5.3.3 Groundwater Development

The most serious problem in Nuwara Eliya is shortage of water source capacity in dry season. The existing surface water sources have limitation in its supply capacity and are assumed to cause approximately 6,500 m^3/day of shortage against the 2015 water demand.

In developing new water sources, surface water has an economical difficulty. In this study, the possibility of groundwater development was investigated through test well construction and its pumping test by the Study Team.

Water supply facility plan was then established including the development of new groundwater sources. It was found through hydrogeological study that prominent shear zones run SE-NW direction along the Lake Gregory and the Barrack Plains Reservoir. Locations of intake facilities (wells) were planned at the places in those zones containing fractures, where close to reservoirs (refer to Figure 5.3). Particular locations of new wells (planned yield of approximately 1,000 m^3/day/well) shall be selected in the expected well field zones in the detailed design stage.

5.3.4 Water Distribution Plan and Transmission Line Requirement

(1) Water transmission method

During rainy season, the maximum utilization of abundant surface water through gravity flow distribution can contribute to reduce power consumption of groundwater pumping and to conserve groundwater resources.

For that purpose, the transmission method of surface water was planned to be changed by season, though realignment of service blocks is not required. In other words, transmission system shall be changed by controlling valves by season to utilize water from surface water sources fluently.

Water transmission method in rainy season was examined mainly for Low Area 1, Low Area 2, Bonavista and Naseby blocks, where the groundwater is used during dry season. Comparison of alternative plans revealed that Low Area 1, Low Area 2, Bonavista and Naseby blocks should be supplied from water sources in Bambarakele and Pedro during rainy season.

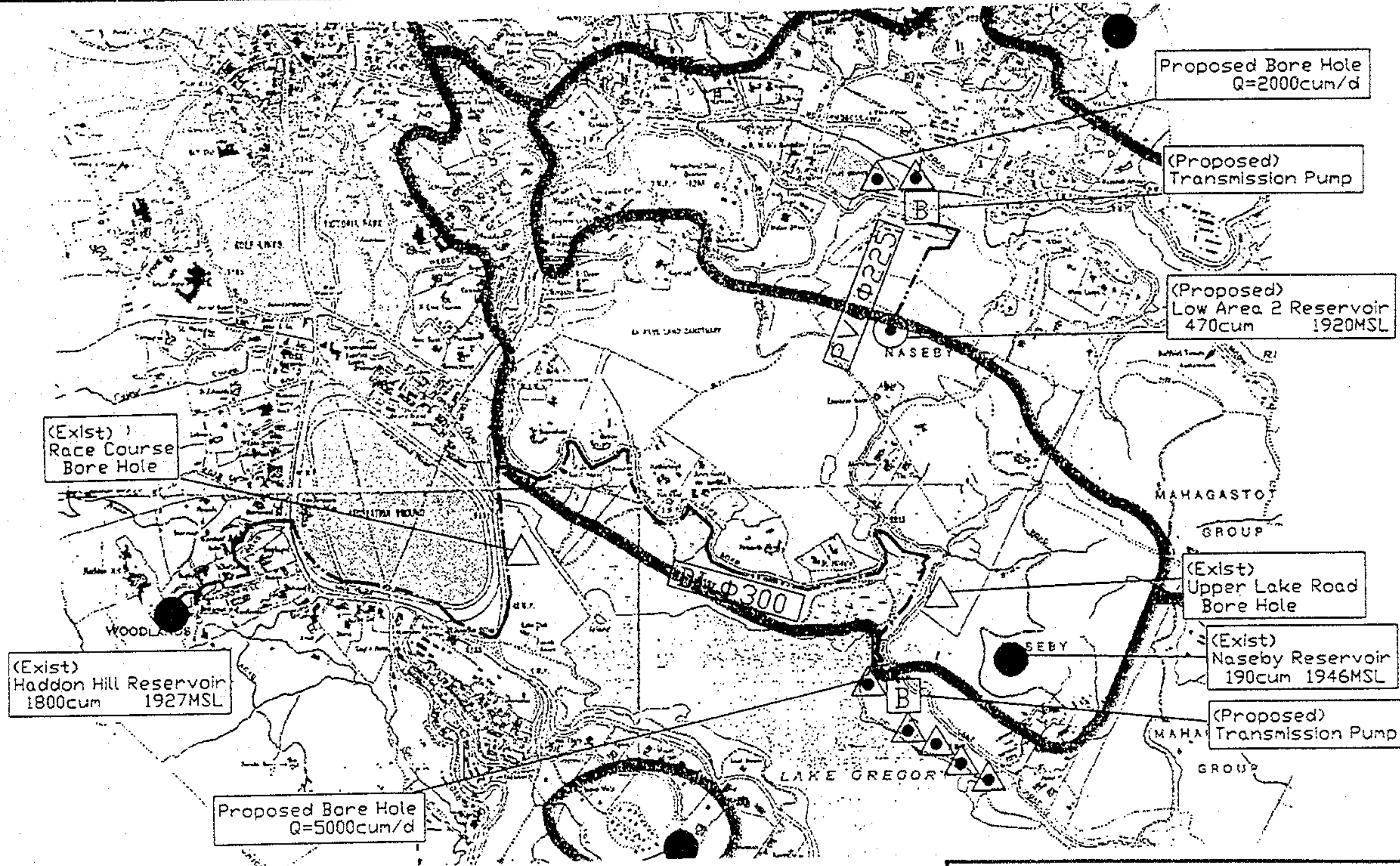


Fig 5.3 Layout of Proposed Wells and Transmission Line

The relationship between water sources and reservoirs in rainy season is shown in Table 5.7, while layout plan of water transmission by season is shown in Figures 5.4 and 5.5.

(2) Water transmission method to Naseby Reservoir

Gravity flow is not applicable for water transmission to Naseby Reservoir, because water level at New Pedro Reservoir (1,948 MSL) as supply source is only slightly higher than water level (1,946 MSL) of recipient reservoir.

As countermeasure to this hydraulic situation, it is planned to transmit water by gravity up to marginal elevation and then apply inline booster pump (0.42 cu.m/min x 25 m x 3.7 kW x 1 unit) for further transmission.

(3) Plan for transmission pipelines from surface water sources

Facility plan for water transmission was prepared paying due attention for effective utilization of the existing transmission line from water sources in Bambarakele, Old Water Field and Pedro to the Haddon Hill distribution reservoir.

Location and diameter to augment transmission line were determined through hydraulic analysis under the normal condition (daily maximum supply amount) in rainy season and preliminary designed as shown in Figure 5.6 and Table 5.8, respectively.

Available water sources for the Haddon Hill Reservoir in rainy season are Bambarakele and Pedro, wherein water from Pedro shall not be passed through the Pedro Reservoir to avoid unnecessary head loss.

Table 5.8 Magnitude of Transmission Line Augmentation for Surface Water Source

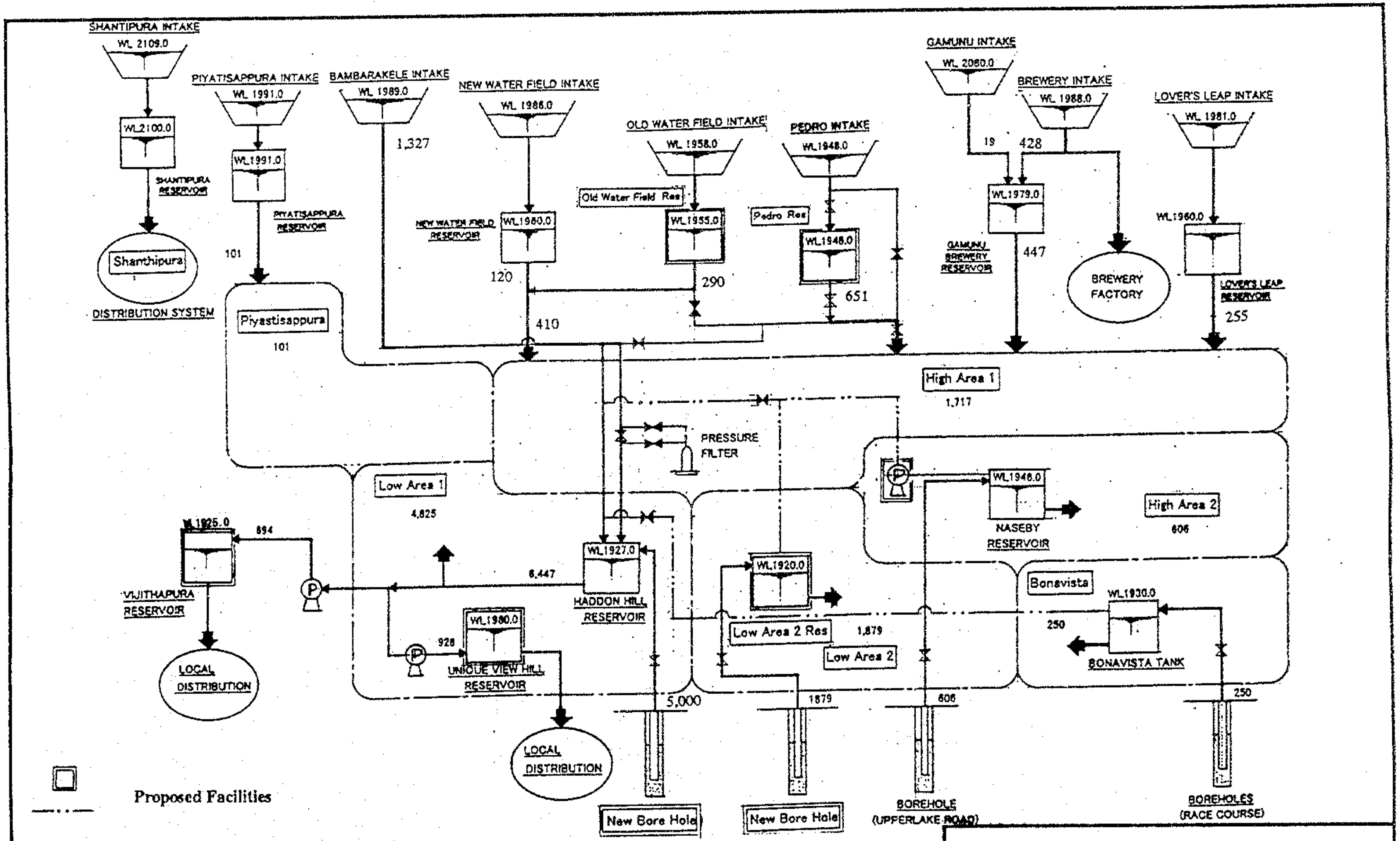
Pipe Material	Diameter (mm)	Length (m)		
		Phase 1	Phase 2	Total
PVC	ϕ110	2,867	-	2,867
DI	ϕ250	3,545	488	4,033
Total		6,412	488	6,900

Table 5.7 Demand and Water Source in Respective Water Service Block by Season

No.	Block		2015 Avg. Daily Demand (m³/d)	2015 Max. Daily Demand A (m³/d)	Water Source: Water Source	Water Source: Yield B (m³/d)	Water Source: Balance C=B-A (m³/d)	Remarks
Dry Season								
1	Shanthipura		-	-	Shanthipura	-	-	
2	Piyatisappura		82	101	Piyatisappura	255	154	
3	High Area 1	Old Water Field	229	282	Old Water Field	290	8	
		New Water Field	95	117	New Water Field	120	3	
		Gamunu	15	19	Gamunu	19	0	
		Brewery	338	417	Brewery	428	11	
		Pedro	514	634	Pedro	651	17	
		Lovers Leap	201	248	Lovers Leap	255	7	
	Sub Total		1,392	1,717		1,763	46	
4	Low Area 1	Haddon Hill	3,912	4,825	Bambarakele	1,327		
		Unique View	752	928	New Borehole	5,000		New Borehole 5units
		Vijithapura	563	694				
	Sub Total		5,227	6,447		6,327	-120	
5	Low Area 2		1,524	1,879	New Borehole	2,000	121	New Borehole 2units
6	High Area 2		491	606	Upper Lake Road Borehole	600	-6	
7	Bonavista		203	250	Race Course Borehole	300	50	
	Total		8,919	11,000		11,245	245	
Rainy Season								
1	Shanthipura		-	-	Shanthipura	-	-	
2	Piyatisappura		82	101	Piyatisappura	1,080	979	
3	High Area 1	Old Water Field	553	682	Old Water Field	3,050		
		New Water Field	114	141	New Water Field	630		
		Gamunu	122	150	Gamunu	670		
		Brewery	310	383	Brewery	1,710		
		Pedro	0	0				
		Lovers Leap	293	361	Lovers Leap	1,615		
	Sub Total		1,392	1,717		7,675	5,958	
4	Low Area 1	Haddon Hill	3,912	4,825	Bambarakele	6,447		
		Unique View	752	928	Pedro			
		Vijithapura	563	694	New Borehole	0		
	Sub Total		5,227	6,447		6,447	0	
5	Low Area 2		1,524	1,879	New Borehole	0		
					Bambarakele	1,879		
					Pedro			
	Sub Total		1,524	1,879		1,879	0	
6	High Area 2		491	606	Upper Lake Road Borehole	0		
					Bambarakele	559		
					Pedro			
	Sub Total		491	606		559	-47	
7	Bonavista		203	250	Race Course Borehole	0		
					Bambarakele	250		
					Pedro			
	Sub Total		203	250		250	0	
	Total		8,919	11,000		17,890	6,890	

Remarks: Wet Season Water Resource

Bambarakele	4,858	m³/d
Pedro	4,277	m³/d
Ttal	9,135	m³/d



Flow Rate : Year 2015 Day Max (cum/d)

Fig 5.4 Proposed Flow Diagram in Dry Season

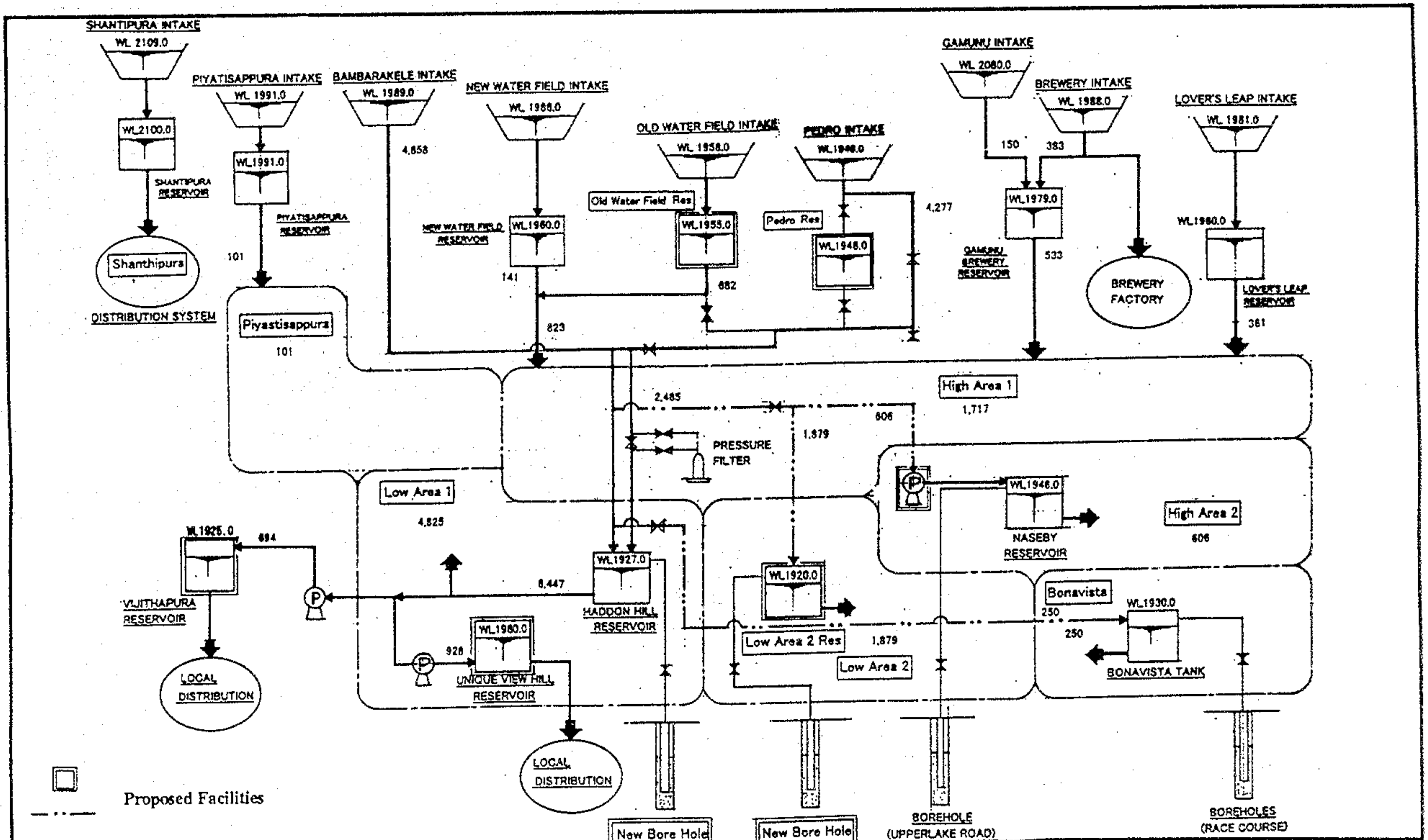


Fig 5.5 Proposed Flow Diagram in Rainy Season

Flow Rate : Year 2015 Day Max (cum/d)

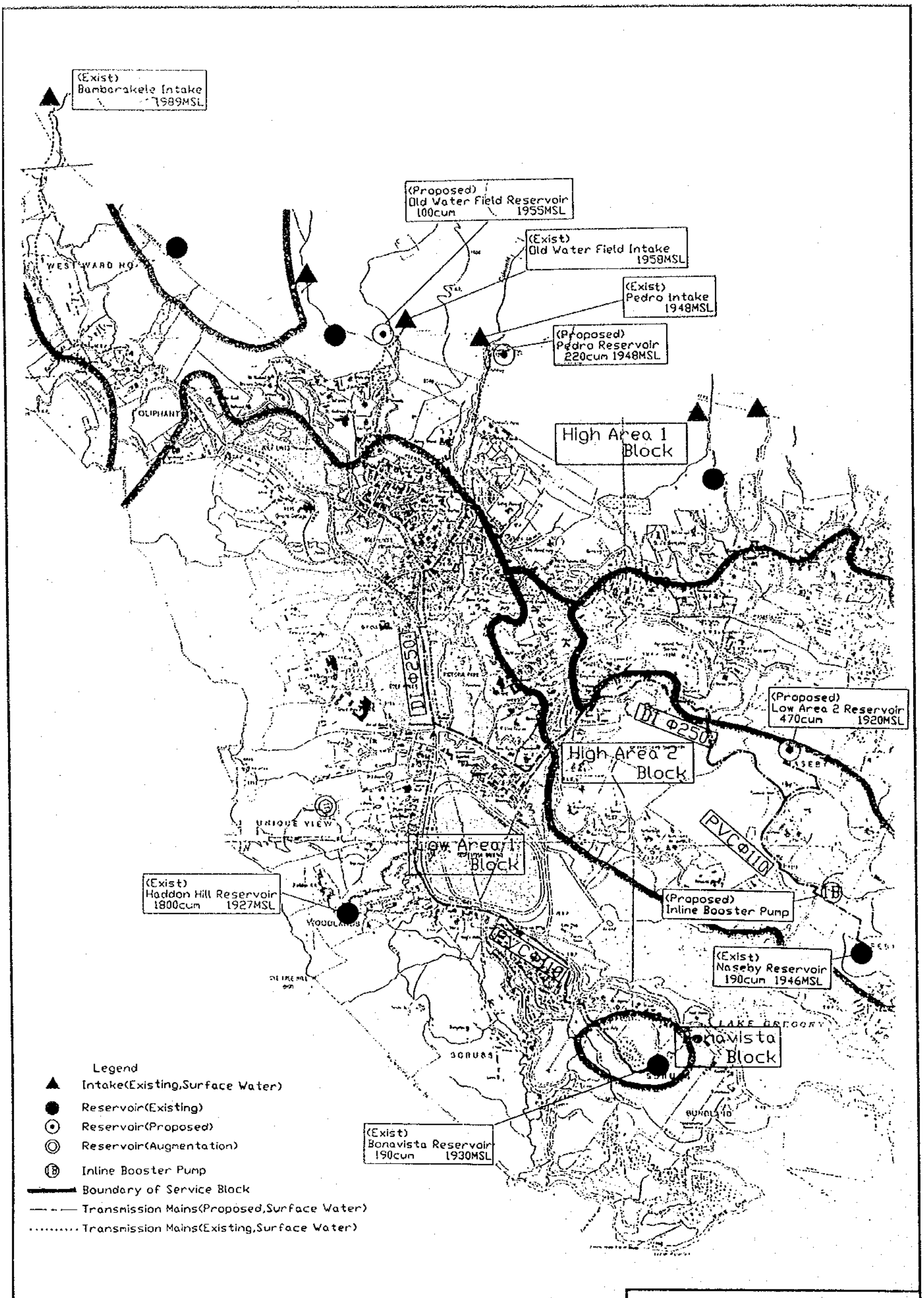


Fig 5.6 Layout of Proposed Transmission Facilities

(4) Utilization of the existing filter tanks

The existing filter tanks are installed near the Victory Park to treat raw water from Bambarakele and Old Water Field, and Pedro water sources, when their water qualities are worse.

At present, the treated water from filter tanks is directly flowing into the distribution main, which may possibly affect to the treatment efficiency due to pressure fluctuation. It is recommended that the treated water pipe should not be connected to the distribution main by means of operation of the existing isolation valves, and should be rerouted to the transmission line running to the Haddon Hill Reservoir.

5.3.5 Plan for Distribution Network

(1) Provision of appropriate water pressure through arrangement of distribution network
The existing distribution network will cause excessively high/low pressure areas against the water demand in 2015. Improvement of distribution network is required by realignment of distribution main corresponding to introduction of new distribution reservoirs, etc.

Required sizes, lengths and pipe materials for distribution network were determined through hydraulic analysis for the target year 2015 under the normal conditions (hourly maximum supply volume). It was verified with the water demand in 2005 so as to minimize the initial investment in the phase 1 project and confirmed that a part of distribution lines could be constructed in phase 2.

Locations of distribution pipelines for augmentation are shown in Figure 5.7, while required volume of pipe materials is summarized in Table 5.9. Several locations of distribution network require realignment of pipe connection corresponding to rearrangement of service blocks.

Improvement effects on water pressure by this realignment are summarized in Table 5.10 under the hourly maximum water demand in 2015.

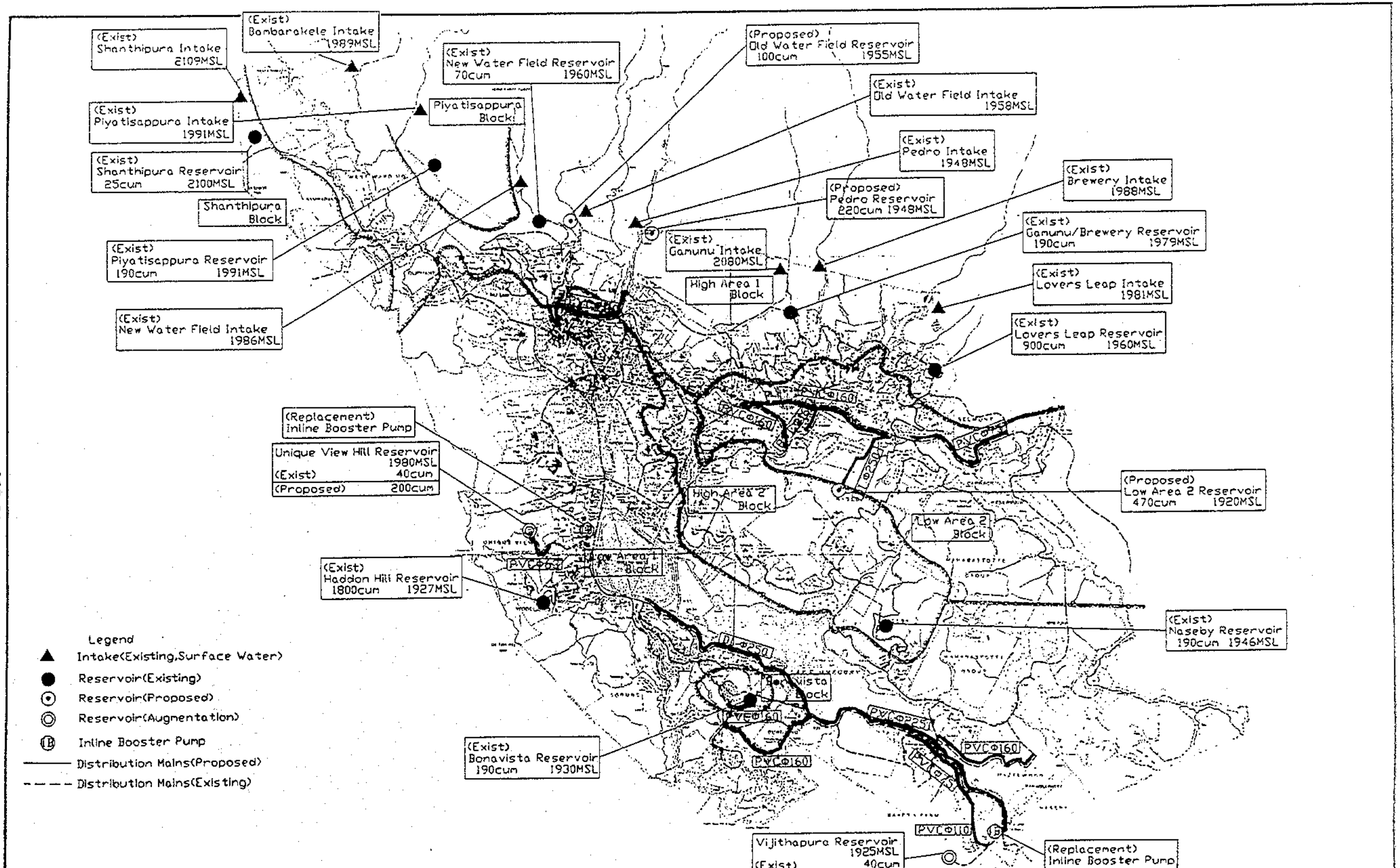


Fig 5.7 Layout of Proposed Distribution Mains

Table 5.9 Magnitude of Distribution Network Augmentation

Pipe Material	Diameter (mm)	Length (m)		
		Phase 1	Phase 2	Total
PVC	63	50	-	50
PVC	75	1,460	-	1,460
PVC	110	1,839	-	1,839
PVC	160	1,828	1,773	3,601
PVC	225	1,760	132	1,892
DI	250	2,069	-	2,069
Total		9,006	1,905	10,911

Table 5.10 Comparison of Dynamic Head at Present and After Improvement

Unit: m

Node	Existing Network	Improved Network	Node	Existing Network	Improved Network
29	1.4	24.6	16	97.4	53.9
104	-0.5	10.5	121	88.3	50.5
112	-6.9	16.3	124	79.4	35.5
179	4.9	12.4	125	71.7	27.5
189	-1.0	7.8	127	78.9	34.8
510	4.2	12.0	131	78.6	34.5
173	2.0	9.5	137	72.0	38.8
528	-4.5	2.0	160	74.2	40.6
40	1.7	9.6	187	73.9	53.8
15	98.2	54.6	300	73.8	56.1

(2) Verification of appropriateness on water level at Low Area 2 distribution reservoir

Hydraulic simulation analysis of distribution network under the normal condition (hourly maximum water demand) in 2015 revealed that when water level at Low Area 2 Reservoir is set at 1,920 MSL, dynamic heads were 13 m in the minimum, 54 m in the maximum and 20 to 40 m in most of the junctions/branches (nodes).

Static heads were 54 m at the maximum and 24 m at the minimum and more or less 30 m at most of the locations, the above simulation results were deemed within the appropriate range of pressures.

(3) Evaluation of existing booster pump capacity at Low Area 1 Block

Low Area 1 block to be served by the Haddon Hill Reservoir is planned to branch water to Vijithapura and Unique View Hill Reservoirs via booster pumps installed in distribution network.

The existing booster pump capacity was evaluated to verify whether they could cope with the rearranged service blocks and future increase of water demand as follows:

1) Booster pump capacity to serve for Vijithapura Reservoir
   The existing pump (0.42 m^3/min x 35 m x 7.5 kW x 1 unit) shall be replaced with an inline booster pump (0.48 m^3/min x 25 m x 3.7 kW x 1 unit).

2) Booster pump capacity to serve for Unique View Hill Reservoir
   The existing pump (0.54 m^3/min x 78 m x 15kW x 1 unit) shall be replaced with an inline booster pump (0.64 m^3/min x 85 m x 18 kW x 1 unit).

5.3.6 Capacity Augmentation of Distribution Reservoir

(1) Distribution Reservoir requiring capacity augmentation

Table 5.11 presents distribution reservoirs with their respective service blocks and capacity balance.

Low Area 2 Reservoir is proposed as a new one to cater for new service block. Distribution reservoirs at Old Water Field and Pedro are directly supplied from the existing water intake facilities at present and are subject to augmentation to meet with hourly fluctuation of water demand during dry season.

Distribution reservoirs at Unique View Hill and Vijithapura blocks require augmentation of their storage capacities to cope with future water demand.

Retention time at distribution reservoir is set to keep the minimum 6 hours capacity over the daily maximum water demand.

Figure 5.8 shows layout of proposed reservoirs and Table 5.12 shows their required capacities, respectively.

Table 5.11 Required Capacity of Reservoirs (Dry Season)

No.	Block		2015 Max. Daily Demand A (m^3/d)	Reserver							
					Name	Water Level (m amsl)	Required Capacity D=6/24*A (m^3)	Existing Capacity E (m^3)	Existing Capacity F (hours)	Balance G=E-D (m^3)	New Facility
1	Shanthipura		-		Shantipura	-	-	-	-	-	
2	Piyatisappura		101		Piyatisappura	1,991.0	25	190	45.1	164.8	
3	High Area 1	Old Water Field	392	New	Old Water Field	1,955.0	98	0	0.0	-98.0	To be constructed 100 m^3
		New Water Field	68		New Water Field	1,960.0	17	70	24.7	53.0	
		Gamunu	19		Gamunu /Brewery	1,979.0	67	190	17.1	123.3	
		Brewery	248								
		Pedro	879	New	Pedro	1,948.0	220	0	0.0	-219.8	To be constructed 220 m^3
		Lovers Leap	111		Lovers Leap	1,960.0	28	900	194.6	872.3	
	Sub Total		1,717					1,160			
4	Low Area 1	Haddon Hill	4,825		Haddon Hill	1,927.0	1,206	1,800	9.0	593.8	
		Unique View	928		Unique View	1,980.0	232	40	1.0	-192.0	To be augmented 200 m^3
		Vijithapura	694		Vijithapura	1,925.0	174	40	1.4	-133.5	To be augmented 140 m^3
	Sub Total		6,447					1,880			
5	Low Area 2		1,879	New	Low Area 2	1,920.0	470	0	0.0	-469.8	To be constructed 470 m^3
6	High Area 2		606		Naseby	1,946.0	152	190	7.5	38.5	
7	Bonavista		250		Bonavista	1,930.0	63	190	18.2	127.5	
	Total		11,000					3,610	7.9		

Required Capacity = Demand (Maximum Daily) × 6hr / 24hr

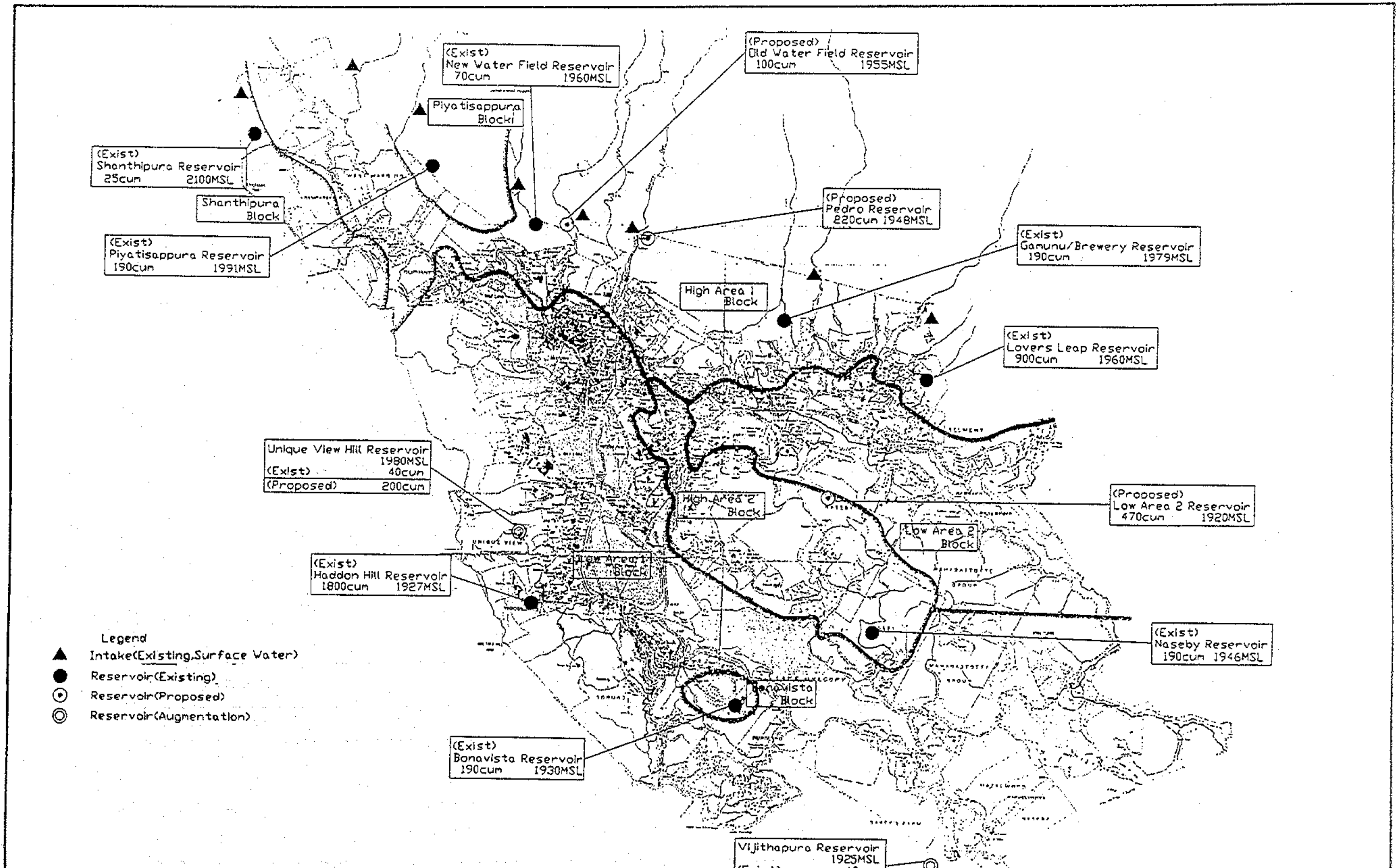


Fig 5.8 Location of Proposed Reservoirs

Table 5.12 Distribution Reservoirs to be Augmented

Distribution Reservoir	Required Capacity (m^3)	Dimension	Design Capacity (m^3)	Remarks
Old Water Field	98.1	W4.5 x L3.7 x D3.0 m x 2 units	100	
Pedro	219.7	W6.0 x L6.2 x D3.0 m x 2 units	220	Elevated reservoir
Low Area 2	469.8	W10.0 x L7.9 x D3.0 m x 2 units	470	
Unique View Hill	192.0	W8.6 x L8.6 x D3.0 m x 2 units	200	Existing reservoir will be continued
Vijithapura	133.5	W8.5 x L5.5 x D3.0 m x 2 units	140	Existing reservoir will be continued

(2) Distribution volume control from High Area 1 Reservoir

Difference of water level among water sources in High Area 1 is 31 m (=1,979-1,948); the highest is at 1,979 m amsl (Gamunu Brewery) and the lowest is at 1,948 m amsl (Pedro).

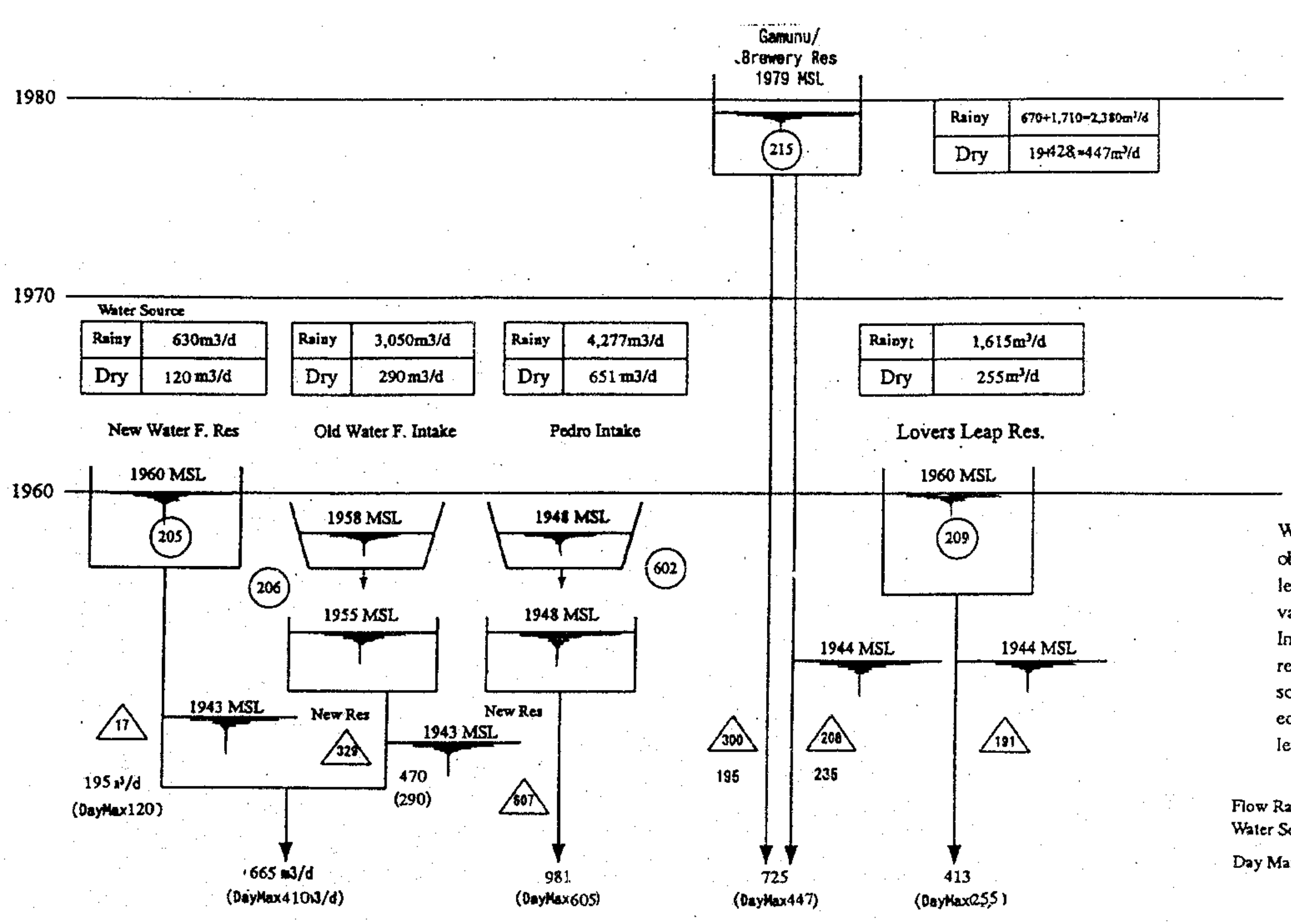
When water level at distribution reservoir is fixed and gravity flow is allowed without any control, the hydraulic simulation result under the normal condition (hourly maximum water demand) in 2015 revealed that water distribution could not meet with source capacity in both dry and rainy seasons since larger volume of water would be supplied from reservoirs having higher water level or smaller head loss in distribution main.

The hydraulic simulation was then repeated under the following pre-conditions.

- Water level at New Pedro reservoir is fixed,
- Distribution volumes at other reservoirs are fixed at source capacity in dry season.

Water level of reservoirs under the fix discharge condition in the High Area 1 block during dry season is shown in Figure 5.9.

When water level at New Pedro Reservoir is fixed, water levels at other reservoirs become lower than the actual water level by 13.0 to 35.0 m. This means that the fixing of water level at New Pedro Reservoir causes actual water level in distribution lines leaving empty conditions in other reservoirs or balanced conditions under lowered water levels. This phenomenon revealed that even if the required volume is secured at respective reservoirs, the principal functions of reservoirs could not be performed. In other word, flow control at each reservoir is inevitable by means of valve operation.



Water levels of each reservoir were obtained by calculation on fixed water level at the Pedro reservoir. Control valves are assumed to be open fully. In order to utilize the capacity of reservoirs, valves should be controlled so that head loss by the valve is equivalent to calculated drop of water level in the figure.

Flow Rate : Dry Season Year 2015 (Hourly Max)
Water Source : Dry Season

Day Max = Hourly Max × 1/2.0 × 11,000/8,919

Fig 5.9 Dynamic Water Level of Reservoirs without Valve Control

Valve control will cause insufficient distribution pressure in some part of service area. However,

a. Such influence will be limited to small area only during the peak demand hours.
b. Conditions for the calculation is the worst one.
c. Actual flow rate will be reduced, but no vacuum condition is expected.

Thus, no specific countermeasure is deemed necessary, except for valve control.

5.3.7 Disinfection Facilities

At present, disinfection (chlorine gas and calcium hypochlorite) is introduced under the ADB project. Gas chlorinator is planned at Haddon Hill Reservoir, while calcium hypochlorite disinfection facilities are being provided other small reservoirs.

Generally, chlorination by gas chlorinator is deemed appropriate for rather large-scale facility, while calcium hypochlorite is suitable for small-scale facility. It is, therefore, recommended that disinfection shall be made by calcium hypochlorite for the raw water at inlet of new reservoirs (Old Water Field, Pedro, and Low Area 2).

5.4 Summary of Development Plan

Facilities to be developed in the project consist of following facilities as presented in Table 5.13.

(1) Intake and conveyance
- New wells
- Conveyance pipeline

(2) Treatment Facility
- Treatment (chlorination) facility

(3) Transmission and Distribution Facilities
- Transmission pipelines
- Distribution reservoirs and pressure control chamber
- Distribution pipeline network

Layout of the facilities in the long-term development plan is presented in Figure 5.10.

Table 5.13 Proposed Facilities for Long-Term Development

				Unit	Quantity Phase 1	Phase 2	Total
1 Intake Facility							
	Well Pump	Well		pcs.	7	-	7
		Pump Equipment	1000 m^3/d x 58 n	set	8	-	8
		Electrical Facili-ties		set	7	-	7
		Pump House	10 m^2	set	7	-	7
	Conveyance Pipe	PVC 160		m	1,240	-	1,240
	Conveyance	Pump Well	21m^3	set	2	-	2
		Pump Equipment	5,000 m^3/d x 68 r	set	2	-	2
			1,900 m^3/d x 63 r	set	2	-	2
		Electrical Facilities		set	2	-	2
		Pump House	25m^2	set	2	-	2
2 Transmission Pipe Line							
		PVC 110	for Surface water	m	2,867	-	2,867
		PVC 225	for Groundwater	m	700	-	700
		DI 250	for Surface water	m	3,545	488	4,033
		DI 300	for Groundwater	m	4,320	-	4,320
		Pump Equipment	600 m^3/d x 25 m	set	1	-	1
			690 m^3/d x 25 m	set	1	-	1
			920 m^3/d x 85 m	set	1	-	1
		Electrical Facilities		set	3	-	3
		Pump House	4 m^2	set	3	-	3
3 Treatment Facility							
	Chlorinator			set	3	-	3
	Chlorination Hous 10 m^2			set	3	-	3
4 Distribution Facility							
	Reservoir						
		Old Water Field	100 m^3	set	1	-	1
		Pedro	220 m^3	set	1	-	1
		Unique View	200 m^3	set	1	-	1
		Vijitapura	140 m^3	set	1	-	1
		Low Area 2	470 m^3	set	1	-	1
	Distribution Pipe						
		PVC 63		m	50	-	50
		PVC 75		m	1,460	-	1,460
		PVC 110		m	1,839	-	1,839
		PVC 160		m	1,828	1,773	3,601
		PVC 225		m	1,760	132	1,892
		DIP 250		m	2,069	-	2,069

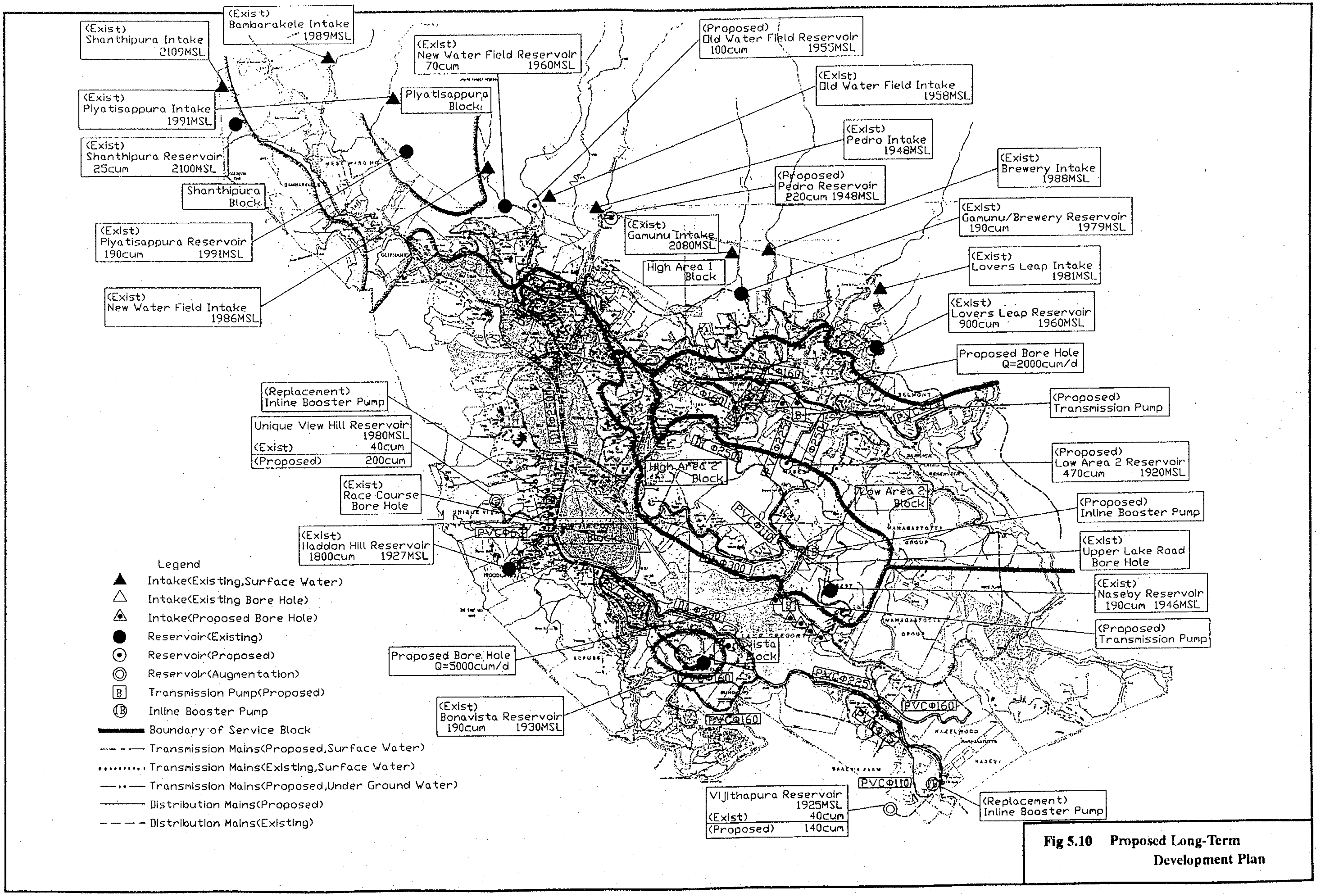


Fig 5.10 Proposed Long-Term Development Plan

5.5 Project Cost

5.5.1 Composition of Project Cost

Composition of project cost is shown below:

Project Cost

- Construction Costs
  - Direct Cost
    - Civil Work
    - Mech./Elec. Work
  - (Site Expenses)
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Equipment Procurement
  - Equipment
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Engineering Services
  - Detailed Design
  - Construction Supervision
- Common Costs
  - General/Administration Expenses
  - Land Acquisition
- Contingencies
- GST (12.5 %)

5.5.2 Conditions for Cost Estimate

Project cost is estimated on the basis of preliminary design of the Master Plan Study. Unit prices and lump sum prices are established considering local conditions, sub-contractors, hiring equipment, available construction equipment and materials as well as suitability of the construction method.

Assumptions and conditions applied for the cost estimate are as follows:

Price level	:	as of Nov. 1998
Foreign exchange rate	:	Sri Lankan Rs. 1.00 = Japanese ¥ 1.80

5.5.3 Project Cost

Total cost of the proposed project is estimated at approximately Sri Lankan Rs. 568 million as shown in Table 5.14.

Table 5.14 **Estimated Total Project Cost**

Unit: Thousand Sri Lankan Rs.

(1) Construction cost		
1) Intake Facilities		112,499
Well / Well Pump		
2) Transmission Pipe		97,196
3) Water Treatment Plant		3,150
Chlorination		
4) Distribution Facilities		115,620
Reservoir	64,513	
Pipe Facilities	49,957	
House Connection Replacement	1,150	
5) NRW Reduction Program (Leak detection)		2,500
7) Rehabilitation of NRW Reduction		17,000
6) Administration cost		18,035
Sub-Total		**366,000**
(2) Procurement of maintenance equipment		**25,000**
(3) Engineering cost		
1) Detailed design	19,600	
2) Construction supervision	16,400	
Sub-Total		**36,000**
(4) Common expenses		
1) General and administration expenses	6,000	
2) Land acquisition	6,000	
Sub-Total		**12,000**
(5) Contingency		**66,000**
(6)GST(12.5%)		**63,000**
Total		**568,000**

Note: Exchange rate: SL Rs 1.00 = Japanese Yen 1.80 (as of Nov. 1998)

5.6 Implementation Schedule

In connection with the target years for this Study (2005 and 2015), all of required facilities will be constructed during Phase 1 by the end of 2003, while Phase 2 to complete the NRW reduction program. Cost for the NRW reduction program is not counted in the study of this stage.

Phase 1 (1999 to 2003) - Priority Project

1999-2000	Preparation of project
2001-02	Detailed design, bidding
2002	Commencement of construction & procurement of equipment
2002-03	Construction
2004	Commencement of operation

Phase 2 (2010 to 2012)

2010	Preparation of project
2011	Detailed design, bidding
2011	Commencement of construction & procurement of equipment

2012 Commencement of operation

The project implementation and disbursement schedule with estimated annual disbursement of project cost is presented in Table 5.15.

Table 5.15 Implementation and Disbursement Schedule of Nuwara Eliya Water Supply Project

Item \ Year	Phase	Phase 1					Phase 2		
		1999	2000	2001	2002	2003	2010	2011	2012
Implementation Schedule									
1. Preparation of Project									
2. Pre-Construction Stage									
2.1 Detailed Design									
2.2 Bidding									
3. Construction									
3.1 Water Source Facilities									
- Civil Work									
- Mechanical/Electrical Work									
3.3 Transmission Facilities									
3.4 Distribution Facilities									
4. Procurement of Equipment									
5. NRW Reduction Program									
Disbursement Schedule	**Total Cost (Million SL Rs.)**				Phase 1	549.0		Phase 2	19.0
1. Land Acquisition	6.0			6.0					
2. Administration	6.0			1.0	1.5	1.5		1.0	1.0
3. Construction Work	346.5				136.5	198.0		2.0	10.0
4. Procurement of Equipment	25.0					25.0			
5. NRW Reduction Program	19.5				8.5	11.0			
6 Engineering Service	36.0			19.0	8.0	8.0		0.6	0.4
7. Contingency	66.0			3.9	23.2	36.9		0.5	1.5
8. GST(12.5%)	63.0			3.7	22.2	35.1		0.5	1.5
Total of Annual Disbursement	568.0			33.6	199.9	315.5		4.6	14.4

Table 5.16 Outline of Nuwara Eliya Water Supply Project

				unit	Phase 1	Phase 2	Total
Frame Value	Project Area				Nuwara Eliya Municipal Council area		Figures in each phase shows the total figures in last year of each phase.
	Target Year				2005	2015	
	Population			person	41,447	49,178	
	Service population			person	33,800	44,300	
	Service Ratio			%	82%	90%	
Water Demand	Unit Water Demand	Domestic		lpcd	107	107	Figures in each phase shows the total figures in last year of each phase.
		Non-Domestic		lpcd	44	44	
		NRW		lpcd	101	50	
		Total		lpcd	252	201	
	Daily Average	Domestic		m^3/d	3,624	4,749	
		Non-Domestic		m^3/d	1,480	1,940	
		NRW		m^3/d	3,402	2,230	
		Total		m^3/d	8,506	8,919	
		NRW-%		%	40%	25%	
	Daily Max			m^3/d	10,200	10,700	
Proposed Facilities	Service Area				Nuwara Eliya Municipal Council area		
	Demand	Average Daily Water Demand		m^3/d	8,506	8,919	8,919
		Maximum Daily Water Demand		m^3/d	10,200	11,000	11,000
	Intake Facility	Location	Upper Lake Road, Uda Pussllawa Road	sites	2 (7 wells)	-	2 (7 wells)
		Capacity		m^3/d	6,000	6,500	6,500
		Facility			Deep Well, Pump Pit, Elect./Mechanic.Equipment		
	Treatment Facility	Location			Old Water Field , Pedro, Low Area 2		
		Capacity		m^3/d	2,920	3,150	3,150
		Treatment Method			Chlorination		
		Disinfection Facility	Chlorinator	sites	3	-	3
	Transmission Facility (Groundwater)	Capacity		m^3/d	6,000	6,500	6,500
		Transmission Pipe	PVC ϕ225	m	700	-	700
			DI ϕ300	m	4,320	-	4,320
		Transmission Pump		stn.	2	-	2
	Transmission Facility (Surface Water)	Capacity		m^3/d	8,514	9,182	9,182
		Transmission Pipe	PVC ϕ110	m	3,545	488	4,033
			DI ϕ250	m	2,867	-	2,867
		Transmission Pump		stn.	3	-	3
	Distribution Facility	Reservoir		units	5	-	5
		Distribution Pipe	PVC ϕ63~225	m	6,937	1,905	8,842
			DI ϕ250	m	2,069	-	2,069
Project Cost	Construction Cost	Construction Cost			354.0	12.0	366.0
		Procurement of Maintenance Equipment			25.0	0.0	25.0
		Engineering Cost			35.0	1.0	36.0
		Common Expenses			10.0	2.0	12.0
		Contingency			64.0	2.0	66.0
		GST (12.5%)			61.0	2.0	63.0
		Total	Unit : Million Rs.		549.0	19.0	568.0
	O & M Cost	Personal Expenses			2,160	2,160	
		Electricity Cost			2,495	2,733	
		Chemical Cost			9	10	
		Repair Cost			6,181	6,181	
		Total	Unit : Thousand Rs./year		10,845	11,084	

CHAPTER 6 PRIORITY PROJECT OF WATER SUPPLY SYSTEM PLAN

6.1 Identification of the Priority Project

Priority areas were selected for the first phase project based on the prioritization of service areas and the feasibility study was conducted thereto with the target year of 2005.

Since the difference in water demand among target years of 2005 and 2015 is only 7 %, transmission and distribution pipelines are designed to meet with the water demand in the target year 2015. Water demand by sub-service area and corresponding water source capacity as well as required capacity of distribution reservoirs are shown in Table 6.1.

6.2 Preliminary Design of Water Supply System

6.2.1 Design Conditions

(1) Topographic condition

Water supply service area situates at about 1,890 m amsl ranging from 1,860 m to 1,990 m. Within this service area, five new distribution reservoirs are planned:

- Old Water Field Reservoir and Pedro reservoir are located near the new water intake (dam) site.
- Unique View and Vijithapura Reservoirs are located as expansion facilities beside the existing ones.
- Low Area 2 Reservoir is planned as a new facility to serve for the Low Area 2.
- Old Water Field and Low Area 2 Reservoirs are to be located on the slopes.
- Vijithapura Reservoir is planned to be constructed after raising original ground elevation for about 2.5 m in order to attain the same ground elevation with the existing reservoir.

Table 6.2 Site Elevation of Proposed Reservoirs

Name of Reservoir	Ground Elevation (m amsl)
Old Water Field	1,965 to 1,955
Pedro	1,933 to 1,934
Unique View	1,982 to 1,980
Vijithapura	1,923.5 to 1925.5
Low Area 2	1,965 to 1,957

Table 6.1 Demand and Capacity of Sources and Reservoirs by Service Block (2005, Dry Season)

No.	Block		2005 Avg. Daily Demand (m^3/d)	2005 Max. Daily Demand A (m3/d)	Water Source: Name	Water Source: Yield B (m^3/d)	Water Source: Balance C=B-A (m^3/d)	Water Source: New Facility	Reserver:	Reserver: Name	Reserver: Required Capacity D=6/24*A (m^3)	Reserver: Existing Capacity E (m^3)	Reserver: Existing Capacity F (hours)	Reserver: Balance G=E-D (m^3)	Reserver: New Facility
1	Shanthipura		-	-	Shanthipura	-	-			Shantipura	-	-	-	-	
2	Piyatisappura		78	94	Piyatisappura	255	161			Piyatisappura	23	190	48.7	166.6	
3	High Area 1	Old Water Field	303	363	Old Water Field	290	-73		New	Old Water Field	91	0	0.0	-90.9	To be constructed $100 m^3$
		New Water Field	53	63	New Water Field	120	57			New Water Field	16	70	26.6	54.2	
		Gamunu	15	18	Gamunu	19	1			Gamunu/Brewery	62	190	18.4	128.1	
		Brewery	192	230	Brewery	428	198								
		Pedro	680	815	Pedro	651	-164		New	Pedro	204	0	0.0	-203.8	To be constructed $220 m^3$
		Lovers Leap	86	103	Lovers Leap	255	152			Lovers Leap	26	900	209.9	874.3	
	Sub Total		1,328	1,592		1,763	171					1,160			
4	Low Area 1	Haddon Hill	3,731	4,474	Bambarakele	1,327	-4,651			Haddon Hill	1,119	1,800	9.7	681.5	
		Unique View	718	861						Unique View	215	40	1.1	-175.1	To be augmented $200 m^3$
		Vijithapura	537	644						Vijithapura	161	40	1.5	-120.9	To be augmented $140 m^3$
	Sub Total		4,985	5,978		1,327	-4,651	New Borehole × 5 units				1,880			
5	Low Area 2		1,453	1,742		0	-1,742	New Borehole × 2 units	New	Low Area 2	436	0	0.0	-435.6	To be constructed $470 m^3$
6	High Area 2		469	562	Upper Lake Road Borehole	600	38			Naseby	140	190	8.1	49.5	
7	Bonavista		193	232	Race Course Borehole	300	68			Bonavista	58	190	19.7	132.0	
	Total		8,506	10,200		4,245	-5,955					3,610	8.5		

(2) Geological condition

Proposed site of Pedro reservoir has surface soil consisting of clay or sandy clay up to the depth of about 3 m and is subject for soil replacement. Unique View reservoir site requires about 2 m depth of soil excavation to meet with the same elevation of the existing reservoir. Other reservoirs are to be constructed on the existing ground elevation.

(3) Reliability of power supply

No particular measure is considered, since the water is planned to be distributed by gravity flow and power interruption is deemed minimal occurrence within tolerable duration for continuous operation of water supply system.

6.2.2 Intake Facility

(1) Water intake method

Future water demand (daily maximum basis) is estimated at 10,200 m^3/day in 2005 and 10,700 m^3/day in 2015, respectively. On the other hand, the existing surface water and groundwater sources have a total supply capacity of about 4,200 m^3/day in dry season. The water gap of about 6,500 m^3/day is hereby planned to be fulfilled by groundwater development.

The groundwater development potential was evaluated through test wells and approximately 1,000 m^3/day is deemed available from one deepwell. In this regard, a total of 7 deepwells are likewise planned to be constructed during the priority project. Five deepwells with a total discharge of 5,000 m^3/day are planned at Low Area 1, while 2 deepwells with a total discharge of 1,879 m^3/day are located at Low Area 2, respectively.

1) Capacity of new deepwell source

The required pump capacity was verified with the water demand in 2005 and concluded that the same capacity would be required both for 2005 and 2015.

a. Facility requirement of new deepwell for Haddon Hill block

Deepwell pump capacity:	0.70 m^3/min. x 58 m x 15 kW x 5 units
Transmission line:	PVC 160 mm dia., L = 1,110 m,

b. Facility requirement of new deepwell for Low Area 2 block

Deepwell pump capacity:	0.70 m^3/min. x 56 m x 15 kW x 2 units
Transmission line:	PVC 160 mm dia., L = 130 m,

2) Booster pump

Groundwater exploited from deepwells are collected to a pump pit and transmitted to respective reservoirs via booster pump.

The required pump capacity was verified with the water demand in 2005 and concluded that the same capacity would be required both for 2005 and 2015.

a. Facility requirement of booster pump for Haddon Hill block

Booster pump capacity: 3.47 m^3/min. x 68 m x 75 kW x 2 units (including 1 standby)

b. Facility requirement of booster pump for Low Area 2 block

Booster pump capacity: 1.30 m^3/min. x 63 m x 30 kW x 2 units (including 1 standby)

Transmission lines and booster pumps are summarized as shown in Tables 6.3 and 6.4.

Table 6.3 Required Transmission Line for Groundwater

Type	Diameter (mm)	Length (m)	Remarks
PVC	160	1,240	Intake 1,110 + 130
PVC	225	700	
DCI	300	4,320	
Total		6,260	

Table 6.4 Required Booster Pumps

Location	Specifications
Haddon Hill Block	3.47 m^3/min. × 68 m × 75 kW × 2 units (including 1 standby)
Low Area 2 Block	1.30 m^3/min × 63 m × 30 kW × 2 units (including 1 standby)

(2) Evaluation of existing deepwell pump facility

Capacities of the existing deepwell pump facilities at Upper Lake Road and Race Course were evaluated corresponding to the rearrangement of service blocks and water demand as follows:

1) Transmission pump capacity at Upper Lake Road for the Naseby block

Existing transmission pump capacity: 0.39 m^3/min. x 82 m x 11 kW x 1 unit

It is concluded that the existing pump can be utilized through the future based on the above evaluation referring to the pump performance curve (H-Q curve).

2) Transmission pump capacity at Race Course for Bonavista block

Existing transmission pump capacity: 0.42 m^3/min x 80 m x 11 kW x 2 units (including 1 standby)

It is concluded that the existing pump can be utilized through the future based on the above evaluation.

6.2.3 Transmission Facility

Required sizes, lengths and pipe materials for transmission lines to supply water from the existing water treatment plant were determined based on the hydraulic simulation for the target year 2015. The simulation result was verified with the water demand in 2005 so as to minimize the initial investment in the priority project and confirmed that a part of transmission line (Node Nos. 9 to 50) having diameter of 250 mm for the length of 488 could be implemented after the priority project. The configuration of transmission lines to be augmented during the priority project was summarized in Table 6.5.

Table 6.5 Transmission Lines Required for Surface Water Supply

Pipe Material	Diameter (mm)	Length (m)
PVC	110	2,867
DCI	250	3,545
Total		6,412

Capacity requirement of transmission pump was also verified to supply water from the existing water treatment plant to the Naseby Block. The pump specification (inline booster pump, 0.42 m^3/min. x 25 m x 3.7 kW x 1 unit) was determined to be same for both the priority project (562 m^3/day in 2005) and the Master Plan (606 m^3/day in 2015).

6.2.4 Distribution Facility

(1) Distribution network

Required sizes, lengths and pipe materials for distribution network were determined based on the hydraulic simulation for the target year 2015. The simulation result was verified with the water demand in 2005 so as to minimize the initial investment in the priority project and confirmed that a part of distribution lines for a total length of 1,905 m could be implemented after the priority project. The configuration of distribution network to be augmented during the priority project was summarized in Table 6.6.

Table 6.6 Distribution Network to be Augmented

Pipe Material	Diameter (mm)	Length (m)
PVC	63	50
	75	1,460
	110	1,839
	160	1,828
	225	1,760
DCI	250	2,069
Total Length		9,006

(2) Booster pump

Booster pumps are required to serve for Vijithapura Reservoir area and Unique View Hill Reservoir area with the following water demand. Pump capacity for both areas are determined to be same in 2005 and 2015.

Table 6.7 Water Demand of Vijithapura and Unique View Hill Reservoir Areas

Service Area	Water Demand (m^3/day)	
	2005	2010
Vijithapura Reservoir Area	644	694
Unique View Hill Reservoir Area	861	928

1) Booster pump capacity to serve for Vijithapura Reservoir

Existing pump shall be replaced with a new inline booster pump.

0.48 m^3/min. x 25 m x 3.7 kW x 1 unit

2) Booster pump capacity to serve for Unique View Hill Reservoir

Existing pump shall be replaced with a new inline booster pump

0.64 m^3/min. x 85 m x 18 kW x 1 unit

(3) Distribution reservoir and disinfection facility

Based on the water demand projection for the priority project, the following distribution reservoirs are planned to be newly constructed or expanded. Disinfection facility shall also be provided for every reservoir.

Table 6.8 Distribution Reservoirs to be Constructed or Augmented

Proposed Location	Required Capacity (m^3)	Dimension and Required Number of Unit	Design Capacity (m^3)	Remarks
Old Water Field	98.1	4.5 mW x 3.7 mL x 3.0 m E.D. x 2 units	100	
Pedro	219.7	6.0 mW x 6.2 mL x 3.0 m E.D. x 2 units	220	Elevated tank
Low Area 2	469.8	10.0 mW x 7.9 mL x 3.0 m E.D. x 2 units	470	
Unique View Hill	192.0	8.6 mW x 8.6 mL x 3.0 m E.D. x 1 unit	200	Existing reservoir shall be utilized.
Vijithapura	133.5	8.5 mW x 5.5 mL x 3.0 m E.D. x 1 unit	140	Existing reservoir shall be utilized.

Legend: E.D. – effective depth

6.2.5 Other Facilities

(1) Flow measurement of distribution amount

Flow measurement is indispensable to assess NRW as a balance between bulk flow from reservoirs and supplied amount to consumers.

There are several types of flow measurement devices, such as mechanical type flow meters and electromagnetic flow meter. From the cost effectiveness viewpoint, mechanical flow meter, which costs only 1/3 to 1/8 of the other type, is selected to be installed in the priority project as shown in Table 6.9. Variation of flow meter sizes is minimized in due consideration of available measuring capacity and ease of O&M by application of common wearing parts.

Table 6.9 Flow Meters to be Installed at Reservoirs

Reservoir	Outflow Pipe Size (mm)	Daily Max. Flow (m^3/day)	Meter Size (mm)
Piyatisappura	75	101	75
New Water Field	100	68	75
Gamunu/Brewery		83	
Gamunu/Brewery		184	
Lovers Leap	225	111	
Bonavista	75	250	
Old Water Field	150	392	
Pedro	200	879	100
Low Area 2	250	1,879	200
Haddon Hill	350	4,825	300

(2) Water quality analysis equipment

Nuwara Eliya water supply system consists of both surface water treatment and deepwell. In this regard, necessary laboratory facility and equipment are considered to cope with general examination of water quality, as described in Chapter 7.

For the time being, the water quality analysis may be limited turbidity, residual chlorine and odor taking account of available manpower resources.

(3) Protection of surface water intake site

Local residents are utilizing raw water intake site for washing place of their clothes. From the viewpoint of water quality conservation at water intake, public washing place shall be provided at downstream of the intake facility.

(4) Investigation of the existing Race Course deepwell

An operation of the existing Race Course deepwell has been suspended due to high sand content in groundwater.

The cause of high sand content shall be investigated to determine possibility for rehabilitation and appropriate rehabilitation method by means of submersible TV observation.

6.3 NRW Reduction Program

In the priority project, the costs for leakage a detection survey for 70 percent of the total length of the distribution network and for leakage repair will constitute 5 percent of the current total construction cost of the existing distribution network.

As a result of these project inputs, the current 56 percent of NRW is expected to be reduced to 40 percent by the target year of 2005 and to 25 % by the master plan target year of 2015.

6.4 Project Cost

Total cost of the proposed project is estimated at approximately Sri Lankan Rs 549 million as shown in Table 6.10.

Table 6.10 Estimated Project Cost

Unit: Thousand Sri Lankan Rs.

(1) Construction cost		
1) Intake Facilities		112,499
Well / Well Pump		
2) Transmission Pipe		93,024
3) Water Treatment Plant		3,150
Chlorination		
4) Distribution Facilities		108,496
Reservoir	64,513	
Pipe Facilities	42,983	
House Connection Replacement	1,000	
5) NRW Reduction Program (Leak detection)		2,500
6) Rehabilitation of NRW Reduction		17,000
7) Administration cost		17,311
Sub-Total		**354,000**
(2) Procurement of maintenance equipment		25,000
(3) Engineering cost		
1) Detailed design	19,000	
2) Construction supervision	16,000	
Sub-Total		**25,000**
(4) Common expenses		
1) General and administration expenses	4,000	
2) Land acquisition	6,000	
Sub-Total		**10,000**
(5) Contingency		**64,000**
(6)GST(12.5%)		**61,000**
Total		**549,000**

Note: Exchange rate: SL Rs 1.00 = Japanese Yen 1.80 (as of November, 1998)

6.5 Financial Evaluation of Priority Project

The results of the financial analysis on the priority project is as follows (refer to Chapter 17 for details):

Following conditions were assumed for the analysis.

(1) Costs

- Project cost presented in Table 6.10 (549 million Rupees).
- Operation and Maintenance cost presented in Table 7.4 (10,845 thousand Rupees per annum)
- Overhead equivalent to 15% of sales amount

(2) Income

- Water tariff is set at 90% of national average water tariff of NWSDB (13.36 Rs./m^3 in 1998). Annual water tariff increase of 1% in real terms is assumed.

- Fifty percent of total project cost is covered by subsidy of the government. Remaining will be borrowed with a policy of 10% annual interest, 24 years payback including 2 years grace period.

(3) Depreciation period is considered as 50 years for civil structures, 15 years for mechanical and electrical equipment, and 15 years for vehicles. Salvage values at 20% of initial cost is considered for mech./elec. equipment, and vehicles.

Tables 6.11 and 6.12 show the results of computation.

Table 6.11 FIRRs by Different Tariff Increase Rate of Priority Project

Tariff Increase Rate	0.0%	0.5%	**1.0%**	1.5%	2.0%
FIRR for F/S	4.26%	5.39%	**6.43%**	7.42%	8.36%

Note: Bold Faces are the recommended Cases.

Table 6.12 Results of Sensitivity Analysis on Priority Projects

Case	Annual Tariff Increase	Variance of Capital Investment and O&M Cost			
		-5%	0%	+5%	+10%
FIRR of F/S	1.0%	7.02%	**6.43%**	5.88%	5.36%

As presented in the above tables, the priority project shows rather good performance, though annual water tariff increase of 1% in real terms is assumed. It is viable financially. Cash flow analysis on the priority project assuming 10% annual inflation rate shows that operating fund is in short by 2009. If required operating fund can be borrowed with 10% annual interest rate, cumulative deficit can be recovered in 2015.

6.6 Implementation Schedule

The priority project, phase 1 of the long-term development plan is expected to be completed by the end of 2003.

Phase 1 (1999 to 2003) Priority Project

1999-2000	Preparation of project
2001-02	Detailed design, bidding
2002	Commencement of construction & procurement of equipment
2002-03	Construction
2004	Commencement of operation

CHAPTER 7 OPERATION AND MAINTENANCE PROGRAM FOR WATER SUPPLY SYSTEM

7.1 Work Program for Operation and Maintenance

7.1.1 Intake Facility and Disinfection Facility

Water supply system in Nuwara Eliya adopts only disinfection for both surface water and groundwater and disinfection facility is designed to be located at each reservoir.

The Operation and Maintenance (O&M) activities for the intake facility and disinfection facility are classified into two categories, - daily and periodical functions. The work categories by O&M type are shown in Table 7.1.

Table 7.1 Work Categories for Water Intake and Disinfection Facility by O&M Type

O&M Category	Working Category
Daily Inspection	-Flow rate of water intake and distribution, -Inspection to water sources, -Operating conditions of disinfection facility, -Operating conditions of mechanical/electrical facilities -Water quality examination
Periodical Work	-Cleaning of water source facility (monthly/seasonal) -Removal of sediments at reservoir (monthly/seasonal) -Inspection/repair of mechanical/electrical facilities (annually) -Overhaul of mechanical/electrical facilities (at 5 to 10 year interval)

The O&M activities for the intake facility and distribution facility should be carried out in accordance with the working program as shown below.

(1) Daily work program

Measurements of intake and treated water quantities are the principal activities in order to supply water to meet demand fluctuations. The washing of clothes upstream of the water intake should be discouraged on a regular basis. The population should be urged to carry out this downstream of the intake. To insure that the required quality of water is produced, inspection of the operating conditions of the disinfection facility and examination of raw water quality are prerequisites. Regular and periodical water quality examination at water sources and reservoir should be carried out. Examinations for major characteristics except turbidity, residual chlorine, and odor shall be contracted out to local contractors/laboratories to obviate the purchase of expensive equipment for infrequent use.

(2) Periodical work program

Periodical O&M items mainly focus on mechanical/electrical facilities. Reservoirs shall be periodically cleaned and sediments shall be removed and disposed of to landfill.

7.1.2 Transmission and Distribution Facilities

O&M activities include daily inspection, site investigation, rehabilitation of damaged pipes, etc. as shown in Table 7.2.

Table 7.2 Work Categories for Distribution Facilities by O&M Type

O&M Type	Working Items
Daily Inspection	-Operation of pumping facilities -Operation of electrical facilities
Site Investigation	-Confirmation of transmission/distribution facilities and their surrounding environment.
Rehabilitation	-Replacement/repair of damaged pipes
Water Quality Examination	-Periodical water quality examination of respective reservoirs and distribution lines.

The O&M for the transmission and distribution facilities should be conducted in accordance with the program below:

(1) Daily inspection

Pumping facilities are designed to operate automatically based on the change of water level in the reservoirs. Daily inspection of pump stations is required to monitor the operating conditions of pumps and associated electrical system.

(2) Site investigation

The transmission and distribution lines, reservoirs and surrounding environment should be surveyed regularly for damages caused by land-subsidence, erosion of slopes by rainfall, etc.

(3) Rehabilitation

Leakage repair of transmission/distribution lines and replacement of wearing parts for pumping equipment is the usual rehabilitation works.

Replacement of damaged pipes is usually sub-let to local contractors based on the annual rehabilitation plan or based on regular inspection reports. Water Board officials in charge of such repair work should prepare reports on situation and cause of damages, and countermeasures taken up for rehabilitation, as future reference for preventive O&M work.

(4) Water quality examination

Periodical sampling and water quality examination should be carried out at reservoirs, distribution lines and taps (end points of distribution lines) to confirm conformity to drinking water quality standards.

7.2 Organization for Operation and Maintenance

The proposed staffing for operation and maintenance is shown below and is 7 persons for Phase 1 and Phase 2.

Table 7.3 Required Number of Staff for O & M of Water Supply System

unit: persons

Field & Position		Phase 1	Phase 2	Assignment
Manager		1	1	Responsible for overall management/ supervision of waterworks
Maintenance	Technician	1	1	Responsible for site works
	Worker	5	5	Responsible for site works
Water Quality Examination**	Chemist	-	-	Water quality examination and control
Total		7	7	

* Vehicle maintenance shall be done by the municipal workshop.

** To be carried out by contract

7.3 Operation and Maintenance Cost

Annual costs for transmission/distribution facilities and water treatment plant operation and maintenance programs as described in the preceding sections are as shown in Table 7.4.

Table 7.4 Operation and Maintenance Cost

Unit: Thousand Rs./year

Item	Phase 1	Phase 2
Personal Expenses	2,160	2,160
Electricity Cost	2,495	2,733
Chemical Cost	9	10
Repair Cost	6,181	6,181
Total	10,845	11,084

CHAPTER 8 GROUNDWATER RESOURCES

Underlying the Nuwara Eliya Study Area are high-grade multi-phase metamorphic Precambrian rocks that are characterized by strong folding, shearing along the fold axes, and extensive regional faults.

A total of 14 single dimension electrical resistivity soundings were conducted in the Nuwara Eliya Study Area to identify the contact of the fresh rock and search for deep fractures. Sounding locations were based on prior sounding locations, and geologic and topographic information.

A total of 8 test wells was drilled during August 1998 and is summarized in the table. Mechanical breakdowns, unreliable water sources, insufficient and incorrect construction materials, and illnesses contributed significantly to delays and construction failures. Locations of the test wells are shown in Figure 8.1. Pump tests (well tests) were conducted or attempted on the completed wells. Pump tests also experienced problems and delays due to insufficient supplies, mechanical problems, and antiquated equipment. All pump tests are single well tests, without an observation well.

Table 8.1 Summary of Test Wells

Test Well Number	Site Name	Construction Status	Pump Test Status	Safe Yield (m^3/day)
33/46A	Victoria Park 1	Abandoned	N/A	N/A
32/27	Upper Lake Rd. 1	Completed	Failed	N/A
33/46	Galway Wildlife Bungalow	Completed	Completed	276
32/28A	Golf Course 1	Abandoned	N/A	N/A
32/28	Golf Course 2	Completed	Completed	770
33/47	Victoria Park 2	Abandoned	N/A	N/A
32/29	Upper Lake Rd. 2	Completed	Incomplete	400
33/48	Upper Lake Rd. 3	Completed	Failed	N/A

In cases where the pump tests failed, the failure was caused by excessive silt and sand in the water due to inadequate development, no screen, and no gravel pack, all problems of well construction.

From drawdown and recovery data for the completed pump tests, preliminary hydraulic parameters were calculated. The pump test conducted at test well 33/46 clearly shows that the yield is somewhat limited and conservatively estimated at 276 m^3/day. However, another series of pump tests would allow a better estimation of the safe yield. The pump test conducted at test well 32/28 clearly shows that the safe yield of 770 m^3/day can be improved. The completed depth is 88 m, indicating that the large diameter bore can be extended deeper. This would allow a higher pumping rate.

Analyses of existing wells, geology, and geophysical data indicate that several distinct hydrogeologic zones exist. Test wells that were drilled yielded additional valuable hydrogeologic data. Typically, a groundwater system of 2 to 4 zones (aquifers, aquitards) is defined by the hydrogeology within the first 200m. Overburden consists primarily of weathered gneisses, and commonly has a thickness of 2 to 50m. In areas of deep overburden, a 2-3m zone of clay and freshly weathered rock can be found just above the contact with hard rock. The clay particles tend to adsorb petroleum chemicals and contaminants, effectively creating an environmental filter and barrier. The hard rock typically has a shallow zone of fractures associated with weathering processes and is usually saturated. A series of faults and shears result in regional-scale deep fracture zones. The shear and fault zones typically extend from 10 to over 100km. These zones generally correspond to areas where more groundwater is available, with the fault zones having the most potential as a resource.

There is a marble formation near the south end of the valley, near the poorly mapped fault in the same area. Wells completed in this zone can be expected to have a good yield and are suitable for households and small farms.

Most of the existing wells in the valley are shallow and do not penetrate the underlying hard rocks. In addition, very little effort has been made to explore deeper zones for groundwater resources due to a lack of understanding and equipment. Several shear zones extend through the long axis of the valley, and 2 prominent faults intersect perpendicular to the shear zone. These features, field survey data, and test well results indicate that groundwater resources are available but are difficult to locate in substantial quantity.

All future pump tests would greatly benefit from having at least one observation well within 20 m of the pumping well. Future groundwater exploration should include geophysical surveys such as electrical resistivity, or seismic, to identify more precisely the water bearing fracture zones. The locations for future consideration should be focused where the faults are located, near the fishery center at the head of the valley, and across the center of town. Test wells should be located in these areas.

Other areas for future consideration are at Lake Gregory, where a lineament appears to cross the lake, and to the south of the lake where the other fault is mapped, near the marble formation.

Generally, the most desirable fracture zone will have a substantial layer of solid rock above it. The nature of fracture zones usually make it necessary to put a screen and gravel pack in the water bearing zone to prevent fracture debris from entering and clogging the plumbing. Additionally, it will be necessary to develop the wells sufficiently to ensure maximum yield and clear, clean water. To correctly evaluate the well and aquifer, it is necessary to conduct a pumping test using one or more properly constructed and spaced observation wells.

Fundamental problems still exist which will certainly prevent the successful development of groundwater resources in the Nuwara Eliya Study Area. Either the correct construction materials are in short supply or not available, such as blank steel casing, high quality PVC casing, commercially made screens. Drill bits are worn, size and type selections are inadequate, and there aren't any portable mud pits. It is clear that fracture zone hydrology in Sri Lanka is poorly understood and that the NWSDB would benefit from assistance and training from experienced and qualified hydrogeologists and groundwater engineers.

It can be seen that there is a very high potential to locate and further groundwater resources in the Nuwara Eliya Study Area. However, this will be difficult, if not impossible, without international assistance. It is strongly recommended that the Sri Lankan government seek and utilize international assistance to resolve water supply problems in the Nuwara Eliya Study Area, as well as improve their ability and equipment resources for future groundwater projects.

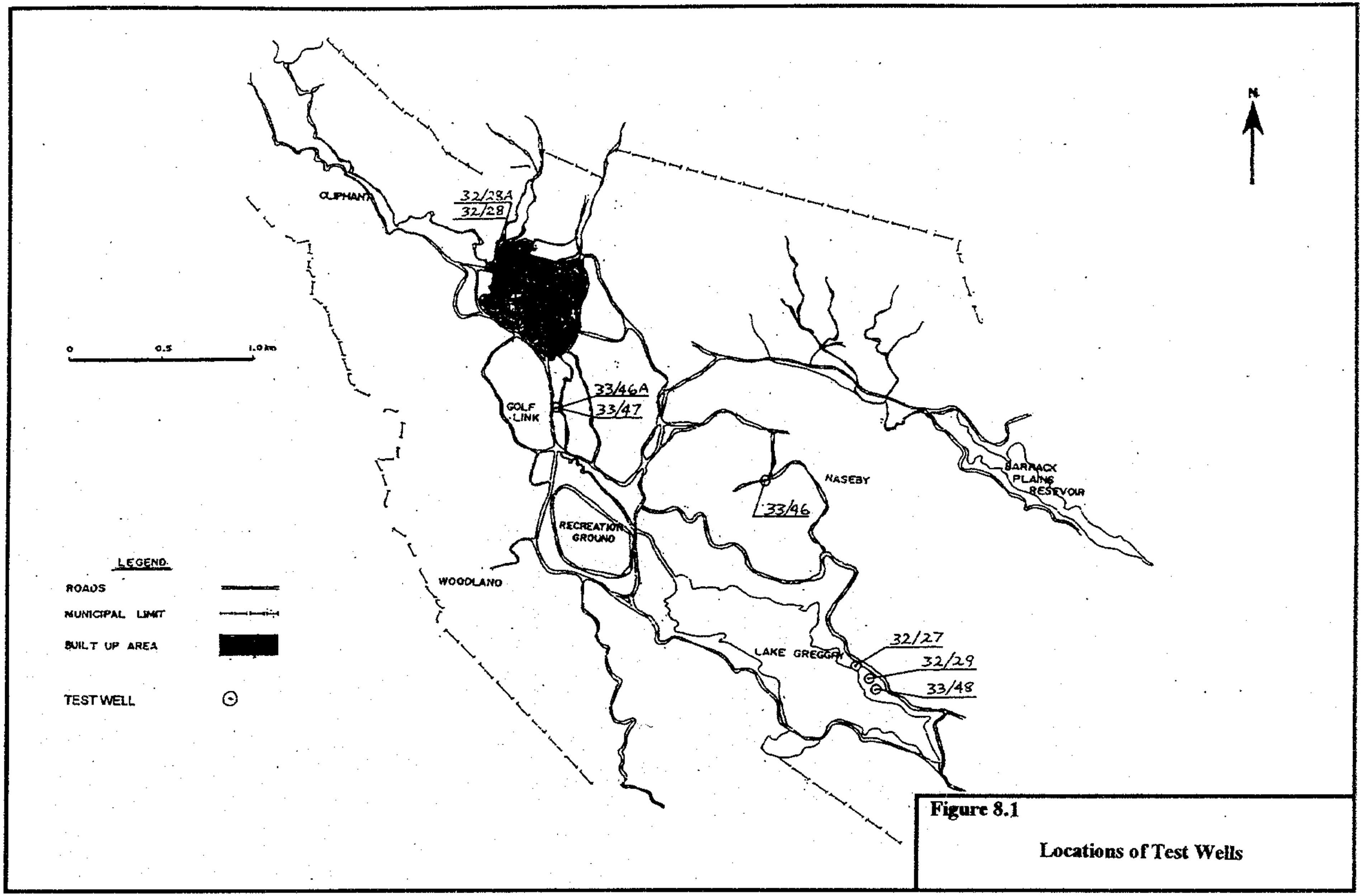


Figure 8.1

Locations of Test Wells

CHAPTER 9 NON-REVENUE WATER REDUCTION PROGRAM

9.1 General

Non-revenue Water (NRW) is defined as the difference between the quantity of water produced and the quantity for which the water utility receives revenue. The difference between unaccounted-for water (UFW) and NRW consists of water use by legal connections that are provided with water at no charge. The current NRW in Nuwara Eliya is estimated at 56 percent.

NRW can be due to a number of causes:

- Transmission main and distribution system leakage
- Reservoir leakage/overflow
- Unbilled legal connections
- Illegal connections
- Service connection meters
- Distribution system pressure
- Production metering
- Administrative errors

Some of these components, unbilled legal connections such as public standposts, for example, are known but not billed for social or economic reasons and only constitute a financial problem for the water utility. Other components, such as leakage, can only be estimated and reduced by relatively expensive methods. The cost of efforts to reduce NRW should not be greater than the value of the water saved by those efforts.

9.2 Estimated NRW Components

Large sections of the study area distribution system operate at insufficient pressure to produce detectable leakage sounds; thus there is no practical method for measuring the level of leakage. However, by subtracting the estimated values for other components from the total NRW, an approximation of current leakage levels can be derived.

The main transmission and distribution system comprises about 64 km of old and a further 18 km of new mains installed under the ADB project. Of the older mains about 40 km are cast iron with rigid joints and where these pipelines are underground there is a large potential for leakage.

Distribution system pipelines are primarily confined to major roads. Therefore significant proportion of the service connections are long, small diameter lines. This has resulted in "bundles" of up to a dozen pipes small diameter (12 to 25 mm) shallow, unprotected service connections in many streets. Water utility staff have identified some 1,000 m of streets with this condition after covering about ten percent of the service area indicating as much as 25 km of service connection pipes is involved which increases the effective pipe length by about 30 percent.

As existing reservoirs and appurtenances are being upgraded and repaired under an ongoing ADB improvement project, leakage/overflow has been assumed to be zero from these.

It is common practice in many water utilities not to bill certain categories of water users and in Nuwara Eliya these are schools, city park, municipal offices, stand posts and one public toilet. Although these customers are not presently metered, the water utility is now implementing a program to install meters. Estimated unbilled legal consumption is 640 m^3/d.

The Nuwara Eliya M.C. has formed a special task force to check for illegal connections in their system and located ten such connections during the first seven months of 1998. Maintenance staff believes that there are relatively few illegal connections, but estimate that these consume about two percent of total production.

Eighty percent of the existing meters are old and have no reverse flow protection devices. All new meters have built in non-return valves. On the average, about sixty meters per month are repaired, or about 20 percent of the total number of installed meters. The most common defect is some type of blockage from rust or sand particles. Based on the above, an overall low service connection meter registration equal to 10 percent of production has been assumed.

Measurement of production from the surface water sources serving Nuwara Eliya is accomplished by means of V-notch weirs and although the available flow data are limited, most has been collected during the dry season and is believed to be a reasonable estimate. During the wet season, flow is in excess of the transmission system capacity and flows cannot be measured. For the purpose of this investigation, production during the wet season has been taken as equal to the estimated capacity of the transmission mains. Pending the availability of more accurate flow measurement data, a value of ten percent of production has been assigned to this NRW component.

The Nuwara Eliya water utility reads meters on a monthly basis and estimate billing quantities for service connections with defective meters by comparison with the last three months metered consumption. Where no metered record is available, consumption is estimated by comparison with metered consumption for similar dwellings. Only six percent of the Nuwara Eliya service connection billings are estimated. Based on the above, administrative error is judged to be negligible.

A summary of the estimated NRW components is therefore:

- Transmission Main and Distribution System Leakage 11%
- Service Connection Line Leakage 8%
- Reservoir Leakage/Overflow 0%
- Unbilled Legal Connections 10%
- Illegal connections 2%
- Low Service Connection Meter Registration 10%
- Production Metering 15%
- Administrative Errors 0%
- Total 56%

As noted previously, estimates of most of the other NRW components are in themselves only general approximations and the resultant component estimates can only provide an approximate range within which the true leakage amount will fall.

9.3 The Cost of Non Revenue Water

Water saved due to implementation of a NRW reduction program is immediately reflected either in a reduction of projected demand or an increase in water utility revenues. The net effect of a successful program is to increase water utility revenue, and thus the ability to pay for water supply augmentation projects, and savings for projects that can be delayed or reduced in size. However, because existing supplies in Nuwara Eliya are inadequate to meet present demands, the question of project postponement does not arise. The cost of NRW reduction can, therefore, be taken as equal to the present day costs to augment existing supplies to a given service area.

The value of water saved due to NRW reduction efforts in Nuwara Eliya would be Rs 9.54 m^3 derived as follows:

Capacity	5,070 m^3/d
Annual O& M Cost	Rs 6,689,000/year
Capital Cost	Rs 156,818,000

Amortized Capital Cost	Rs 10,970,000/year
Average Annual cost	Rs 17,659,000/year
Unit NRW Cost	Rs 9.54 per m^3

9.4 Recommended NRW Reduction Program

The recommendations to reduce NRW are based on limited data available. The form and emphasis of the NRW reduction program presented below should, therefore, be periodically reviewed and updated to ensure that program efforts are cost effective.

9.4.1 Waste Management Districts

The location of areas where there are high concentrations of leaking pipes or illegal connection activity is best accomplished by dividing the distribution system into waste management districts that can be isolated from the rest of the distribution system by means of appropriately placed valves. Water supply to the district can then be measured by specialized waste meters and the results compared to billing record data.

Experience on NRW reduction programs in Colombo indicates that waste meters cannot be effectively employed where: (a) low distribution system pressures exist; (b) consumers have tanks that are filled at night; (c) high system connectivity; or (d) valves are in poor condition, insufficient in number or not properly located. Because all of these conditions exist to a significant degree in the Nuwara Eliya water supply system, the classical approach to leakage estimation by comparing minimum night flows to service meter records cannot be employed. Visual inspection and sounding methods are the only practical means of leak detection until conditions have been improved.

9.4.2 Leak Detection and Repair

Increases in the number and severity of leaks that usually accompany the addition of new water supplies to an existing system can overwhelm the existing leak repair capacity and increase NRW. Implementation of the NRW reduction program should be carefully coordinated with the schedule of improvements to the water systems to allow maintenance staff time to deal with the higher leakage repair work load.

9.4.3 Unbilled Legal Connections

Although most unbilled legal connections are for worthy social causes, the cost of such connections should not necessarily be borne by the water utility. Most of these uses are of benefit to the population at large and their costs should more appropriately be shouldered by some more broadly based financing mechanism (e.g. property tax). In most cases in the study area this is already being done or policy decisions have been made which will eventually result in shifting the burden of these costs away from the water utility.

9.4.4 Illegal Connections

Nuwara Eliya has a special team charged with locating illegal connections. The presence of numerous long service connection lines before the service meter provides ample opportunity for additional illegal connections to be made before the meter. These conditions should be corrected to minimize the probability that illegal connections will remain undetected.

9.4.5 Service Connections

It appears that the major causes of NRW in the Nuwara Eliya water system are related to the service connections. Although it is not clear whether the greatest impact is due to the extensive "bundles" of service connection pipes or under registration of the meters, it is apparent that their collective impact is large. Over 98 percent of the leaks repaired by the maintenance staff are associated with service connection leakage and service meters brought in for repairs have major under-registration problems.

Consideration should be given to using the more advantageous, locally produced and competitively priced polyethylene pipe (PE) for small diameter distribution main extensions and service connection lines instead of the PVC currently used.

As supplies increase with implementation of the proposed water system improvements, meter clogging should eventually diminish, but in the mean time attention to keeping repaired or newly installed pipes free from debris and periodic flushing of mains should help to minimize the problem.

Correction of the service meter flow reversal problem requires: adequate 24 hour pressures in the distribution system; provide effective reverse flow prevention devices; ensure that the reverse flow prevention devices on existing service meters are operational; and install all new service connections in accordance with appropriate back flow prevention plumbing regulations.

Nuwara Eliya appears to be coping with the service meter repair needs with existing meter workshop facilities and equipment, but lacks adequate meter calibration equipment.

9.4.6 Distribution System Pressure

Although some areas do exist in the Nuwara Eliya water system where excessive pressures aggravate the leakage problem, these areas are not extensive and some valves will be provided under the proposed improvement project to eliminate existing areas of excessive system pressure.

9.4.7 Production Metering

It is recommended that suitable (electromagnetic or other type suitable for metering a raw water source) bulk flow meters be installed on the transmission mains to provide an accurate means of measuring production in the future.

9.4.8 Customer Leakage and Waste

As the additional supplies develop under the water system improvement project, leakage and wastage on the consumer side of the meter is expected to escalate. Although leakage and waste on the customer side of the service meter are generally not considered to be the problem of the water utility, excessive water use by water utility customers, even though they pay for it, ultimately increases the water supplies that must be developed. Given the relatively high cost of new water supplies in the study area, it is a benefit to the water utility to minimize future demand by raising public awareness of this problem and enlist their support in the conservation of water public education programs that included use of TV spots, newspaper articles, radio commercials, posters, leaflets, public meetings and school competitions. A recommended adjunct to the public education methods noted above is to provide assistance to the customer in identifying sources of leakage and waste. One technique that has met with success elsewhere is to pinpoint customers that could potentially have a leakage and waste problem by computer searches of the billing records which identify customers where usage has increased dramatically from the same month the previous year, or even to a level more than some percentage above their average use for the last few months. Notification to customers with a potential problem can be included with their monthly bill. Assistance to the customer in identifying and repairing sources of leakage and waste can be provided by the water utility in the form of lists of plumbers certified to posses the skills and equipment required for the detection and rectification of leakage and waste problems.

9.4.9 Technical Assistance and Training

The establishment of an effective NRW reduction capability will require upgrading of the study area water utility staff capabilities in a number of areas:

- Leak detection methods and equipment
- Bulk meter repair and calibration
- Service meter calibration
- Service connection installation and repair
- Leak repair methods and equipment
- Pipe installation methods

9.4.10 Data Collection

One important observation as a result of this analysis is that there are areas where data, essential to planning and implementation of an effective NRW reduction program, are either not available or inadequate. The information that should be collected and recorded in support of the NRW reduction program is:

- Distribution system pressures
- Leak repairs (leakage rate, type of pipe, reason for leak)
- Valves (type, last date inspected, repaired, operated, condition)
- Bulk meter flow measurements
- Service meter records
- Waste meter flow measurements

9.5 Estimated Costs

A number of defects in the Nuwara Eliya water system are either responsible for the excessive NRW rates or make it difficult to identify the causes of NRW, the most important of which have been discussed above. The corrective actions needed are:

- Replace "bundles" of service connection lines with appropriately sized distribution main extension pipes
- Provide adequately calibrated bulk meters on all sources of supply

- Repair or replace gate valves to drop tight condition
- Repair or replace ball valves on reservoirs to prevent overflow losses
- Install air valves as required to minimize service meter reversal
- Replace old pipes with excessive leakage
- Relay pipes that have not been buried to an adequate depth
- Repair or replace leaking service connection valves
- Repair or replace under registering service meters
- Install meters on all service connections
- Provide additional leak detection equipment
- Provide adequate leak repair equipment and materials
- Provide additional meter repair and calibration equipment
- Provide waste metering equipment
- It is arguable as to which of these items of system rehabilitation should be attributed to the cost of NRW reduction and which are simply standard maintenance responsibilities. No matter what the costs are charged against, all the system improvements will be required to support an NRW reduction program.

The cost estimate given below was based on sounding 70 percent of existing distribution pipes by foreign specialists and that leak repair was 5 percent of the distribution pipelines cost.

9.6 Implementation

The estimated magnitude of the various components of NRW reduction program presented are necessarily approximate due to the limited amount of data currently available. The recommended NRW reduction program that is based upon the current estimate should consequently be regarded as only a starting point for development of a more detailed program. Implementation of the NRW reduction program should proceed in stages. An initial data gathering stage should be carried out to provide an adequate basis for a refined estimate of NRW components and the costs to upgrade existing facilities to the point where conventional leakage and loss detection methods can be applied. Once this information is available, development of a detailed short term and long term action plan can proceed, followed by full-scale implementation of the recommended NRW reduction program. It is suggested that technical assistance in planning, coordination and implementation of the NRW reduction program be provided to study area water utilities.

PART III SEWAGE AND SANITATION

CHAPTER 10 CURRENT SANITATION SYSTEM IN THE STUDY AREA

Sewage is discharged, on-site, throughout Nuwara Eliya area to 1) septic tanks and/or soakage pits, 2) latrines, primarily in the rural but also in the urban areas, and 3) wastewater treatment plants at some small developments.

Wastewater collection, treatment, and disposal in Nuwara Eliya are similar to that experienced in Kandy. On-site disposal is practiced using septic tanks with or without soakage pits, pit latrines or temporary latrines as reported in the Nuwara Eliya Environmental Study, 1996. Of the estimated population of 35,000, some 63 percent use water sealed toilets and 24 percent use pit latrines. There are eight public toilets in the NEMC.

Although treatment plants are provided, both the General Hospital and the Ceylon Brewery discharge wastewater without proper treatment, to adjacent streams, which flow to the Barrack Plains Reservoir. The hospital plant originally consisted of a sedimentation tank and a disinfection basin with effluent discharged to a soakage pit. Presently, discharge from the hospital contains both sewage and biohazardous materials which seriously jeopardizes the public health of the community. The brewery has constructed a new treatment plant but it is still under testing, due to improper removal of color. Existing facilities include, besides the hospital and the brewery facilities, a treatment plant located at the Inter Fashion textile factory to treat wash water from its operations. The plant consists of coagulation, sedimentation, and slow sand filtration. It appeared to be operated correctly and is treating wastewater from the factory satisfactorily. Sewage from the employees is discharged to septic tanks. Also some major hotels have their own secondary treatment system.

Most of theses effluent qualities of BOD and SS are substantially higher than the Central Environment Agency's standards (BOD_5: 30 mg/l, SS: 50 mg/l). The plan is improperly designed and the operation/maintenance suffers from inexperienced operators. It is recommended that the wastewater treatment plant be operated in a proper manner as soon as possible and that all drain lines are connected to the plant.

Contamination is high in both of the two catchment areas of Nuwara Eliya. The Nanu Oya, which runs through the downtown area and enters Lake Gregory, is used primarily for sewage collection and irrigation of home gardens. Lake Gregory is experiencing problems of eutrophication and siltation which causes significant growth of water plants. Although fishing was a major activity, Lake Gregory can no longer support fish in its waters. The Barrack Plains Reservoir is worse and is now no more than a mosquito breeding swamp fully covered with water plants.

All areas in NEMC, except the above mentioned areas, have on-site treatment facilities, mainly septic tanks and soakage pits, in lieu of central sewerage collection and treatment systems. The analyses show high concentration of SS which is due to excessive septage or sludge overflowing.

The sludge generated from septic tanks and hotels and factories are collected by a gully sucker, which is operated by the Municipal Council. NEMC has one gully sucker with a capacity of 7.0 m^3 and the operation is minimal. At present, sludge collected in Nuwara Eliya is disposed in pits located at the remote forest.

Septic tank sludge should be removed about every year. A system for regular collection of sludge should be implemented in both areas under consideration. With the introduction of the new facilities, the volume of sludge will increase and the present disposal sites will not be adequate to accommodate increased volumes of sludge and leachate. If remedial measures are not taken, the excess sludge and leachate will flow out to adjacent streams resulting in contamination of the streams and shallow aquifers.

In 1995 the Asian Development Bank financed the Urban Development Sector Project in which the storm drainage system of Nuwara Eliya was improved and is now reported to be acceptable. However, urbanization and development of vegetable fields in the catchment area will require additional improvements in the future to control flooding in the town center.

CHAPTER 11 PLANNING FUNDAMENTALS FOR SEWERAGE SYSTEM

11.1 Service Area and Service Level

The scope of work defines the area, for which the sewerage and sanitation improvement master plans are to be formulated, as the Nuwara Eliya Municipality.

The Master Plans are to be developed for the target year of 2015 and are to include the most densely populated and commercial areas. The Policy for the Sanitation/Sewerage services also includes:

a. In areas of low density, the continued use of low cost sanitation facilities.
b. In areas of high population and commercial density and where pollution of the environment or public health is a major concern, collection of wastewater by a sewerage system and provision of adequate low cost treatment and disinfection and provision for the safe disposal of effluent and sludge.
c. The combination of sewerage systems with nearby population centers where practical, to reduce capital and operation and maintenance costs.
d. The improvement of community public health by the elimination of raw wastewater discharges upstream of existing or proposed water intakes.
e. The improvement of the environment for one of the major industries in the area, Tourism.
f. To meet the requirements of the National Environmental Regulations.

Criteria to determine the target area for sewerage planning were established taking into account the above mentioned principal objectives, policies and the present conditions of the following:

a. Large-scale commercial areas
b. High population density
c. Large-scale facilities, such as schools, hotels, housing schemes, religious and institutional, both existing and proposed
d. Conservation of the natural environment (tourist spots etc.)
e. Reduction of pollutants from water sources.

There are several implications for provision of a public sewerage service, including 1) Cost and time requirement, 2) Accountability of executing agency, 3) Affordability of beneficiaries, and 4) Different states of urbanization by area.

Among the whole municipality area, two areas are considered to be served by the sewerage system. The first area, which is located in the Nanu Oya catchment area, covers the most of municipality area and Lake Gregory. The another area, which is located in the Barrack Plains catchment area, is also important due to existence of the hospital and industries.

Taking the above selection criteria into consideration, the sewerage service area was selected around the city center commercial area, a portion of Lake Gregory in the Nanu Oya catchment area and surrounding area, including the hotels, the Base Hospital and the brewery in the Barrack Plains catchment area. The service area covers some 314 ha.

11.2 Served Population

Based on the population data prepared by the Regional Rural Development Project in 1997, the population in 2005 and 2015 in the Nuwara Eliya municipality has been estimated. The population in the service area is 8,681, or 17 percents of total projected population data in 2015, covering the area of 314 ha which is 21 percents of whole municipality area.

11.3 Design Sewage Flow

In order to obtain design per capita sewage flow, an assumption that 80 percent of water consumption is discharged to the sewerage system is made for both domestic and non-domestic water supply. Non-domestic consumption consists of consumption by shops, restaurants, hospitals, hotels, offices etc. and by industries. Because most commercial facilities are located in the downtown area of the municipality, it has been assumed that excluding industrial use, 80 percent of the non-domestic water is consumed in the sewerage service area in 2015 and 60 percent in 2005. A hundred percent of industrial wastewater is discharged at the area where the brewery and garment factories are located.

Groundwater infiltration to the sewer system is assumed equivalent to a flow of 15 percent of the daily average sewage flow (domestic and non-domestic sewage flow).

As a result, the daily average per capita sewage flow in the service area has been estimated as follows:

Table 11.1 Per Capita Sewage Flow

Flow	Present (1997)	2005	2015
Domestic	74 lpcd	74 lpcd	74 lpcd
Non-Domestic	36 lpcd	39 lpcd	51 lpcd
Infiltration	20 lpcd	20 lpcd	23 lpcd
Total	130 lpcd	133 lpcd	148 lpcd

A peak factor of 1.2 for Maximum/Average daily flow was employed. This is the same peak factor used for water supply planning. In this study, sewage flow was measured at Hanthana Housing Scheme and peak factors calculated by using a modified form of Babbit's M-Curve, were obtained.

Therefore, peak factors for the Sewerage System are:

Maximum Daily / Average Daily : 1.2

Hourly Maximum / Average Daily : 2.0

Table 11.2 Design Sewage Flow

Characteristics	2005	2015
Area (ha)	314	314
Population	7,317	8,680
Average Daily Sewage Flow	2,000 m^3/d	2,300 m^3/d
Maximum Daily Sewage Flow	2,300 m^3/d	2,800 m^3/d
Hourly Maximum Sewage Flow	3,800 m^3/d	4,500 m^3/d

The daily and hourly maximum values of flow shown above include groundwater infiltration, which is considered to be constant.

11.4 Design Sewage Quality

Among other characteristics, BOD (Biochemical Oxygen Demand) and SS (Suspended Solids) are important water quality parameters in planning and designing sewage treatment plants. BOD, in particular, is a key parameter in the determination of the required capacity of sewage treatment plants.

Two methods are commonly used to determine BOD of sewage. The first method is the estimation of BOD by use of the unit BOD pollution excreta load per capita per day and the unit water consumption. The second method is, of course, the estimation of BOD based on the result of a comprehensive water quality examination of actual sewage sampled from the study area.

Using 38 g/capita/day as the unit BOD_5 pollution load, the BOD_5 for domestic sewage is calculated at 404 mg/l, while for non-domestic BOD_5 concentration, a half of the BOD_5 concentration of domestic sewage, i.e.202 mg/l, was assumed.

Sewage quality surveys were conducted to determine the status of domestic sewage during the dry season and the rainy season. The survey was carried out at three different housing types, namely high-income, middle-income, and low-income houses, and at the Hanthana Housing Scheme in Kandy where an existing sewerage system is available for sampling. The results of the sewage quality survey for domestic sewage, domestic sewage (gray water) are BOD_5: 289 mg/l, SS: 765 mg/l in March 1998 and BOD_5: 177 mg/l, SS: 133 mg/l in August 1998, while combined sewage from a hotel shows BOD_5: 91 mg/l, SS: 136 mg/l in March and BOD_5: 115 mg/l, SS: 23 mg/l in August, respectively.

There are differences in BOD concentrations for both domestic and non-domestic sewage between the above estimations and the results of the actual water analysis. These differences originate primarily from some samples that did not contain sewage from toilets. Therefore, the values obtained from the above estimations were used for sewage quality assumptions.

a. Domestic sewage (642 m^3/day)

   BOD_5 404 mg/l

b. Non-domestic sewage (1,496 m^3/day)

   BOD_5 202 mg/l

c. Ground water Infiltration (200 m^3/day)

   BOD_5 0 mg/l

d. Mixed sewage

   $BOD_5 = (404 \times 642 + 202 \times 1{,}496) / 2{,}338 = 240.2$ mg/l say 240 mg/l

Therefore, a BOD_5 level of 240 mg/l and an SS level of 250 mg/l were adopted in this Study.

CHAPTER 12 SEWERAGE AND SANITATION SYSTEM LONG-TERM DEVELOPMENT PLAN

12.1 Population and Sewage Flow

Planning fundamentals were established in a previous section, and the major values developed therein for sewerage system planning are summarized as follows:

Table 12.1 Planning Fundamentals in Nuwara Eliya

Planning value	2005	2015
Area (ha)	314	314
Population	7,317	8,680
Average Daily Sewage Flow (m^3/day)	2,000	2,300
Maximum Daily Sewage Flow (m^3/day)	2,300	2,800
Hourly Maximum Sewage Flow (m^3/day)	3,800	4,500
BOD (mg/l)	240	
SS (mg/l)	250	

12.2 Conditions and Design Criteria for Facility Planning

For sewerage collection system, Manning's formula is used for the calculation of flow velocity and sewers is designed to convey peak flows. The size of the main sewer must be determined the minimum flow velocity of 0.75 m/sec to ensure the self-cleansing velocity at full flow and maximum velocity of 3.0 m/sec to protect the pipe against sewer erosion. Sewer diameter is selected with at least 200% of the estimated flow for the diameter of 600 mm or less, while at least 150% of the estimated flow for the diameter of more than 600 mm.

Piping materials are selected considering corrosion resistance, local availability etc.

Diameter of 100 mm	: PVC - Type 600 (service connection)
Diameter of 150 to 600mm	: Vitrified Clay Pipe
Diameter of more than 600 mm	: Concrete Pipe with Anti-corrosion Coating

The following fundamentals and criteria are used in the study of the sewage treatment plants.

Planned design flow

Average Daily Flow	2,300 m^3/day	
Maximum Daily Flow	2,800 m^3/day	
Hourly Maximum Flow	190 m^3/hour	(= 4,500 m^3/day)

Planned water quality

Influent:	BOD_5	240 mg/l	SS	250 mg/l
Effluent:	BOD_5	30 mg/l	SS	50 mg/l

Phased construction (maximum daily sewage flow)

Phase 1 (in 2005)	1,400 m^3/day
Phase 2 (in 2015)	1,400 m^3/day
Total	2,800 m^3/day

12.3 Selection of Optimum System

12.3.1 Sewage Collection System

The plan and design of sewage collection systems are different depending on the collection method. The characteristics of four alternative collection systems (separate, combined, interceptor and small bore) which could be used in Nuwara Eliya are examined.

Selection of the optimum collection system is consider 1) Construction cost, 2) Operation and maintenance cost, 3) Septage disposal, 4) Sanitation Improvement, and 5) Environmental improvement.

In the city center of Nuwara Eliya, an existing open drain system is available. In the remaining areas, only limited stormwater channels are available with major flows carried in natural streams. In new combined systems, new underground drainage piping and pumping stations should be constructed with three times more capacity than those in a separate system to accommodate stormwater. For small bore systems, improvement in sanitation at individual houses is not satisfactory as residents must still maintain septic tanks to use the sewerage system. Therefore, a separate system is recommended as the optimum sewage collection system.

12.3.2 Sewage Treatment System

The design of a sewage treatment plant must attain reliability, sustainability, and operability not only from the viewpoint of technical design and manpower capability but also from the viewpoint of least cost for operation and maintenance.

Among many well-developed and popular sewage treatment methods, the Trickling Filter (TF), Oxidation Ditch (OD), Aerated Lagoon (AL) and Stabilization Pond (SP) were further reviewed. In general, these methods are suitable for tropical developing countries.

The select of the most appropriate treatment method is done with the consideration of such items as 1) Quality of treated water, 2) Area requirement, 3) Construction cost, 4) Operation & maintenance cost, and 5) Difficulty of operation & maintenance.

The aerated lagoon method is recommended for this particular site because it is superior in power consumption, construction, and operation/maintenance cost as well as in the ease of operation and maintenance.

12.3.3 Sludge Treatment / Disposal

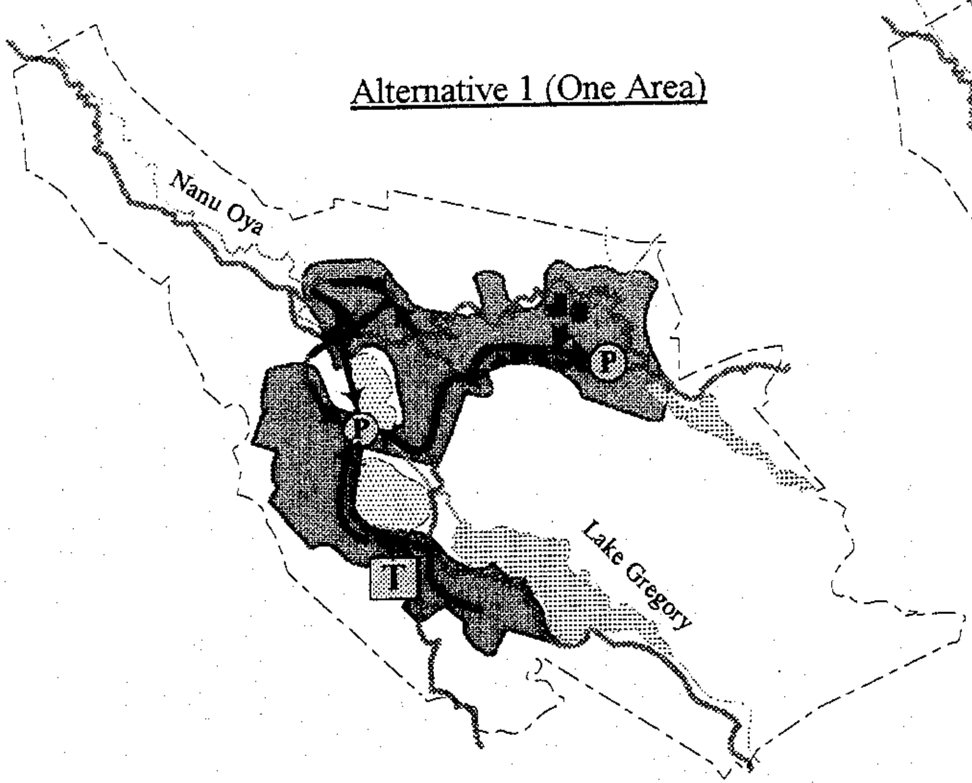
A continuous and stable sludge treatment/disposal method is one of the most essential components of a sewage and sanitary plan. In modern technology, the final outcome of sewage treatment is sludge. Even on-site treatment facilities such as septic tanks and soakage pits etc. produce sludge. Generally, sludge consists of water, inorganic and organic substances. Productive usage of the sludge will result in the optimum disposal of the sludge.

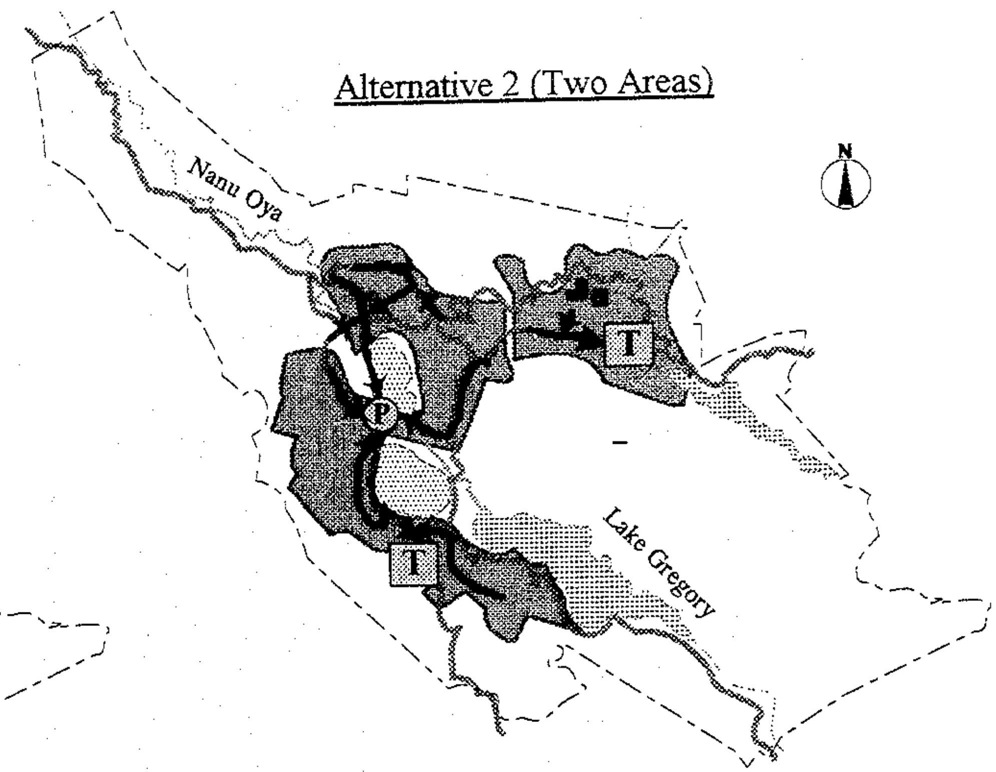
The objectives of sludge treatment are 1) to separate solids in the sludge and reduce the volume, 2) to stabilize the nature of the sludge, and 3) to process the sludge for reuse (or disposal)

Considering the sewage treatment method, the environmental and other conditions in Nuwara Eliya MC, stabilization of solids occurs in aerated lagoons and natural drying of the lagooned sludge is recommended. Composting facilities at the municipality dumping site are under construction. Sludge from the proposed sewage treatment plants could be utilized for composting or disposed at dumping site.

12.3.4 Integration / Separation of Sewerage Service Area

Preliminary design for both alternatives, i.e. integration or separation is suggested for this service area has been carried out, and the locations of major facilities are shown in Figure 12.1. An outline of facilities and the construction costs for both alternatives are summarized in the same figure.





Item		Alternative 1 (One Area)	Alternative 2 (Two Areas)	
			Nuwara Eliya	N'Eliya Central
Area		314ha	172ha	142ha
Population		8,700	5,800	2,900
Sewerage Treatment Plant		2,800 m3/d	2,000m3/d	800m3/d
Pumping Station		No1 PS : 0.0148m3/sec	No1 PS : 0.0148m3/sec	—
		No2 PS : 0.0470m3/sec	No2 PS : 0.0322m3/sec	—
Pipe	Gravity Line	φ150~400mm ,L=16,764m	φ150~400mm ,L=10,897m	φ150,225mm ,L=5,687m
	Pressure Line	φ150,200mmFCD ,L=2,020m	φ200mmFCD ,L=620m	—

Figure 12.1

Alternative of Service Area

The considerations on the evaluation for the two proposed alternatives are 1) Construction cost, 2) Operation and maintenance cost, 3) Manpower requirement for operation and maintenance, and 4) Difficulty of operation and maintenance.

Alternative 1 is superior to Alternative 2 in all aspects of evaluation. Alternative 1, an integrated sewerage system, is recommended.

12.4 Preliminary Design of Sewerage System

Layout of sewerage system in Nuwara Eliya is shown in Figure 12.2.

Sewage Collection System

The summary of sewer and pumping stations are shown in the following tables.

(1) Sewer

Table 12.2 Summary of Sewer Plan

Item	Diameter (mm)	Length (m)
Clay - Lateral	150	5,200
Clay Pipe	150 to 400	11,560
DI Pipe	150 to 200	2,920
Service Connection	Units	2,690

(2) Pumping Station

Table 12.3 Summary of Pumping Station Plan

Location	Specification
Nuwara Eliya - 1	Submersible Pump, 0.89 m3/min, 39 m, 11 kW, 2 sets
Nuwara Eliya - 2	Submersible Pump, 2.82 m3/min, 24 m, 22 kW, 2 sets

Sewage Treatment System

The preliminary design for the sewage treatment plant was prepared with the following capacity.

Location	Treatment Method	2005	2015
Nuwara Eliya	Aerated Lagoon	1,400 m^3/day	2,800 m^3/day

Figure 12.2

Layout of Sewerage System

(1) Layout

Original land for the treatment plant is nearly square and located on a sloping area at the edge of a tea plantation. However, as a result of the Steering Committee Meeting, the proposed site was changed due to the difficulty of acquiring the land and an alternative site was proposed at the nearest agricultural land. The proposed land is currently used as a private agricultural land on a sloping area with sufficient for the setting of a sewage treatment plant of 2,800 m^3/day. Tentative layout of the sewage treatment plant is shown in Figure 12.3.

(2) Specifications of Facilities

Specifications for each facility of the sewage treatment plant together with numbers, dimensions and design parameters are given in Table 12.4.

Table 12.4 Specifications of Sewage Treatment Plant

Facilities	Specifications
1. Grit Chamber and Screen	
Type	Parallel Flow Type
Dimension	0.5 m W x 2.7 m L x 0.3 m D
Water Surface Load	1,778 m^3/m^2/day
Average Velocity	0.15m/sec
Number of Basin	3 basins (including 1 stand-by)
2. Complete Mixing Aerated Lagoon	
Type	Rectangular Type
Dimension	14.0 m W x 25.0 m L x 3.0 m D
Aeration Power Level	13 kW
Retention Time	1.5 days
Number of Basin	4 basins
3. Partial Mixing Aerated Lagoon	
Type	Rectangular Type
Dimension (Cell)	12.0 m W x 16.0 m L x 4.0 m D
Aeration Power Level	6 kW
Retention Time	2.0 days
Number of Basin	3 cells x 4 basins
4. Disinfection Tank	
Type	Rectangular Type
Dimension	1.0 m W x 15.0 m L x 1.0 m D
Retention Time	15.4 min
Number of Basin	2 basins

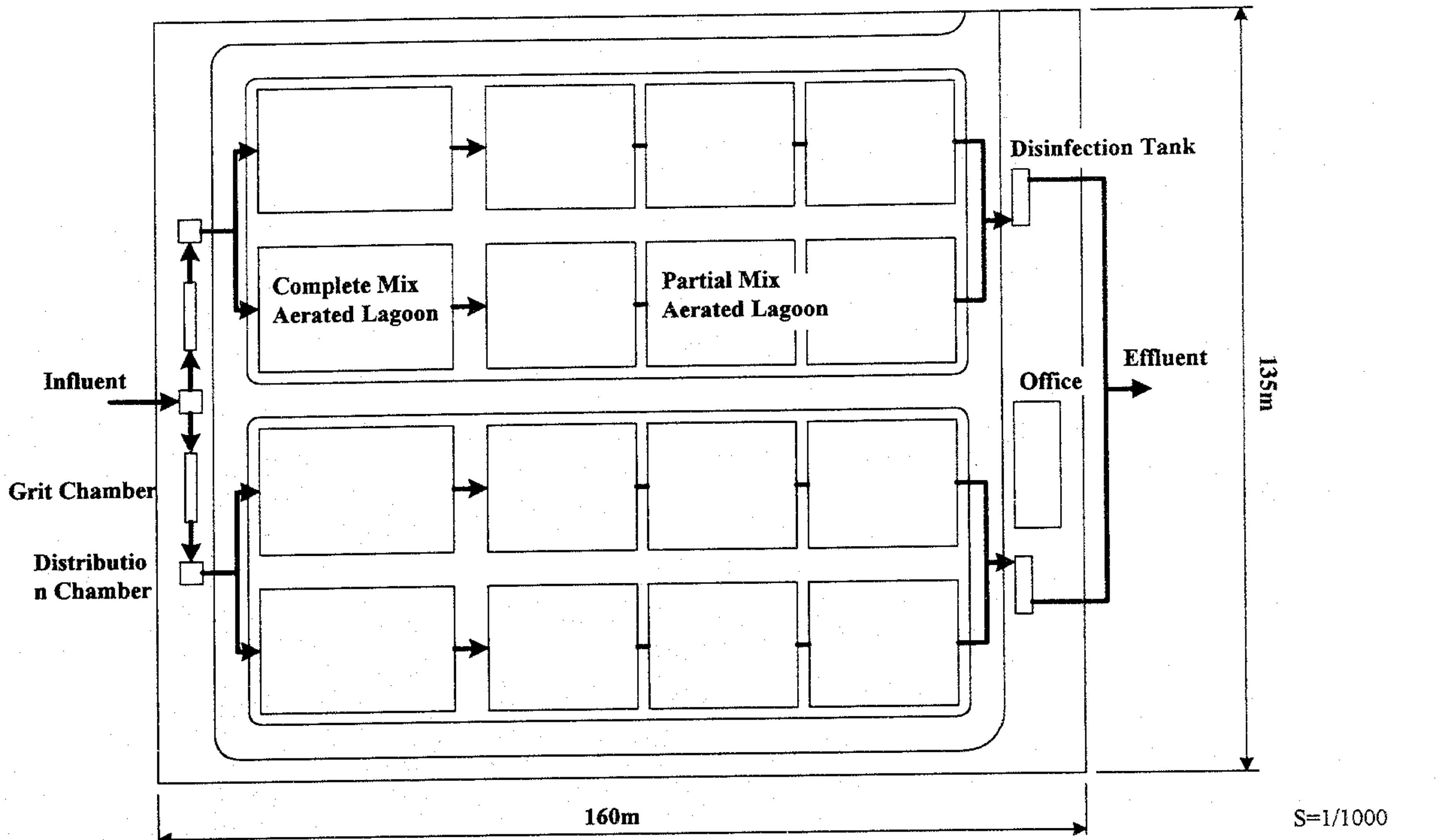


Figure 12.3

Layout of Sewage Treatment Plant

12.5 Sanitation Facilities

On-site sewage treatment/disposal is important, not only for small rural communities, but also for urban/semi-urban households which are not served by the public sewerage system. The study of on-site treatment/disposal was undertaken to offer alternatives from the viewpoints of low-cost sanitation and technical aspects, corresponding to the differences among the locations such as a cluster of households, apartments, and individual households. The study also looked into technical options as an intermediate countermeasure for those unsewered households situated in the transitional areas for on-site treatment.

The high SS is a result of overflowing of septage or sludge from the bottom of septic tanks. This will cause clogging of the seepage pits and shorten the operation life of the pits.

Percolation tests were conducted during the rainy season in August 1998 at two locations in NEMC, namely Barrows Road and Bonavista. Barrows Road is located in a valley and Bonavista is located in a hilly area.

The recommended method of disposal of septic tank effluent are shown in Sri Lanka Standard SLS 745, 1986, "Code of Practice for Design and Construction of Septic Tanks" these indicate the following disposal methods for the two locations

Barrows Road and Bonavista

a. Dispersion trench, or
b. Sub-surface biological filter with under drains and the effluent led into a drain or used for gardening.

After the new sewerage system is introduced in Nuwara Eliya MC, the system will only cover the central area of the Municipal Councils, mainly commercial areas. Residential areas surrounding these central areas will continue to use on-site facilities such as septic tanks and soakage pits for sometime. The population and houses which is expected to be served by on-site treatment are 29,829 in 2005 and 27,349 in 2015, also numbers of houses are 6,163 in 2005 and 5,561 in 2015, respectively.

To improve this situation, it is proposed that sludge from septic tanks and soakage pits be regularly removed, at least once in every five years. The expected sludge that will be generated daily for five years if regularly removed is 9.9 m^3 in 2005and 9.0 m^3 in 2015. The volume of sludge collected from septic tanks will be comparatively small when compared with the capacities of the plants and as a result sludge collected could be treated at sewage treatment plants.

12.6 Project Cost

Project cost is composed of the following items

<u>Project Cost</u>

- Construction Costs
  - Direct Cost
    - Civil Work
    - Mech./Elec. Work
  - (Site Expenses)
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Equipment Procurement
  - Equipment
  - (Packing/Transportation Cost)
  - (Import Tax)
  - (Administration Cost, partial)
- Engineering Services
  - Detailed Design
  - Construction Supervision
- Common Costs
  - General/Administration Expenses
  - Land Acquisition
- Contingencies
- GST (12.5 %)

The project cost is estimated on the basis of the preliminary design for the Master Plan facilities. Unit prices and lump sum prices were determined considering local conditions, subcontractors, equipment, available construction equipment and materials as well as suitability of the proposed construction method.

Assumptions and conditions used for the cost estimate are as follows:

Price level	:	as of November 1998
Foreign exchange rate	:	Sri Lankan Rs. 1.00 = Japanese ¥1.80

Total cost of the proposed project is estimated in Sri Lankan Rs. as shown in Table 12.5.

Table 12.5 Project Cost of Nuwara Eliya Sewerage Project

Unit: Thousand Sri Lankan Rs.

(1) Construction cost		
1) Collection System		236,022
Trunk / Main Sewers		
Sewer Laterals		
2) Pumping Station		10.617
Civil Work	2,462	
Mechanical / Electrical Work	8,155	
3) Sewage Treatment Plant		152,278
Civil Work	73,321	
Mechanical / Electrical Work	78,957	
4) Administration cost		21,083
Sub-Total		**420,000**
(2) Procurement of maintenance equipment		25,000
(3) Engineering cost		
1) Detailed design	19,000	
2) Construction supervision	16,000	
Sub-Total		**35,000**
(4) Common expenses		
1) General and administration expenses	8,000	
2) Land acquisition	24,000	
Sub-Total		**32,000**
(5) Contingency		77,000
(6) GST (12.5%)		74,000
Total		**663,000**

Note: Exchange rate: SL Rs. 1.00 = Japanese Yen 1.80 (as of November, 1998)

12.7 Implementation Schedule

In connection with the target years of this Study (2005 and 2015), Phase 1 is an urgent and priority project which is expected to be completed by the end of 2003, while the overall project, Phase 2, will be completed by the end of 2013.

Phase 1 (1999 to 2003)		- Priority Project
	1999 -2001	Preparation of project
	2001 - 02	Detailed design and bidding
	2002	Commencement of construction
	2002 - 03	Construction
	2004	Commencement of operation
Phase 2 (2009 to 2013)		
	2009 - 11	Preparation of project
	2011 - 12	Detailed design, bidding
	2012	Commencement of construction

2012 - 13	Construction
2014	Commencement of operation

Implementation and disbursement schedules are shown in Table 12.6.

Table 12.6 Project Implementation and Disbursement Schedule of Nuwara Eliya Sewerage Project

Item \ Phase / Year		Phase 1: 1999	2000	2001	2002	2003	Phase 2: 2009	2010	2011	2012	2013
Implementation Schedule											
1. Preparation of Project											
2. Pre-Construction Stage											
2.1 Detailed Design											
2.2 Bidding											
3. Construction											
3.1 Collection System											
- Trunk Mains											
- Sewer Laterals											
3.2 Sewage Treatment Plant											
- Civil Work											
- Mechanical/Electrical Work											
4. Procurement of Equipment											
Disbursement Schedule	**Total Cost (Million SL Rs)**	Phase 1	418.0				Phase 2	245.0			
1. Land Acquisition	24.0			24.0							
2. Administration	8.0			1.0	1.5	1.5			1.0	1.5	1.5
3. Construction Work	420.0				70.0	180.0				40.0	130.0
4. Procurement of Equipment	25.0					25.0					
5. Engineering Service	35.0			11.0	3.5	6.0			8.0	2.0	4.5
6. Contingency	77.0			5.5	11.0	32.0			1.5	6.5	20.5
7. GST (12.5 %)	74.0			5.5	10.0	30.5			1.5	6.0	20.5
Total of Annual Disbursement	663.0			47.0	96.0	275.0			12.0	56.0	177.0

Table 12.7 Outline of Nuwara Eliya Sewerage Project

Phase			Unit	Phase 1	Phase 2	Remarks
Frame Values	Service Area			City center commercial area, a potion of Lake Gregory, including the hotels, hosipital and brewery.		The values in phase 2 column shows these for the whole project .
	Target Year			2005	2015	
	Service Area		ha	84	314	
	Population		Pop	33,800	44,300	
	Service Population		Pop	1,830	8,680	
	Percentage of Service Population		%	5%	20%	
Sewage Flow	Per Capita Sewage Flow	Domestic	lpcd	74	74	The values in phase 2 column shows these for the whole project .
		Non-Domestic	lpcd	39	51	
		Infiltration	lpcd	20	23	
		Total	lpcd	133	148	
	Design Sewage Flow	Daily Average Sewage Flow	m3/d	1,200	2,300	
		Daily Maximum Sewage Flow	m3/d	1,400	2,800	
		Hourly Maximum Sewage Flow	m3/d	2,400	4,500	
Phase			**Unit**	**Phase 1**	**Phase 2**	**Total**
Facility	Planning Area			Northern area of city center, including the hotels, hospital and brewery.	Excluding Phase 1 column in Sevice area.	—
	Sewage Treatment Plant	Treatment Method		Arerated Lagoon		
		Capacity	m3/d	1,400	1,400	2,800
		Facilities		Grit Chamber, Complete Mixing Aerated Lagoon, Partial Mixing Aerated Lagoon, Disinfection Tank		
	Pumping Station	Submersible Pump	Nr	2	0	2
	Sewer Pipe	Lateral Sewer Clay φ150mm	m	4,000	1,200	5,200
		Trunk Sewer Clay φ150-400mm	m	8,190	3,370	11,560
		Puressure Pipe DI φ150、200mm	m	2,020	0	2,020
		Service Connection	Nr	750	1,940	2,690
Project Cost	Construction	Direct Construction Cost	Milli. Rs.	250	170	420
		Procurement of Maintenance Equipment	Milli. Rs.	25	0	25
		Engineering Cost	Milli. Rs.	20.5	14.5	35
		Administration and Land Acquisition	Milli. Rs.	28	4	32
		Contingency	Milli. Rs.	48.5	28.5	77
		GST 12.5%	Milli. Rs.	46	28	74
		Total	Milli. Rs.	418	245	663
	Operation and Maintenance	Personnel Expense	Thou. Rs.	840	1,176	—
		Electricity Cost	Thou. Rs.	1,947	2,504	—
		Chemical Cost	Thou. Rs.	27	51	—
		Repair Cost	Thou. Rs.	483	871	—
		Tatal	Thou. Rs.	3,297	4,602	—