.		8,562	9,846						9,846
Horana U.C.		3,360	3,864					1,500	2,364
Sub-Total		531,927	611,716	335,870	33,326	26,043	53,200	1,500	161,777
New Service Area									
Towns East Kaduwela	281	6,630	7,624		7,624				
Panagoda	402	0	0			0			
Pannipitiya	411	5,386	6,194			6,194			
Madiwela/Kotte	528	3,097	3.562	3.562					
Madiwela/Kotte	529	7,263	8,352	8,352					
Maharagama	552	8,301	9,546	9,546					
Battaramulla (High)	563	15,609	17,950	17,950					
Battaramulla (Low)	568	2,341	2,693	2,693					
Batta. (Remote)	574	1,499	1,724	1,724					
Total Towns East		50,125	57,644	43,826	7,624	6,194	0	0	0
Towns South Homagama	498	3,979	4,576			4,576			
Panadura (Keselwatte)	496	6,181	7,108						7,108
Kesbewa (exis. Maharagama)	529A	5,888	6,771	6,771					
Kesbewa (Main)	542	10,112	11,040						11,040
Kesbewa (Sub Area)	552	3,085	4,137			4,137			
Panadura P.S.	494	520	598						598
Total Towns South		29,765	34,230	6,771	0	8,713	0	0	18,746
Towns North Wattala South	122	11,995	13,795	13,795					
Mahara South	132	0	0	0					
Mahara North	141	3,547	4,079	4,079					
Ragama	145	6,239	7,174	7,174					
Welisala, kandana	156	9,643	11,090	11,090					
Ja Ela U.C.	161	8,843	10,175	10,175					
Wattala North	165	4,594	5,283	5,283					
Katana P.S. (South)	166	0	0	0					
Katunayake EPZ	170	0	0	0					
Katunayake U.C. North	174	0	0	0					
Katana P.S. (North)	183	0	0	0					
Total Towns North		44,866	51,595	51,595	0	0	0	0	0
Biyagama Biyagama (incl. EPZ)	127	15,532	17,862	17,862					
Biyagama	121	9,312	10,709	10,709					
Biyagama	132	1,796	2,066	2,066					
Total Biyagama		26,641	30,637	30,637	0	0	0	0	0
Far South Sitawaka (Padduka)	428	0	0						
Bandaragama (West)	494	0	0						
Bandaragama (East)	497	1,394	1,603						1,603
Horana P.S.	1000	0	0						
Total Area Far South		1,394	1,603	0	0	0	0	0	1,603
Total of New Service Area		152,791	175,709	132,830	7,624	14,907	0	0	20,349
Total Service Area		684,718	787,426	468,700	40,950	40,950	53,200	1,500	182,000

Table 7.3 (cont'd) Water Demand and Supply Balance for the Kalu Ganga Project (Year 2020)

Service Area/Division	Node No.	Demand in 2020		Water Supply Source					
		Daily	Daily	Existing					New
		Ave.	Max. (f=1.15)	Amba-tale	Kalatuwawa (90%) North Line	Kalatuwawa (90%) South Line	Labu. (90%)	Horana	Kalu Ganga
		842,372 m³/d	968,727 m³/d	468,700 m³/d	40,950 m³/d	40,950 m³/d	53,200 m³/d	1,500 m³/d	364,000 m³/d
Existing Service Area									
Colombo M.C.		277,561	319,219	55,430	25,372		53,200		185,216
Dehiwala/Mt.Lavinia M.C.		69,084	79,447			12,924			66,523
Kotte U.C.		51,215	58,897	58,897					
Kolonnawa U.C.		16,720	19,228	19,228					
Moratuwa U.C.		43,959	50,553						50,553
Kotti/Mulleriyawa P.S.		31,116	35,784	35,784					
Peliyagoda U.C.		10,449	12,016	12,016					
Wattala Mabole U.C.		10,656	12,255	12,255					
Kelaniya P.S.		41,946	48,238	48,238					
Panadura U.C.		9,395	10,804						10,804
Horana U.C.		4,314	4,961					1,500	3,461
Sub-Total		566,436	651,401	241,848	25,372	12,924	53,200	1,500	316,557
New Service Area									
Towns East Kaduwela	281	13,546	15,578		15,578				
Panagoda	402	0	0						
Pannipitiya	411	8,231	9,466			9,466			
Madiwela/Kotte	528	3,926	4,515	4,515					
Madiwela/Kotte	529	9,222	10,606	10,606					
Maharagama	552	13,202	15,183	15,183					
Battaramulla (High)	563	29,058	33,417	33,417					
Battaramulla (Low)	568	4,359	5,012	5,012					
Batta. (Remote)	574	3,940	4,530	4,530					
Total Towns East		85,484	98,307	73,263	15,578	9,466	0	0	0
Towns South Homagama	498	8,231	9,466			9,466			
Panadura (Keselwatte)	496	10,326	11,874						11,874
Kesbewa (exis. Maharagama)	529A	11,612	13,354	13,354					
Kesbewa (Main)	542	23,751	26,152						26,152
Kesbewa (Sub Area)	552	6,085	8,160			8,160			
Panadura P.S.	494	2,483	2,855						2,855
Total Towns South		62,488	71,861	13,354	0	17,626	0	0	40,881
Towns North Wattala South	122	20,353	23,406	23,406					
Mahara South	132	1,163	1,337	1,337					
Mahara North	141	6,562	7,546	7,546					
Ragama	145	10,015	11,517	11,517					
Welisala, kandana	156	15,355	17,658	17,658					
Ja Ela U.C.	161	14,717	16,924	16,924					
Wattala North	165	6,970	8,016	8,016					
Katana P.S. (South)	166	1,759	2,023	2,023					
Katunayake EPZ	170	7,280	8,372	8,372					
Katunayake U.C. North	174	0	0	0					
Katana P.S. (North)	183	0	0	0					
Total Towns North		84,173	96,798	96,798	0	0	0	0	0
Biyagama Biyagama (incl. EPZ)	127	16,165	18,589	18,589					
Biyagama	121	16,953	19,496	19,496					
Biyagama	132	4,653	5,351	5,351					
Total Biyagama		37,771	43,436	43,436	0	0	0	0	0
Far South Sitawaka (Padduka)	428	813	935			935			
Bandaragama (West)	494	1,823	2,096						2,096
Bandaragama (East)	497	3,385	3,892						3,892
Horana P.S.	1000	0	0						
Total Area Far South		6,020	6,923	0	0	935			5,988
Total of New Service Area		275,936	317,326	226,852	0	28,026	0	0	46,869
Total Service Area		842,372	968,727	468,700	40,950	40,950	53,200	1,500	364,000

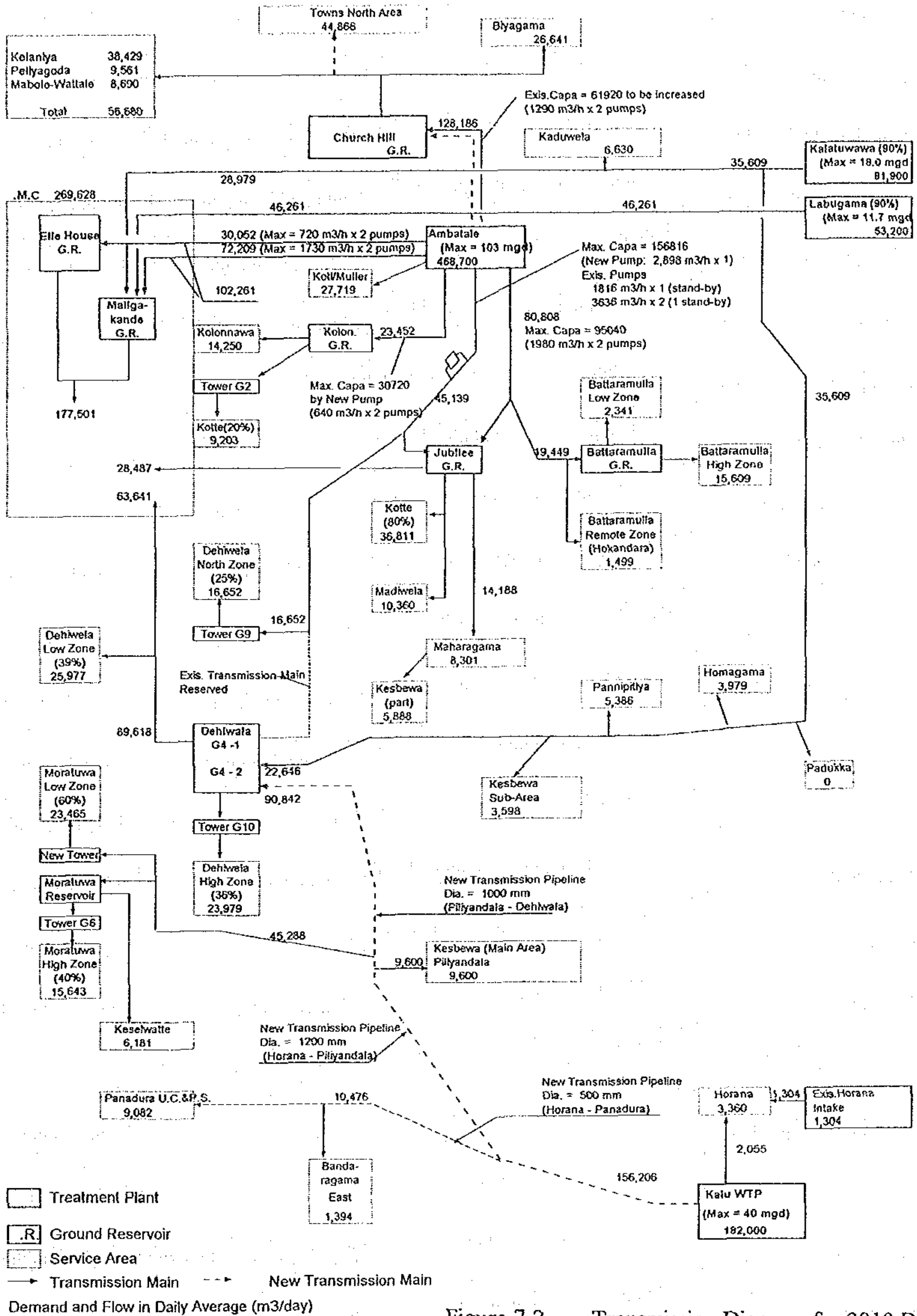
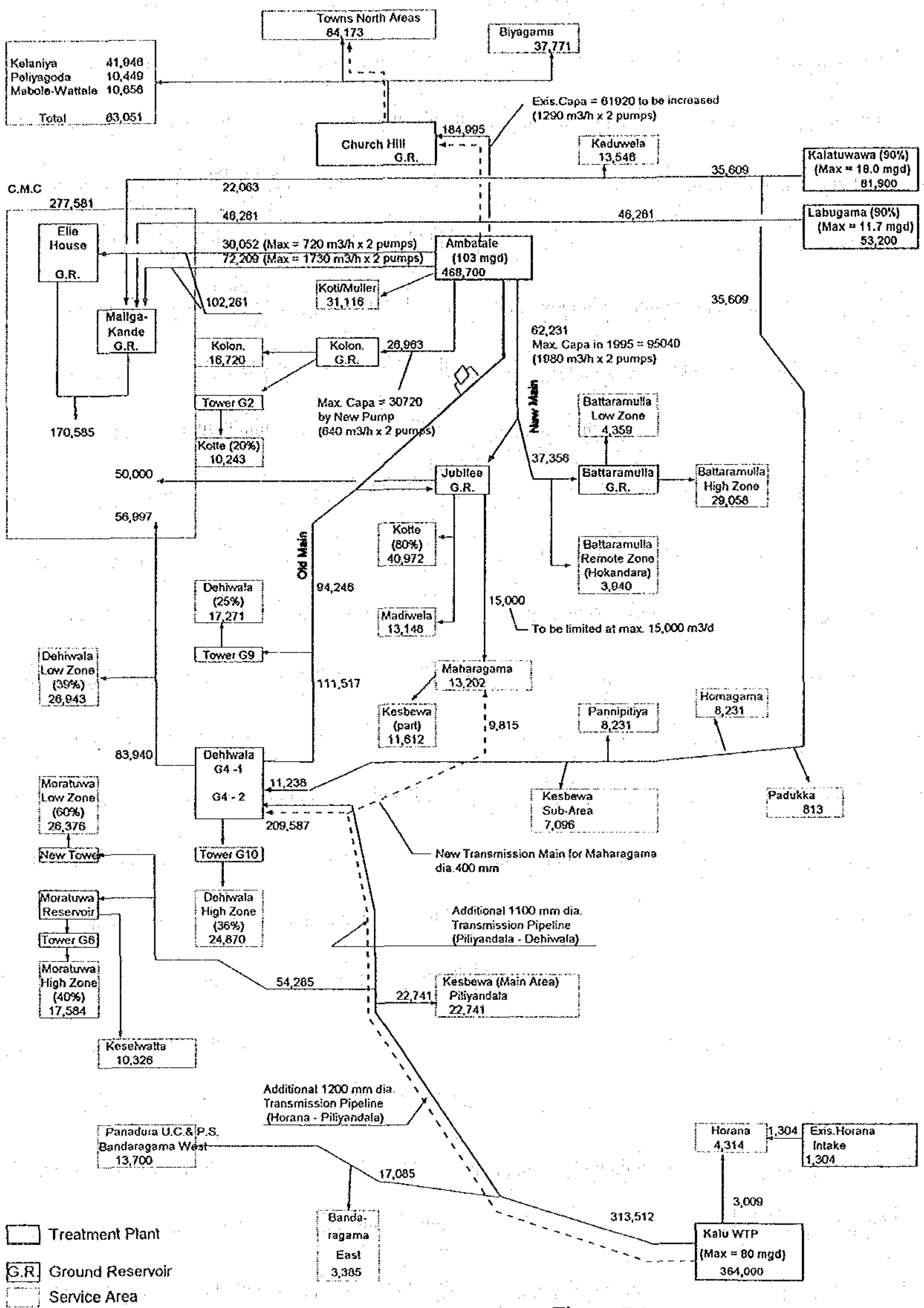


Figure 7.2 Transmission Diagram for 2010 Demand



Transmission Main   New Transmission Main

Demand and Flow in Daily Average (m3/day)

Figure 7.3

Transmission Diagram for 2020 Demand

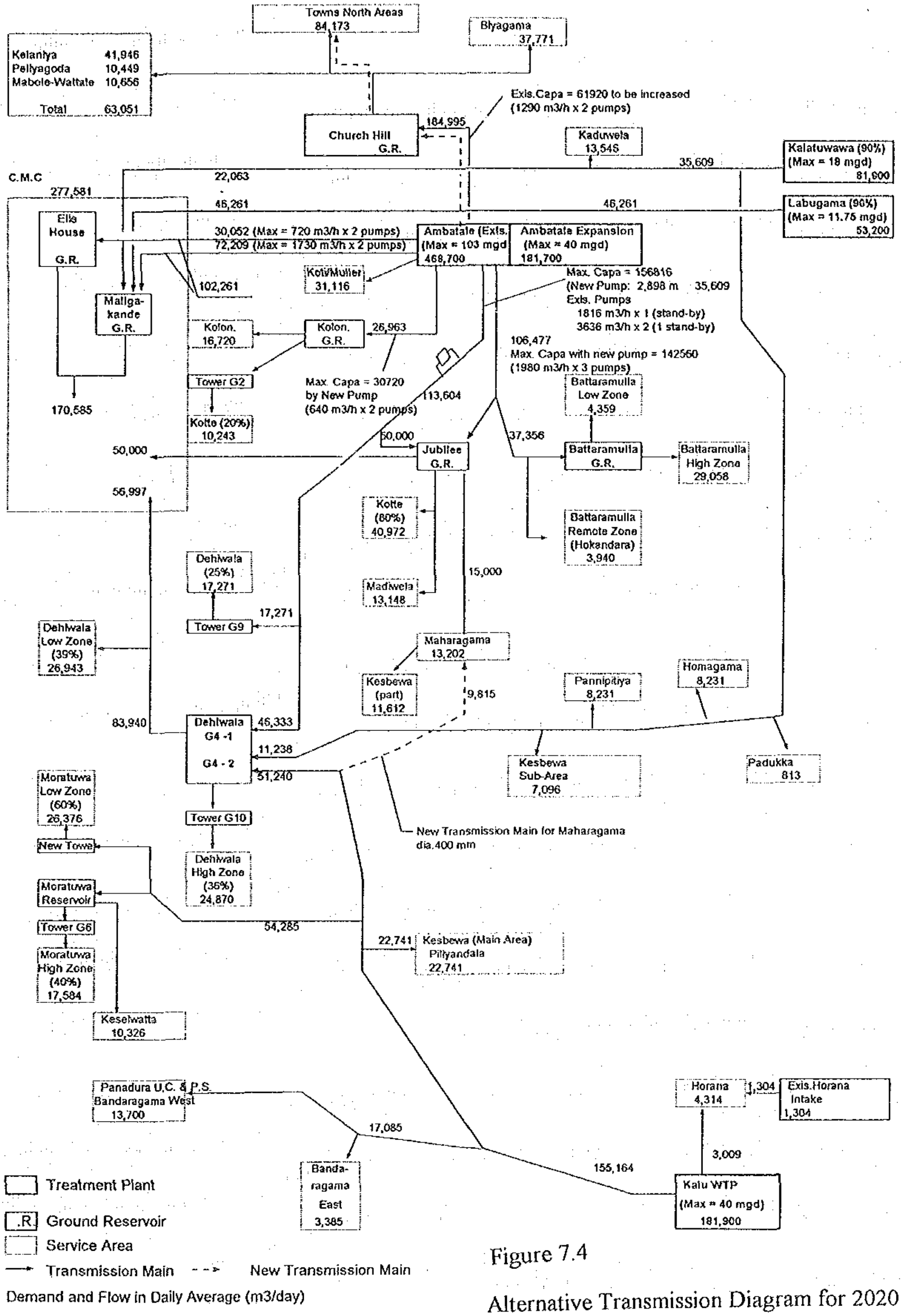


Figure 7.4

Alternative Transmission Diagram for 2020 Demand

7.2 Basic Unit Cost

Basic unit costs for land acquisition, direct construction works, and O & M works has been studied for the selection of best alternative as described below.

7.2.1 Unit Costs for Construction and Land Acquisition

Basic unit costs for land acquisition, direct construction works and operation and maintenance works has been studied for selection of the best alternative as described below.

- intake
- raw water transmission main
- water treatment plant
- clear water reservoir
- distribution reservoir
- clear water transmission main
- distribution pipe

The estimate in the master plan review stage was approached by the unit cost basis for the civil works and land acquisition, and lump sum cost basis for mechanical and electrical works. The unit costs for major items of direct construction works and land acquisition were preliminary determined referring to the NWSDB's "Rates 1993", records of similar water supply projects, prevailing current market prices and other sources as presented in Table 7.4. It should be noted that these unit construction costs are preliminary which have to be further reviewed in the feasibility study stage for the financial cost estimate on the selected plan. An explanation of unit costs of civil works and cost for mechanical and electrical works is briefly given as follows.

(1) Direct Construction Cost

1) Civil Works

Table 7.4 Civil Works Unit Costs

Structure/Item	Unit Costs (Rs.)	Conditions
Intake		
* excavation in common soils	700/m^3	includes partial coffering costs
* excavation in rocks	2,000/m^3	"
* concrete for grit chamber	15,000/m^3	includes form work and re-bar
* concrete for tower	35,000/m^3	"
Raw Water Transmission Main (ductile iron pipe)		supply, delivery and laying costs
* DN 1400 mm	75,000/m	
* DN 1600 mm	130,000/m	

Table 7.4 Civil Works Unit Costs (cont'd)

Water treatment works		
* excavation in common soils	400/m^3	excavation, loading and hauling
* excavation in rocks	1,200/m^3	"
* concrete (210 kg/cm^2)	15,000/m^3	with formwork and re-bar
* fill	650/m^3	by selected material
* backfill	380/m^3	by excavated material
* filter gravel	1,750/m^3	selected gravel
* filter sand	3,500/m^3	selected sand
* sand	700/m^3	ordinary sand
Transmission and Distribution		supply, delivery and laying costs
* DN 1800 mm DI	160,000/m	
* DN 1600 mm DI	130,000/m	
* DN 1500 mm DI	100,000/m	
* DN 1400 mm DI	75,000/m	
* DN 1200 mm DI	56,000/m	
* DN 1000 mm DI	40,000/m	
* DN 900 mm DI	33,000/m	
* DN 800 mm DI	30,000/m	
* DN 600 mm DI	20,000/m	
* DN 500 mm DI	15,000/m	
* DN 400 mm DI	11,000/m	
* DN 350 mm DI	9,000/m	
* DN 300 mm DI	7,500/m	
* DN 250 mm DI	6,000/m	
* DN 200 mm DI	5,000/m	
* DN 200 mm PVC	3,000/m	
* DN 150 mm PVC	2,500/m	
* DN 100 mm PVC	2,000/m	
* DN 80 mm PVC	1,000/m	
* Water Tower	14,000/m	for 2,000m^3 capacity
* Water Tower	15,000/m	for 1,000m^3 capacity

2) Mechanical and Electrical Works

The costs for mechanical and electrical works was estimated on the lump sum basis assuming the required components and its capacity. Applied cost for comparison is site delivery plus erection costs basis excluding custom duties.

(2) Land Acquisition Cost

The unit costs for land acquisition are provided as shown in Table 7.5 for alternative comparison. Data source is the NWSDB. The unit costs for the selected alternative will be confirmed with the land officer of the NWSDB in the succeeding field survey.

Table 7.5 Unit Land Cost

Area/Location	Unit Costs (Rs.)	Conditions
Intake		
* No.1 (Udugama)	300/m^2	Owner: K.M.Millinona/Wimalawathi
* No.2 (Uduwara)	450/m^2	New Chahel State
Water Treatment Plant		
* No.1 (Ramunekanda)	1,000/m^2	Hill - Top EL of 120 m Owner : (to be investigated)
* No.2 (Ellakande)	1,000/m^2	Hill - Top EL of +90 m MSL Owner : Sorana Rubber Plantation
* No.3 (Ellakande)	1,000/m^2	Hill - Top EL of +90 m MSL Sorana Rubber Plantation
* No.4 (Titawalakande)	1,000/m^2	Hill - Top EL of 90 m Owner: Titawalakande Estate
* No.5 (Wewalakande)	-	Top EL of +90 m MSL Government-owned Land
* No.6 (Udugama)	300/m^2	Owner: K.M.Millinona/Wimalawathi
* No.7 (Udugama)	300/m^2	
* No.8 (Bellapitiya)	1,500/m^2	Boralugaha Land Estate

7.2.2 Unit Costs of Labor, Power and Chemicals

The Unit costs for labor, power and chemicals for operation and maintenance works are provided referring mainly to the costs records of operation and maintenance of the existing Ambatale Water Treatment Plant in 1993 as tabulated in Table 7.6.

Table 7.6 Unit Costs of Labor, Power and Chemicals

Item	Unit Cost (Rs.)
Labor cost for operation and maintenance	
* staff	10,000/month
* labor	250/day
This is costs for normal working hour.	
Power cost for plant operation	
* < 50 kVA	4.0/kwh
* > 50 kVA	3.8/kwh
Chemical cost for plant operation	
* alum	12,000/ton
* lime	10,500/ton
* chlorine	27,500/drum (900 kg)
* bleaching powder	750/Tin (50 kg)

Note: Power cost is based on the new tariff and a unit charge at the basic rates indicating in Section 5 "Industrial Tariff " in the Gazette of the Democratic Socialist Republic of Sri Lanka effective from 1st February 1994. The rates above exclude a maximum demand charge and a fixed charge.

Supply source for these materials assumes from domestic and abroad, India, Thailand and others.

While, monthly expenditure of the existing Ambatale Water Treatment Plant (305,000 m^3/d) indicates Rs.12,936,000 in total and 70, 3.5, and 26.5 percent of ratios for power, labor and materials costs, respectively in an average for last six months from June to December 1993, following to the monthly expenditure reports of the NWSDB Ambatale Treatment Plant.

7.3 Design Criteria/Condition

7.3.1 Intake

1) Intake Mouth

Passing Velocity : 15 - 30 cm/sec

2) Grit Chamber

Retention Time : 10 - 20 min
Horizontal Velocity : 2 - 7 cm/sec
Effective Water Depth : 3 - 4 m
Depth for Settled Grit : 0.6 - 1.0 m

7.3.2 Treatment

(1) Planned Treatment Capacity

1) Maximum Day Demand

The maximum day demand for the target year 2010 shall be 182,000 m^3/day taking into consideration of peak factor as 1.15 as given in the previous sub-section. In like manner, maximum day demand for the target year 2020 shall be 364,000 m^3/day.

2) Design Capacity

For determination of design capacity of the treatment facilities, water use within the yard of treatment plant and unpredictable loss is totally counted as 5 percent of the maximum day demand on the basis of world-wide experiences. Thus design capacity amounts to 192,000 m^3/day and 383,000 m^3/day for the target year 2010 and 2020, respectively.

(2) Drinking Water Standards

The standards for water quality in Sri Lanka are based on the SLS 614, 1983; Part 1 Physical and Chemical Requirement, and Part 2, Bacteriological requirements, which are similar to the WHO Standards as given in Table 7.7 and 7.8.

Table 7.7 Specification for Potable Water, SLS 614 (1983)

PART 1 - Physical and Chemical Requirements

Characteristic	Maximum Desirable Level	Maximum Permissible Level
pH	7.0 - 8.5 units	6.5 - 9.0 units
Color	5 units	30 units
Odor	Unobjectionable	Unobjectionable
Taste	"	"
Turbidity	2-JTU	8-JTU
Elect. Conductivity	750 µS/cm	3,500 µS/cm
Chloride (Cl)	200 mg/l	1,200 mg/l
Chlorine-Free Residual (Cl)	-	0.2 "
Alkalinity (as $CaCO_3$)	200 "	400 "
Ammonia-Free	-	0.06 "
Ammonia-Albuminoid	-	0.15 "
Nitrate (as N)	-	10 "
Nitrite (as N)	-	0.01 "
Fluoride (as F)	0.6 "	1.5 "
Phosphates-Total (PO)	-	2.0 "
Total Solids	500 "	2,000 "
Hardness Total (as $CaCO_3$)	250 "	600 "
Iron-Total (as Fe)	0.3 "	1.0 "
Sulphate	200 "	400 "
Calcium	100 "	240 "
Magnesium	30 to 150 *	150 "
Copper	0.05 "	1.5 "
Manganese	0.05 "	0.5 "
Zinc	5.0 "	15.0 "
Aluminium	-	0.2 "
Arsenic	-	0.05 "
Cadmium	-	0.005 "
Cyanide	-	0.05 "
Lead	-	0.05 "
Mercury	-	0.001 "
Selenium	-	0.01 "
Chromium	-	0.05 "
Anionic Detergents (as MBAS-LAS)	0.2 "	1.0 "
Phenolic Compounds (as Phenolic OH)	0.001 "	0.002 "
Oil & Grease	-	1.0 "
Pesticide Residue	(Refer to WHO &	FAO requirements)
Chem. Oxygen Demand (COD)		10 mg/l

* Depending on sulphate content, i.e. for 205 mg/l sulphate, max. Mg. is 30 mg/l; for less sulphate, more Mg. is allowed.

Table 7.8 Specification for Potable Water, SLS 614 (1983)

Part 2 - Bacteriological Requirements

Requirements	
1.	Pipe born water supplies:
-	Throughout any year, 95 percent of the samples shall not contain any coliform organisms in 100 ml.
-	None of the samples examined shall contain more than 10 coliform organisms per 100 ml.
-	Coliform organisms shall not detectable in 100 ml of any two consecutive samples.
-	None of the samples examined shall contain E. Coli in 100 mg/l (Fecal coliform).
2.	Individual and small community supplies
-	None of the samples examined shall contain more than 20 coliform organisms per 100 mg/l on repeated examination.
-	No sample shall contain E. Coliform in 100 mg/l (Fecal coliform)

Note: Individual or small community supplies include wells, bores and springs.

(3) Design Manual

For designing purpose on structures and related facilities, the 'Design Manual on Small Community Water Supplies, prepared for the NWSDB with the WHO assistance in 1982 and the Design Manual on Water Quality and Treatment prepared in the Water Supply and Sanitation Project with the UNSAID assistance in March 1989 shall be basically referred to this Study. In addition, Design Criteria for Water Works Facilities, Japan Water Works Association, and other design criteria in the UK and USA are also referred when needed to supplement Sri Lankan design criteria.

7.3.3 Transmission and Distribution

(1) General

Friction Formula : Hazen-Williams Formula

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

where,
- H : friction loss (m)
- C : friction coefficient — 120 for cement lined DIP and SP; 130 for PVC pipe
- D : diameter of pipe (m)
- Q : flow rate (m^3/sec)
- L : pipe length (m)

Maximum flow rate 2.0 m/sec

(2) Transmission

Pipe Material : Ductile iron pipe (DIP) or steel pipe (SP)
Internal lining : Cement mortar lining

Peak Factor : 1.15 (times daily maximum demand)

(3) Distribution

Pipe Material : Ductile iron pipe (DIP) for diameter 250 mm or larger
Unprasticized polyvinyl chloride (uPVC) pipe for diameter less than 250 mm

Peak Factor : Vary according to the water demand in the service area referred to statistics in Japan

$$F = a \times (q/24)^b$$

where, F : hourly peak factor (ratio to daily average flow)
q : daily average demand (m^3/d)
a, b : constant parameter (see table below)

Category	Area	a	b
A	mixture of residential and commercial area	1.9503	-0.0301
B	residential area	3.1124	-0.0850

Source : Statistics of Peak Factor from Water Supply Operation in Japan, "Design Criteria for Waterworks Facilities" Japan Water Works Association

Peak factor for each service area is calculated as follows:

Service area	Category	Ave.Demand (m^3/d)		Peak Factor	
		2010	2020	2010	2020
Dehiwala					
North Zone	A	16,691	17,298	1.6	1.6
High Zone	A	11,914	12,347	1.6	1.6
Low Zone	A	38,004	39385	1.6	1.6
Moratuwa					
High Zone	A	15,692	17,639	1.6	1.6
Low Zone	A	23.416	26,321	1.6	1.6
Panadura	A	8,562	9,395	1.9	1.9
Kesbewa	B	13,709	30,906	1.8	1.7
Keselwatte	B	6,263	10,462	1.9	1.9
Homagama	B	3,312	7,343	2.0	1.9
Bandaragama	B	0	2,501	-	2.1
Horana	B	3,360	4,314	2.0	2.0

Minimum hydraulic head = 10 m at peak demand

Storage capacity of reservoir and tower

for emergency case (stoppage of supply from the source)
----> more than 8 hours is recommended
for absorbing demand variation
----> to be examined from flow analysis

7.4 Selection of Proposed Sites for Water Supply Facilities