CHAPTER 4 PLANNING FUNDAMENTALS FOR WATER SUPPLY SYSTEM

CHAPTER 4 PLANNING FUNDAMENTALS FOR WAETR SUPPLY SYSTEMS

4.1 Population

4.1.1 Present and Projected Population

Grama Nilidhari population data for the Nuwara Eliya Municipal Council area was obtained from the Ministry of Policy Planning and Implementation as shown in Table 4.1.

Table 4.1 1993 Population in Nuwara Eliya

Grama Nilidhari	Urban	Rural	Estate	Total
No.535 Nuwara Eliya	1,066	0	0	1,066
No.535A Mahagastota	1,895	0	0	1,895
No.535B Kalukele	1,279	0	0	1,279
No.535C Kellegala	2,049	0	0	2,049
No.535D N'Eliya Central	0	3,962	0	3,962
No.535E Sandathenna	0	2,407	0	2,407
No.535F Hawa Eliya West	1,721	0	0	1,721
No.535G Hawa Eliya North	2,076	0	0	2,076
No.535H Hawa Eliya East	1,641	0	0	1,641
No.535I Buluela	0	1,981	0	1,981
No.535J Toppass	0	0	2,285	2,285
No.535K Bambarakele	1,586	522	0	2,108
No.535L Nuwaraeliya West	1,946	0	0	1,946
No.535M Shanthipura	0	1,588	0	1,588
No.535N Kalapura	0	2,770	0	2,770
Totals	15,259	13,230	2,285	30,774

Although the Buluela area lies outside of the Municipal Council limits, it currently receives it's water supply from the Municipal Concil water utility and has therefore been included for the purposes of this investigation.

Future population growth in the Study Area has been estimated based on growth rates developed by the Urban Development Authority (UDA)[1], as presented in Table 4.2. On this basis, it is estimated that total population in the study area will increase to 42,867 by 2015 and about 45,000 by 2020, as shown in Table 4.2.

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[1] Urban Development Plan Nuwara Eliya, Urban Development Authority, 1997

Table 4.2 Projected Population in Nuwara Eliya

Grama Nilidhari	Population					
	1997	2000	2005	2010	2015	2020
No.535 Nuwara Eliya	1,186	1,285	1,436	1,574	1,703	1,844
No.535A Mahagastota	2,108	2,284	2,552	2,797	3,028	3,278
No.535B Kalukele	1,423	1,541	1,723	1,888	2,044	2,213
No.535C Keliegala	2,279	2,469	2,760	3,025	3,274	3,545
No.535D N'Eliya Central	4,408	4,774	5,336	5,848	6,331	6,854
No.535E Sandathenna	2,678	2,900	3,242	3,553	3,846	4,164
No.535F Hawa Eliya West	1,915	2,074	2,318	2,540	2,750	2,977
No.535G Hawa Eliya North	2,309	2,502	2,796	3,064	3,317	3,592
No.535H Hawa Eliya East	1,826	1,977	2,210	2,422	2,622	2,839
No.535I Buluela	2,204	2,387	2,668	2,924	3,166	3,427
No.535J Toppass	2,542	2,753	3,077	3,373	3,651	3,953
No.535K Bambarakele	2,345	2,540	2,839	3,112	3,369	3,647
No.535L Nuwara Eliya West	2,165	2,345	2,621	2,872	3,110	3,367
No.535M Shanthipura	1,767	1,914	2,139	2,344	2,538	2,747
No.535N Kalapura	3,081	3,338	3,731	4,089	4,427	4,792
Totals	34,235	37,083	41,447	45,425	49,178	53,240
Growth rate(%/yr)	2.7	2.7	2.25	1.85	1.6	1.6
Service population (%)	73	73	82	86	90	94
Service Population	24,991	28,600	33,800	39,100	44,300	50,000

4.1.2 Target Water Supply Service Population

Previous investigations[2] estimated that there are an average of 5.7 persons per direct connection and 70 persons per standpost in the Nuwara Eliya service area. These figures were used to estimate the present service population as summarized below:

Number of direct connections	3,936
Number of Standposts	45
Population served:	
Direct connection	22,435
Standposts	3,150
Total	25,585
Percent of Total Population Served	73
Percent of Service Population Served by:	
Direct connection	88
Standposts	12

[2] Feasibility Study for Nuwara Eliya Water Supply, M. MacDonald & Partners, 1989

For the purposes of this investigation, it has been assumed that the proportion of population within the Study Area that will be provided with piped water service will increase from the present 73 percent to 90 percent by the year 2015, and 94 percent by 2020. As shown in Table 4.2, the estimated water system service population is expected to increase to 44,300 by 2015 and to about 50,000 by 2020.

4.2 Design Quantities

4.2.1 Unit Water Use

The bulk of the existing Nuwara Eliya water supply is obtained from surface streams whose yield varies widely with the amount of rainfall during any given year. Because of this, supplies are limited during dry years and estimates of present water use should not be made on the basis of dry year records. A comparison of billing records for 1995 (a wet year), 1997 (a very dry year) and 1994 (an average year), is given in Table 4.3. When adequate flow is available during the dry months (December-March) as was the case in 1994 and 1995, water use increases as is to be expected with the arrival of hot weather and the tourist season. During a dry year (1997), water use is curtailed because the supply is insufficient to meet demand. According to Nuwara Eliya water utility records, about 70 percent of all connections have been provided with operational water meters. It is therefore reasonable to assume that billing records are a reasonably accurate reflection of actual water consumption. The 1995 data has therefore been used to estimate present water use patterns. Based on the 1995 data, and the current number of direct connections (3,936), the average water use per connection is 978 liters per connection and 151 liters per capita, including all residential, commercial, institutional and industrial users. Approximately 71 percent of this amount (107 lpcd) is for domestic use, and the balance (44 lpcd) for commercial use.

There are a number of factors that can be expected to influence the unit water consumption rate in the future, including tourism, tariff structure, standpost retirement, affluence level and home garden use.

Table 4.3 Billed Water Use in Nuwara Eliya

Billed Water Use (m3/month)			
Month	1994	1995	1997
January	112,013	120,183	104,607
February	138,917	119,190	90,650
March	123,802	118,106	86,345
April	113,205	119,221	85,650
May	108,057	115,141	104,106
June	102,245	111,719	108,008
July	104,029	115,238	110,474
August	102,305	118,557	111,612
September	107,398	118,144	131,315
October	104,759	112,789	109,064
November	112,771	115,092	102,972
December	138,663	122,417	137,342
Total	1,368,164	1,405,797	1,282,145
Average Month	114,014	117,150	106,845

4.2.2 Tourism

A significant tourist population visits the Nuwara Eliya area during the peak season, which occurs sometime in April. It has been estimated that as many as 100,000 tourists visit the area each year.[3] An estimate of the maximum tourist population to be expected during high season has been made based on data supplied by the Municipal Council on Tourist accommodations and a count of the number of visitors to local attractions. Existing tourist accommodations consist of about 375 hotel rooms and 375 guesthouse rooms. Several new hotels are currently under construction in the area and a drive-by survey indicated that about 200 new hotel rooms will be available within a year. Assuming full occupancy and two guests per room there could be about 1,900 tourists in hotel rooms and guesthouses. Municipal Council data on one day visitors suggest that as many as 2,000 additional visitors come for one day tours, for a total of about 3,900 tourists during peak days. The number of visitors is expected to rise substantially in the near future, so for the purposes of this investigation it has been assumed that the Council area water utility will have to provide for about 5,000 tourists in the near term. Assuming that tourist water use during the peak season is 150 lpcd for hotels and guest houses and 50 lpcd for one day visitors, the estimated additional tourist water demand would amount to about 390 m^3/d, or about 10 percent higher than the average daily water use. An appropriate peaking factor should be included in the design of future water system improvements to cater to this demand.

[3] Nuwara Eliya Draft Development Plan, Hettiarachchi, Ms J., UDA, 1990

4.2.3 Tariff Structure

A new water rate structure has recently been imposed (January 1998) by the Nuwara Eliya water utility that is significantly higher than the previous rate structure and includes sharply higher unit rates for high consumption customers. A comparison of previous and present water rate structures in Nuwara Eliya is given below:

Quantity (m^3/month)	Jan 1998	1990
0-10	Basic*	Basic**
11-20	Rs. 2.00/m^3	Rs. 0.50/m^3
21-30	Rs. 5.00/m^3	Rs. 0.50/m^3
31-40	Rs. 7.50/m^3	Rs. 1.00/m^3
41-50	Rs. 10.00/m^3	Rs. 1.00/m^3
51-80	Rs. 12.50/m^3	Rs. 1.00/m^3
Over 80	Rs. 12.50/m^3	Rs. 2.50/m^3

* : 1/2" - Rs.5; 3/4" & 1" - Rs.10; 1-1/2" & 2" - Rs.25
** : 1/2" - Rs.5; 3/4" - Rs.7.5; 1" - Rs.10; 1-1/2" - Rs.20; 2" - Rs.25

As shown above, the new Nuwara Eliya water rates are four to 10 times higher than the previous ones. Although the new rates may result in some reduction in per capita water use, the magnitude of any such reduction is extremely difficult to estimate. Experience elsewhere suggests that only very large increases in water rates result in significant reductions in unit water use. Although the new rates appear to be substantially higher than the previous ones, it has been eight years since the last increase, and it is therefore possible that much of the rise will be seen as only an adjustment for inflation by the public and not have the intended impact on water use. NWSDB experience with water rate increases (in the three to four hundred percent range) elsewhere indicate that very large rate increases tend to result initially in significant decreases, but that much of that decrease tends to disappear as customers adjust to the new rate structure. Nonetheless, the Nuwara Eliya rate increase is so large that some reduction in use should occur.

4.2.4 Standpost Retirement

Nuwara Eliya officials have recently reduced the number of public standposts from 60 to 45 and have indicated that they intend to remove essentially all standposts in the near future. Water users that have been accustomed to obtaining their supply from standposts will presumably be forced to utilize other sources such as streams, shallow wells and sharing or purchase from households that have a direct connection to the water system. The net effect as far as the water utility is concerned should be a reduction in the quantity of unbilled water. If all of the present standpost users were forced to rely on other consumers with direct connections for their water supply, the unbilled water quantity could be reduced by only two to three percent.

4.2.5 Affluence Level

As economic development raises income levels, per capita water use tends to rise with the introduction of more water using devices in the home. Experience in other countries at similar development levels indicates that affluence generated increases in unit water use are usually in the five to ten liters per capita per decade range.

4.2.6 Home Garden Water Use

Previous investigations have suggested that a large proportion (up to two thirds of the billed amount) of the residential water supply is being used to water home gardens. An examination of the monthly billing records indicates that this is an unlikely scenario. Although water use during the dry period does increase, the increase is only on the order of ten to twenty percent. Much of the increase is undoubtedly due to the fact that the peak water use period coincides with the tourist season and with the higher than normal household use that usually occurs during hot weather.

A sample survey of 37 selected households with home gardens was carried out in Nuwara Eliya. The results of this survey indicated that as much as thirteen percent of the public water supply is used by these households for home gardening. A survey of 200 randomly selected households in Nuwara Eliya indicated that 47.4 percent of households used the municipal water supply for some type of home gardening. Applying this percentage to the home garden water use indicated by the 37 households noted above yields a home garden water use of about six percent of total water use.

4.3 Recommended Unit Water Use

As discussed above, the factors that could change the present unit water use rate (151 lpcd) would either result in relatively minor changes or would tend to cancel each other out. There appears to be no adequate data at this point in time to expect the present unit rate to significantly increase or decrease in the future. For the purposes of this investigation, future water demand has therefore been estimated based on the present unit water use rate. It is suggested that this assumption be reviewed after the new water rate has been in place for several years. Continuation of the ongoing program of meter installation should also provide more accurate water use data in the future that can be used to refine this estimate.

4.4 Non-Revenue Water (NRW)

As shown in Table 4.4, the total amount of water for which the Water utility received revenue in 1997 was 1,282,145 m^3, or an average of 3,513 m^3/d. The total water produced during the year was 2,946,691 m^3, or 8,073 m^3/d. The difference between these two figures, or 56 percent of total production, is NRW, or leakage, waste and illegal connections. Even allowing for the age of some of the water system facilities, this is an unacceptably high level of NRW. For the purposes of this study, it has been assumed that an integral part of any water system improvement project will be a vigorous program to reduce NRW. Reduction of NRW to 25 percent by 2015 has been selected as a reasonable target for the Nuwara Eliya water utility, and has been incorporated into projections of future water demand.

Table 4.4 Non-Revenue Water in Nuwara Eliya

Month	Production (m3/month)	Billed Quantity (m3/month)			NRW (%)
		Domestic Use	Non-Domestic	Total	
January	247,566	74,272	30,335	104,607	58
February	160,188	64,538	26,112	90,650	43
March	134,137	60,837	25,508	86,345	36
April	120,930	63,032	22,618	85,650	29
May	245,520	74,563	29,543	104,106	58
June	285,750	76,438	31,570	108,008	62
July	295,275	78,608	31,866	110,474	63
August	295,275	79,399	32,213	111,612	62
September	285,750	92,180	39,135	131,315	54
October	295,275	79,090	29,974	109,064	63
November	285,750	74,384	28,588	102,972	64
December	295,275	95,978	41,364	137,342	53
Total	2,946,691	913,319	368,826	1,282,145	56

4.5 Projected Water Demand

Based on the data and assumptions presented above, projected water demand to the year 2020 was calculated as presented in Table 4.5.

Table 4.5 Projected Water Demand for Nuwara Eliya

		1997	2000	2005	2010	2015	2020
Population	Total Population	32,235	37,083	41,447	45,425	49,178	53,240
	Service Ratio (%)	73	77	82	86	90	94
	Service Population	24,991	28,600	33,800	39,100	44,300	50,000
Unit Water Use (lpcd)		107	107	107	107	107	107
Water Demand (m^3/d)	Domestic	2,674	3,066	3,624	4,192	4,749	5,361
	Non-Domestic	1,043	1,253	1,480	1,712	1,940	2,189
	Sub-Total	3,717	4,319	5,104	5,904	6,689	7,550
	NRW Rate (%)	56	56	40	33	25	25
	NRW	4,731	5,496	3,402	2,908	2,230	2,517
	Total	8,448	9,815	8,506	8,812	8,919	10,067
Unit Water Use (Excluding NRW, lpcd)		151	151	151	151	151	151
Unit Water Use (Including NRW, lpcd)		338	343	252	225	201	201

CHAPTER 5 WATER SUPPLY SYSTEM LONG-TERM DEVRLOPMENT PLAN

CHAPTER 5 WATER SUPPLY SYSTEM LONG-TERM DEVELOPMENT PLAN

5.1 General

Nine surface water sources are presently used in Nuwara Eliya. The yield of such water sources is able to meet demand during the rainy season. However, the demand during the dry season between December to March or April cannot be met by these supplies. Two groundwater wells have been utilized to supplement these surface water supplies to local areas in the vicinity of the wells. Their yields, however, are not enough to fulfill the difference between supply and demand. Although additional two wells are being constructed under an ADB project, their yields will still not be enough to meet demand. Several hotels, factories and banks have their own wells to augment their needs for water. Most consumers, including ordinary households have their own storage tanks to cope with the rationed water supply in the dry season.

Because of the expected high cost for the additional surface water source development, priority was given to an assessment of the potential for groundwater development. An analysis of groundwater development potential was conducted by a hydrogeologist, including the evaluation of drilling and pumping tests for five test wells.

Rearrangement of the existing distribution system was also evaluated with a view to utilizing the surface water sources more effectively during the rainy season. This will also contribute to a reduction of NRW.

5.2 Policy for Planning

The long-term development plan for the water supply system in Nuwara Eliya was planned under the following planning policies:

- Raw water intake facilities, transmission pipes, distribution reservoirs, and distribution pipeline network required to fulfil the demands up to the target year 2015. The cost required for rehabilitation of the existing distribution pipelines is estimated for the purpose of NRW reduction.
- Continuous water supply for 24 hours a day, even in the dry season, so that residents can enjoy a satisfactory water supply.
- Existing water sources shall continue to be used in the future because they can be operat-

ed satisfactorily. Surface water sources, especially, have sufficient yield during the rainy season and will also meet about half the future demand in the dry season

- Existing transmission/distribution systems are to be improved so that surface water sources can be utilized efficiently, in order and that water pressure in the system will be optimized for NRW reduction.

5.3 Considerations for Facility Planning

5.3.1 Water Sources

(1) Existing Water Sources

Although the existing water sources appear to be adequate to meet present demand during years of plentiful rainfall, supply is often limited during dry years. Water production during 1997, a dry year, from Nuwara Eliya surface water sources is summarized in Table 5.1. The lowest surface water flow during that year was 4,031 m^3/d. During the pre-

Table 5.1 Nuwara Eliya Surface Water Source Production in 1997

(unit: l/s)

Water Sources *	Banbarakele, New Water Field, Pedro	Lover's Leap	Gamunu, Brewerey	Piyatissa-pura	New Water Field	Total	
Reservoir	Haddon Hill	Lover's Leap	Gamunu Mawata	Piyatissa-pura	New Water Field	(l/s)	(m3/d)
Jan	65.883	9.807	5.887	8.098	2.650	92.325	7,977
Feb	44.763	8.924	4.074	6.568	1.890	66.219	5,721
Mar	34.104	7.306	1.390	4.631	2.650	50.081	4,327
Apr	31.624	3.559	6.228	3.559	1.680	46.650	4,031
May	76.660	6.568	3.080	1.290	4.074	91.672	7,920
Jun	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Jul	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Aug	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Sep	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Oct	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Nov	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Dec	76.660	4.074	22.357	3.080	4.074	110.245	9,525
Total	789.654	64.682	177.158	45.706	41.462	1,118.662	96,652

*: Besides them, Shanthipura source is serving to lacal service area.

vious ten years of rainfall record, there were two years that had up to 17 percent less rainfall during the dry period, suggesting that the reliable yield from the existing surface water sources is probably closer to 3,300 m^3/d. The approximate safe yield of the existing Nuwara Eliya water sources, including the 900 m^3/d available from groundwater sources, is therefore about 4,200 m^3/d. In terms of reliable long-term supply, the existing sources can provide only about 72 lpcd to the present service population, not including NRW (4,200 m^3/d / 25,585 people x 0.44).

Based on the assumed safe source yield during the rainy season, the capacity of water sources to be developed totals 6,500 m^3/d, as shown in Table 5.2. The relationship between demand and supply will be as presented in Figure 5.1.

Table 5.2 Required Water Source Development in Nuwara Eliya

Description	Quantity (m^3/d)
(a) Average Daily Demand	8,919
(b) Maximum Daily Demand (1.2 times of Avg. Daily Demand, a x 1.2)	10,700
(c) Capacity of Existing Water Sources during Dry Season	4,200
(d) Required New Water Source (b-c)	6,500

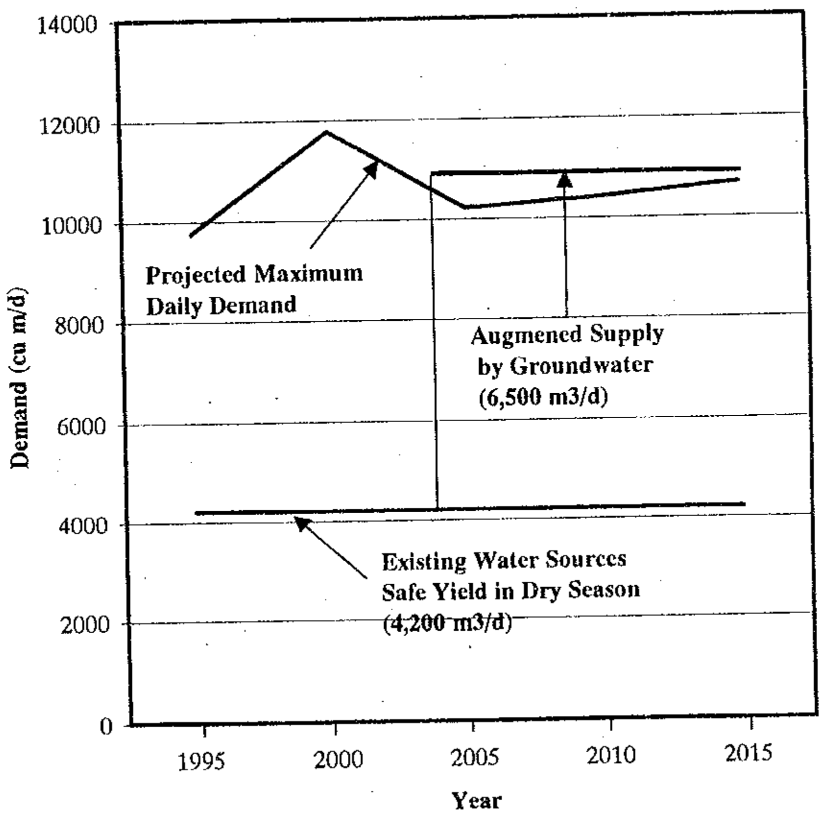


Figure 5.1 Water Demand VS. Supply Capacity

(2) Potential Water Sources for Nuwara Eliya (refer to Appendix 5.1)

Three sources have been identified that could potentially be developed to provide additional water for Nuwara Eliya.

- A stream near Jayalanka
- The existing Bambarakele source
- Groundwater

Although only very limited flow measurement data are available for the surface water sources, sufficient information on rainfall, rainfall-runoff coefficients and evaporation rates are available for nearby catchment areas to allow an approximate estimate of yield from the proposed sources to be made. It is important to note that such an approximation is not as reliable as an analysis based on actual stream flow data and is not considered to be an adequate basis for design and construction of an impoundment facility.

Development of each of the surface water sources will require construction of impoundment, treatment, pumping and transmission facilities. Figure 5.2 illustrates the general arrangement of these facilities for the Jayalanka and Bambarakele sources.

Three potential sites for construction of wells have been identified in the study area. The locations of these sites and the alignment of the transmission mains from the wells to service reservoirs in the Nuwara Eliya distribution system are also shown in Figure 5.2.

A summary of the characteristics of the two potential surface water impoundment is presented in Table 5.3.

Table 5.3 Characteristics of Potential Surface Water Impoundments

Item	Jayalanka	Bambarakele
Surface Area (ha)	20.0	6.2
Catchment Area (ha)	568	220
Storage volume (m^3)	2,100,000	550,000
Usable Storage volume (m^3)	1,575,000	412,500
Dam Length (m)	270	220
Water Elevation (msl)		
Low water	1,920	1,940
High Water	1,940	1,960
Approximate Yield (m^3/d)	5,950	4,200

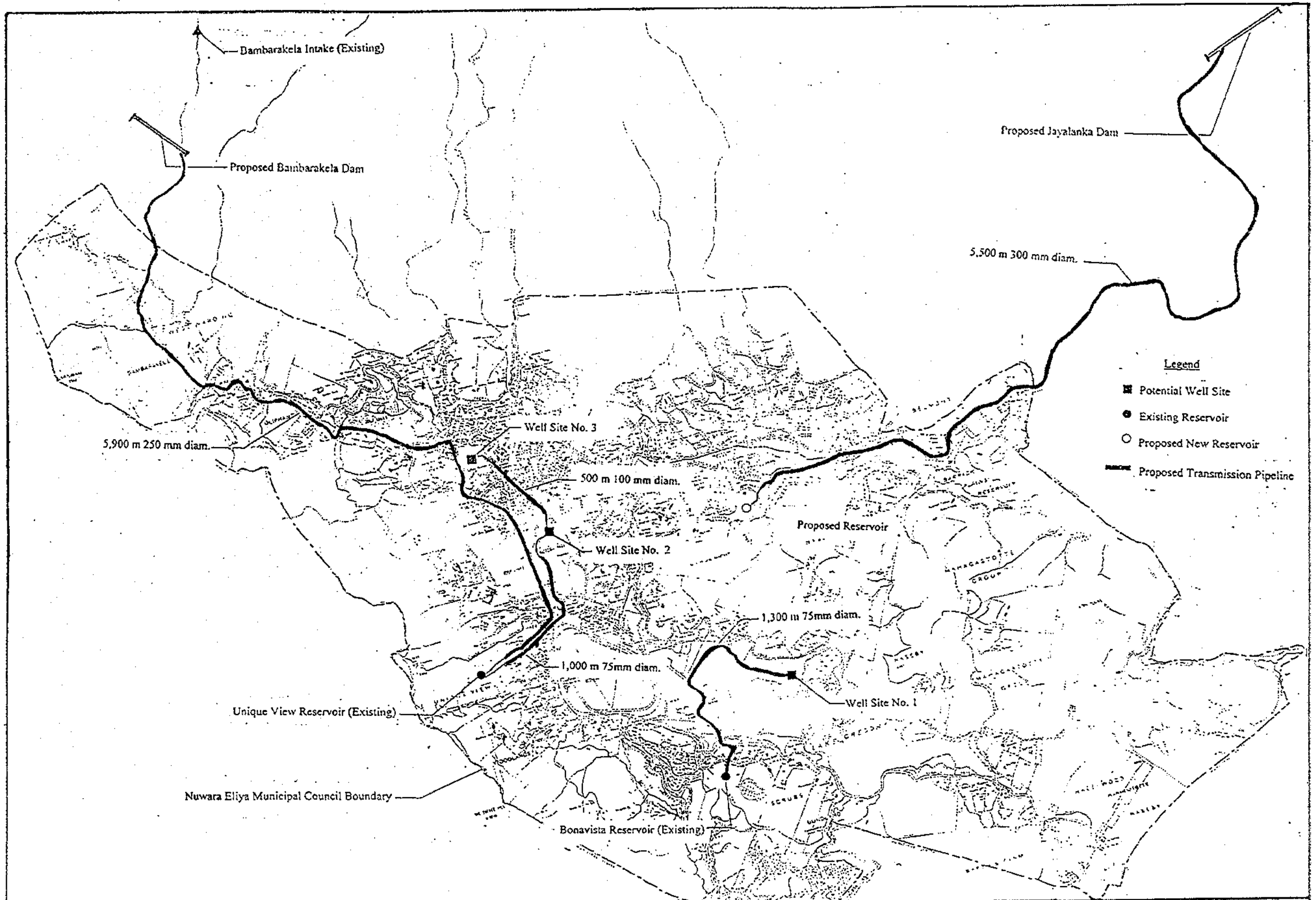


Figure 5.2 Location of Potential Water Sources for Nuwara Eliya

As can be seen from inspection of Table 5.3, the surface water source with the largest potential yield is at Jayalanka. A serious problem with this source is the presence of extensive vegetable plots in the catchment area where the heavy use of fertilizer and agrochemicals to control pests pose a pollution threat. A considerable portion of the catchment area is used for growing tea, and it is estimated that up to 2,000 tea estate workers are housed there.

Acquisition of land used for vegetable cultivation is expected to cost about Rs.5,000,000 per hectare. Land costs for the area to be flooded by the impoundment, the dam site itself and a reasonable safety zone around the reservoir could cost in the neighborhood of Rs.150,000,000. A suitable level of protection against pollution would require as a minimum provision of adequate sanitation facilities for the resident catchment area population. Depending upon the extent of pollution by agrochemical compounds, it may be necessary to provide some form of advanced treatment or purchase and retire additional agricultural land. Some of the resident population may have to be resettled, with the attendant financial and social costs that are associated with any resettlement activity.

Although the yield from the Bambarakele source is estimated at 4,200 m^3/d (see discussion above), a portion of this yield is already being used and cannot be counted as a new source.

The lowest flow measurement available for Bambarakele, from an admittedly very limited amount of flow data, is 1,650 m^3/d, which occurred in 1997. It is unlikely that this figure represents the low flow for a twenty year period of record that is commonly accepted as being required to establish a safe yield for a municipal water supply system. In the ten years of rainfall record currently available for the area, total rainfall during the dry months were up to 17 percent lower than the 1997 figure on two occasions. This suggests that the safe yield of the Bambarakele source without an impoundment is less than 1,650 m^3/d, possibly as low as 1,400 m^3/d. Given the above, it would appear that augmentation of the Bambarakele source by construction of an impoundment reservoir could increase the safe yield available to the community by about 2,800 m^3/d.

The Bambarakele source has some bacterial contamination due to human activities in the catchment area. Plans are under way to deal with this problem by installing pressure filters on the delivery main. Although filtration should be adequate for a stream source, additional treatment will be required after an impoundment reservoir has been built.

Open storage reservoirs tend to accumulate nutrients from the catchment area and are subject to algae growth problems that cause excessive clogging of filters. A conventional treatment string, with sedimentation, coagulation and filtration would be required for this source.

Hydrogeologic data in the Nuwara Eliya area is somewhat limited at the present time and it is difficult to accurately estimate the total yield that can be expected from groundwater. It is, however, the consensus among hydrogeologists working in the area that extraction of enough water to meet all of Nuwara Eliya's future needs (approximately 6,500 m^3/d) is unlikely. Electrical resistivity surveys and test well drilling carried out under the current investigation should allow a better estimate of local groundwater potential to be made.

Production from existing wells in the area varies from less than 100 m^3/d to 600 m^3/d. For the purposes of this investigation, individual well production has been assumed to be 300 m^3/d. For the purposes of comparing groundwater to alternative sources of water for Nuwara Eliya, it has been assumed that 900 m^3/d can be obtained from this source.

Estimated costs associated with development of the three alternative water sources are presented in Appendix 5.1. As a result of calculation, groundwater development shows the least cost per cubic meter of developed water, i.e., groundwater around Rs.17.8/m^3, Jayalanka Rs.44.6/m^3, and Bambarakele Rs.75.4/m^3. Because of this and the available yield, it is recommendable that groundwater sources be developed for the project.

5.3.2 Water Quality

(1) Drinking Water Quality Standards

Supplied water should meet the water quality standards for drinking water in Sri Lanka, which are specified in SLS 614, 1983; Part 1 Physical and Chemical Requirement, and Part 2, Bacteriological requirements (which are similar to the WHO Standards) as given in Appendix 5.2.

(2) Raw Water Quality

The results of water quality analysis of the existing water sources conducted by the Study Team (refer to Chapter 15) were evaluated as follows:

1) Current status of water quality

There are nine existing surface water sources including Bambarakele, Shanthipura, Pedro, Old water field, New water field, Piyatisappura, Brewery, Gamunu, and Lover's Leap. All parameters of the surface water sources, except for pH, free ammonia, total coliform, and E-coli., are within permissible limits set in the relevant SLS. The existing ground-water sources show the same results of water quality as the surface water sources, however, all the water quality parameters of test wells constructed under this study were within permissible level set in the SLS.

The pH values of some samples were slightly lower than the requirements of the SLS. In addition, PO_4 values sometimes exceed the required standard in the rainy season. It is necessary to monitor these qualities continuously. Pesticides were not detected in any samples.

2) Proposed treatment process and measures

Considering the water quality examination results of the surface water, existing wells and test wells, it may be judged that only chlorination is necessary to treat the water from the proposed water sources.

In order to ensure disinfection, the dosing point for chlorine should be carefully selected to satisfy the necessary residual chlorine concentration requirements at the end of distribution system. In case the surface water quality does not meet the requirements of the SLS, the following measures may be taken.

- Shut down of the intake of the deteriorated water sources
- Alternative use of surface water sources which are in good condition.
- Effective use of the existing filter tanks during periods of high turbidity taking raw water from Bambarakele, Old Water Field, and Pedro water sources

5.3.3 Transmission and Distribution

(1) General

Friction Formula used in the design of pipelines:Hazen-Williams Formula

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

where, H: friction loss (m)
C: friction coefficient

120 for cement lined DCIP and SP (for nominal diameter)
130 for PVC pipe (for internal diameter)
D: diameter of pipe (m)
Q: flow rate (m^3 /sec)
L: pipe length (m)

Maximum flow velocity: 3.0 m/sec

Optimum pipe diameters of pipes are employed taking account of capital and O&M cost for both the pipeline and pumping facility.

(2) Transmission

Pipe Material: Ductile Casr-iron pipe (DCIP) or steel pipe (SP)

Internal lining: Cement mortar lining

Peak Factor: 1.2 (times of average daily demand) (refer to Appendix 5.3)

(3) Distribution

Pipe Material: Ductile Cast-iron pipe (DCIP) for diameter 250 mm or larger
Unplasticized polyvinyl chloride (uPVC) pipe for dia. less than 250 mm

Peak Factor: 2.0 (refer to Appendix 5.3)

Minimum hydraulic head: 10 m at peak demand

Storage capacity of reservoir: more than 6 hours of the maximum daily demand

5.4 Problems and Countermeasures on Existing Water Supply Facilities

5.4.1 Problems and Countermeasures

an analysis of current water source yields shows a remarkable difference between dry and rainy seasons in the Nuwara Eliya area. The potential safe yield during the dry season is only 4,200 m^3/d, which increases to about 20,000 m^3/d during the rainy season. Tables 5.4 and 5.5 summarize a block-wise balance in capacity between existing water sources and water demand in the years 2005 and 2015.

Another outstanding problem is the excessively high or low water pressures in the service areas.

Therefore, the following objectives shall be given to the proposed project:

(1) Augmentation of water source capacity and effective utilization of water

(2) Provision of appropriate water pressure

Table 5.4 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		

Table 5.5 Demand and Capacity of Sources and Reservoirs by Service Block (2015, Dry Season)

No.	Block		2015 Avg. Daily Demand (m^3/d)	2015 Max. Daily Demand A (m3/d)	Water Source Name	Yield B (m^3/d)	Balance C=B-A (m^3/d)	New Facility	Reserver	Name	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		-	-	Shanthipura	-	-			Shantipura	-	-	-	-	
2	Piyatisappura		82	101	Piyatisappura	255	154			Piyatisappura	25	190	45.1	164.8	
3	High Area 1	Old Water Field	318	392	Old Water Field	290	-102		New	Old Water Field	98	0	0.0	-98.1	To be constructed 100 m^3
		New Water Field	55	68	New Water Field	120	52			New Water Field	17	70	24.6	53.0	
		Gamunu	15	19	Gamunu	19	0			Gamunu/Brewery	67	190	17.1	123.3	
		Brewery	201	248	Brewery	428	180								
		Pedro	713	879	Pedro	651	-228		New	Pedro	220	0	0.0	-219.8	To be constructed 220 m^3
		Lovers Leap	90	111	Lovers Leap	255	144			Lovers Leap	28	900	195.2	872.3	
	Sub Total		1,392	1,717		1,763	46					1,160			
4	Low Area 1	Haddon Hill	3,912	4,825	Bambarakele	1,327	-5,120			Haddon Hill	1,206	1,800	9.0	593.8	
		Unique View	752	928						Unique View	232	40	1.0	-192.0	To be augmented 200 m^3
		Vijithapura	563	694						Vijithapura	174	40	1.4	-133.5	To be augmented 140 m^3
	Sub Total		5,227	6,447		1,327	-5,120	New Borehole × 5 units				1,880			
5	Low Area 2		1,524	1,879		0	-1,879	New Borehole × 2 units	New	Low Area 2	470	0	0.0	-469.8	To be constructed 470 m^3
6	High Area 2		491	606	Upper Lake Road Borehole	600	-6			Naseby	152	190	7.5	38.5	
7	Bonavista		203	250	Race Course Borehole	300	50			Bonavista	63	190	18.2	127.5	
	Total		8,919	11,000		4,245						3,610	7.9		[illegible] facility design was set at 11,000 3..
			8,919	8,919×1.2= 10,700		4,245	-6,455								

(3) Reduction of incidences on supply interruption and decreased supply volume
(4) Conservation of groundwater resources

With the above objectives, the following scope of work will be adopted in the proposed project:

(1) Establishment of water supply service block
(2) Groundwater development
(3) Provision of distribution network
(4) Provision of transmission pipeline
(5) Provision of distribution reservoirs
(6) Countermeasures against leakage (details are referred to in Chapter 11)

Necessary measures and expected effects are summarized in Table 5.6.

Table 5.6 Necessary Measures and Expected Effects

Necessary Measures \ Expected Effects	Augmentation of Water Source Capacity and Effective Utilization of Water	Provision of Appropriate Water Pressure	Reduction of Incidences on Supply Interruption and Decreased Supply Volume	Conservation of Groundwater Resources
Groundwater Sources Development	○		△	
Establishment of Service Block	○	○	△	
Provision of Distribution Network		○	○	
Provision of Transmission Pipeline				○
Provision of Distribution Reservoirs		○	○	
Countermeasures Against Leakage	○		○	

Legend: ○ - Effects are expected.
△ - Indirect effects or minor direct effects are expected.

5.4.2 Establishment of Water Supply Service Block

(1) Purpose

Since the Study Area had 56 percent of NRW in 1995, the reduction of NRW through effective utilization of water is regarded as one of the most important measures to augment water supply capacity.

Generally, leakage and illegal connection are deemed to be major causes of NRW, though their share of contribution to NRW is not known at present.

If leakage represents a major part of the NRW, the regulation of unbalanced water pressure being caused by topographic features and the establishment of water supply service blocks for the effective utilization of water will be the most appropriate countermeasures to reduce leakage and contribute to provide the appropriate distribution pressure.

In other words, water pressures in respective water supply service blocks will be maintained at reasonable levels through the subdivision of water supply service areas into several blocks. For that purpose, the rearrangement of water service blocks will be conducted. Rearrangement will be conducted taking into account differences in ground elevation and the provision of distribution reservoirs with appropriate water levels corresponding to their ground elevation in the respective blocks.

It should be noted, however, that rehabilitation of leaking pipes is a prerequisite upon completion of the leakage survey, in order to maximize the effect of the above mentioned countermeasures.

(2) Practical Measures to Establish Water Supply Service Blocks

The contour line distribution of Nuwara Eliya is shown in Figure 5.3, while water supply service blocks established under the ADB study are shown in Figure 5.4.

The Nuwara Eliya water supply service area is situated at a relatively low elevation of between 1,860 m to 1,940 m, being surrounded by mountains. In the ADB water supply service blocks, the service area is supposed to be subdivided into six blocks, but such six blocks, indicated by the thick lines in Figure 5.4, do not exist in terms of actual operation status. The actual service area consists of four blocks (most valves are closed at dotted lines, but one or two valves are open to allow the flow of water to neighboring blocks).

Although the ADB water supply service blocks are designed taking into account differences in ground elevations, the rearrangement of the blocks is considered indispensable based on the results of the water source capacity review undertaken during the dry season and the new groundwater development. The rearrangement of water supply service blocks will be carried out taking into consideration the following:

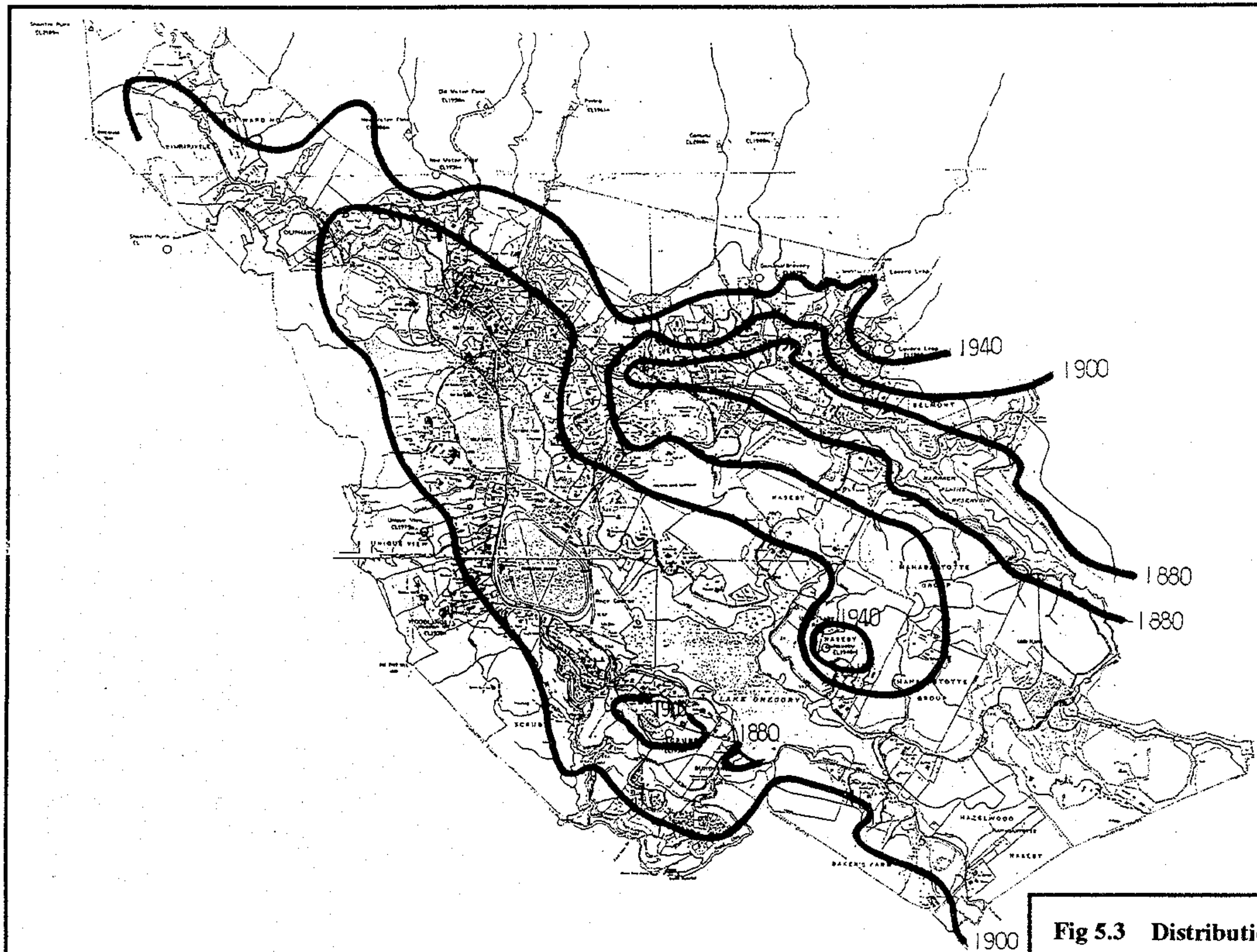


Fig 5.3 Distribution Contour Line in Nuwara Eliya

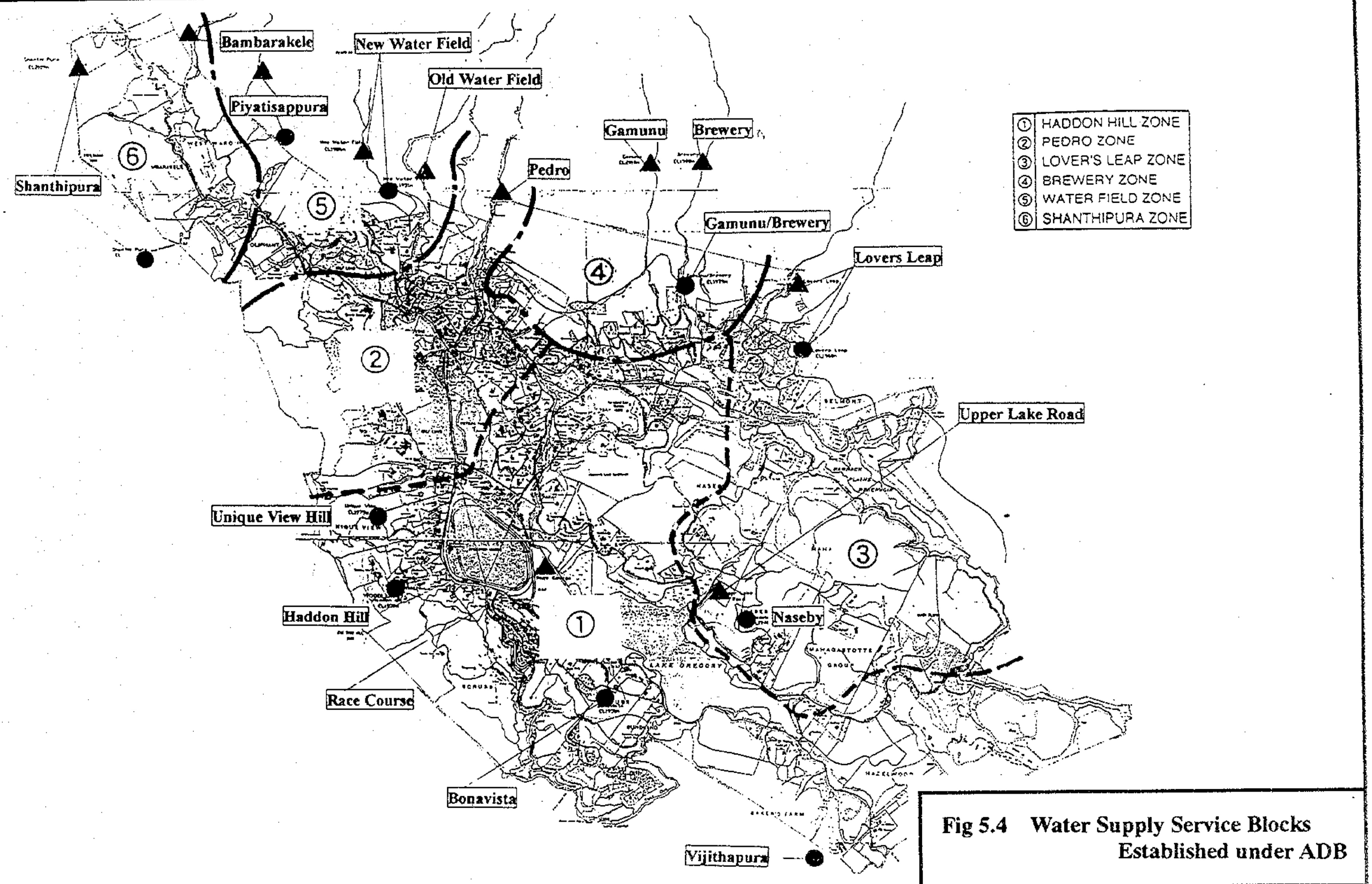


Fig 5.4 Water Supply Service Blocks Established under ADB

1) Static water pressure shall be controlled below 5 kg/cm^2 in respective blocks to reduce leaking volume.
2) Consideration of water source capacity during the dry season.
3) Consideration of water intake locations and distribution facilities.

Water supply service blocks rearranged under this study are described from the viewpoint of water supply during the dry season as shown below (refer to Figure 5.5). Water supply during the rainy season is separately presented in the section for the plan of transmission lines.

1) Shanthipura

The Shanthipura service area forms an isolated block since the water intake facility is situated nearby and the water source capacity can meet the water demand. It may be judged that Shanthipura does not require a further development of its water supply system except for some minor changes. Shanthipura, therefore, will not be the subject of the facility planning.

2) Piyatissapura

This block is situated on the northwestern edge of Nuwara Eliya at a relatively high elevation of more than 1,940 m above msl. The Piyatissapura water source is located in the vicinity and the boundary of the water supply service block is drawn within the water source capacity. The water level of the Piyatissapura distribution reservoir is 1,991 m amsl.

3) High Area 1

The northern part of Nuwara Eliya has a high elevation of 1,900 to 1,940 m amsl and the existing water source in the vicinity. However, the existing water sources, except for Bambarakele, have insufficient supply capacity during the dry season resulting in difficulty subdividing this service area by the existing water source. One water supply service block is, therefore, formulated within the supply capacity of the existing water sources consisting of Old Water Field, New Water Field, Gamunu, Brewery, Pedro, and Lover's Leap.

Old Water Field and Pedro that presently have no distribution reservoirs should be provided with new distribution reservoirs. The water levels of distribution reservoirs in this block range from 1,950 to 1,980 m amsl.

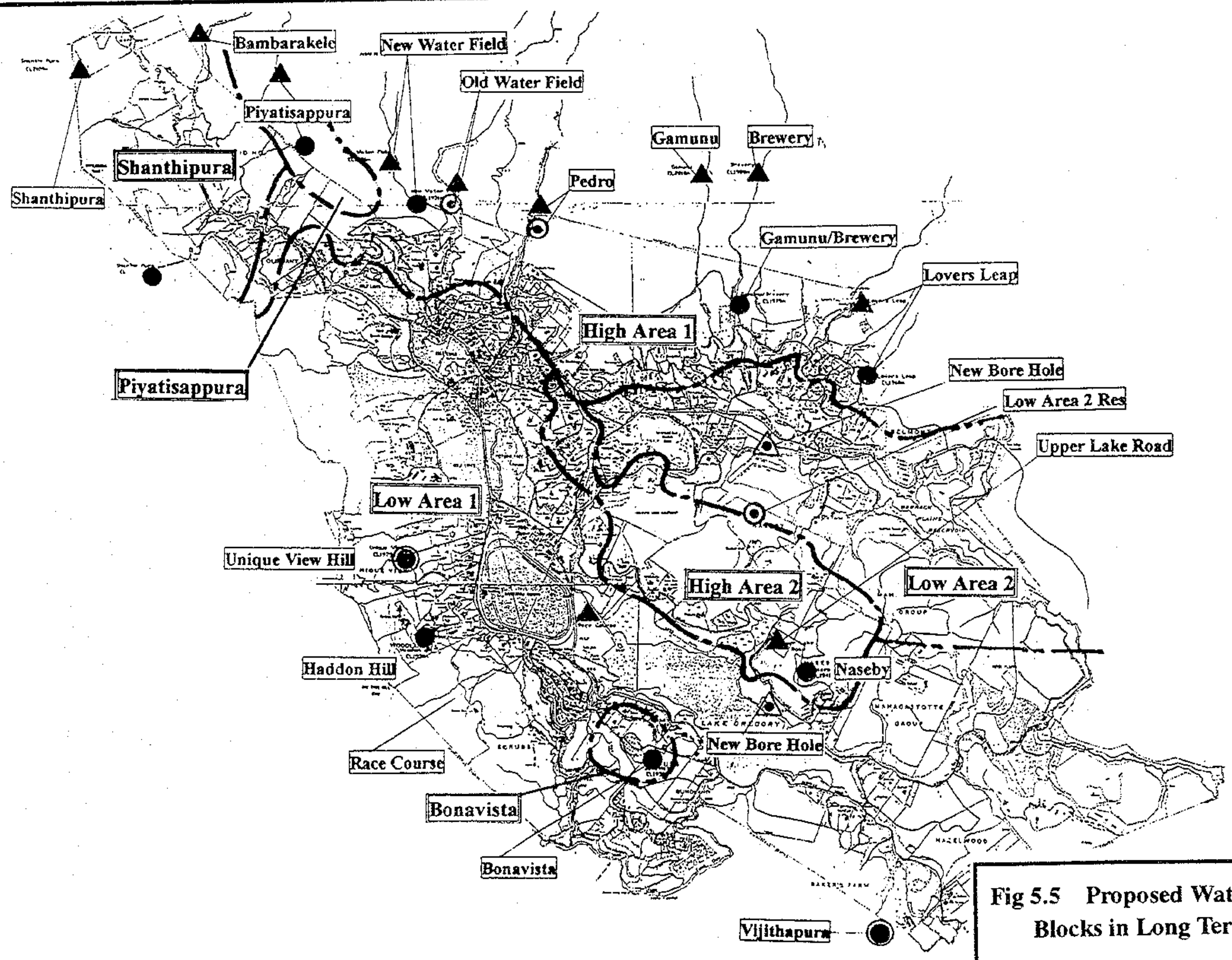


Fig 5.5 Proposed Water Supply Service Blocks in Long Term Development Plan

4) High Area 2

The central part of Nuwara Eliya is bounded by Lake Gregory and Barrack Plains Reservoir is considered as high ground with elevations ranging from 1,900 to 1,950 m amsl. Naseby distribution reservoir which receives water from existing groundwater source at the Upper Lake Road is located in this area.

The boundary of the water supply service block within the supply capacity of the existing water sources is drawn covering areas with elevations higher than 1,900 m amsl.

The water level at Naseby distribution reservoir is 1,946 m amsl.

5) Low Area 1

Areas from the northwestern Nuwara Eliya towards Lake Gregory in the southeast have relatively low elevations at about 1,880 m amsl, while a section in the southern area is higher than 1,900 m amsl, where water supply service points are scattered in the area.

This particular area is served by the existing Haddon Hill distribution reservoir supplied from the Bambarakele water source. It also includes Unique View Hill Reservoir and Vijithapura Reservoir.

This service area is designated to form one block, excluding the service block of the Bonavista distribution reservoir located at the south side of Lake Gregory.

The water level at the Haddon Hill distribution reservoir is 1,930 m amsl.

6) Low Area 2

Barrack Plains Reservoir and its surrounding area have elevations of 1,860 to 1,900 m amsl bounded by the northern area and central high ground are the lowest areas in Nuwara Eliya.

In this water supply service block, the water source is planned to rely on newly developed groundwater as shown in Tables 5.4 and 5.5 with a new Low Area 2 distribution reservoir to be provided.

The water level at the Low Area 2 distribution reservoir is 1,920 m amsl.

7) Bonavista

A part of south side in Lake Gregory forms high ground with elevations of more than 1,900 m amsl. A new service block will be formulated to cater for the surrounding area of the Bonavista distribution reservoir employing the Race Course groundwater source.

The water level at Bonavista distribution reservoir is 1,930 m amsl.

5.4.3 Groundwater Development

The most serious problem facing the Nuwara Eliya water supply service is shortage of water capacity during the dry season. The existing surface water source has limitations in its supply capacity as discussed in section 5.3.1, such that it is assumed to have an approximate shortfall of 6,500 m^3/day against the 2015 projected water demand.

In the development of new water sources, surface water is subject to economic limitations (refer to section 5.3.1).

In this study, the possibility of groundwater development was investigated through test well construction and pumping tests by the hydrogeologist of the Study Team. The availability of groundwater was confirmed.

Therefore, a water supply facility plan was established based on the development of new groundwater sources. The locations of new wells, each with a capacity of approx. 1,000 m^3/day, will be selected at locations in the expected water field zones identified by the hydrogeologist.

Based on the results of the investigation, it was found that prominent shear zones runs SE-NW direction along the Gregory Lake and the Barrack Plains Reservoir. Locations of intake facilities (wells) were planned at the locations in those zones containing fractures, close to reservoirs (refer to Figure 5.6).

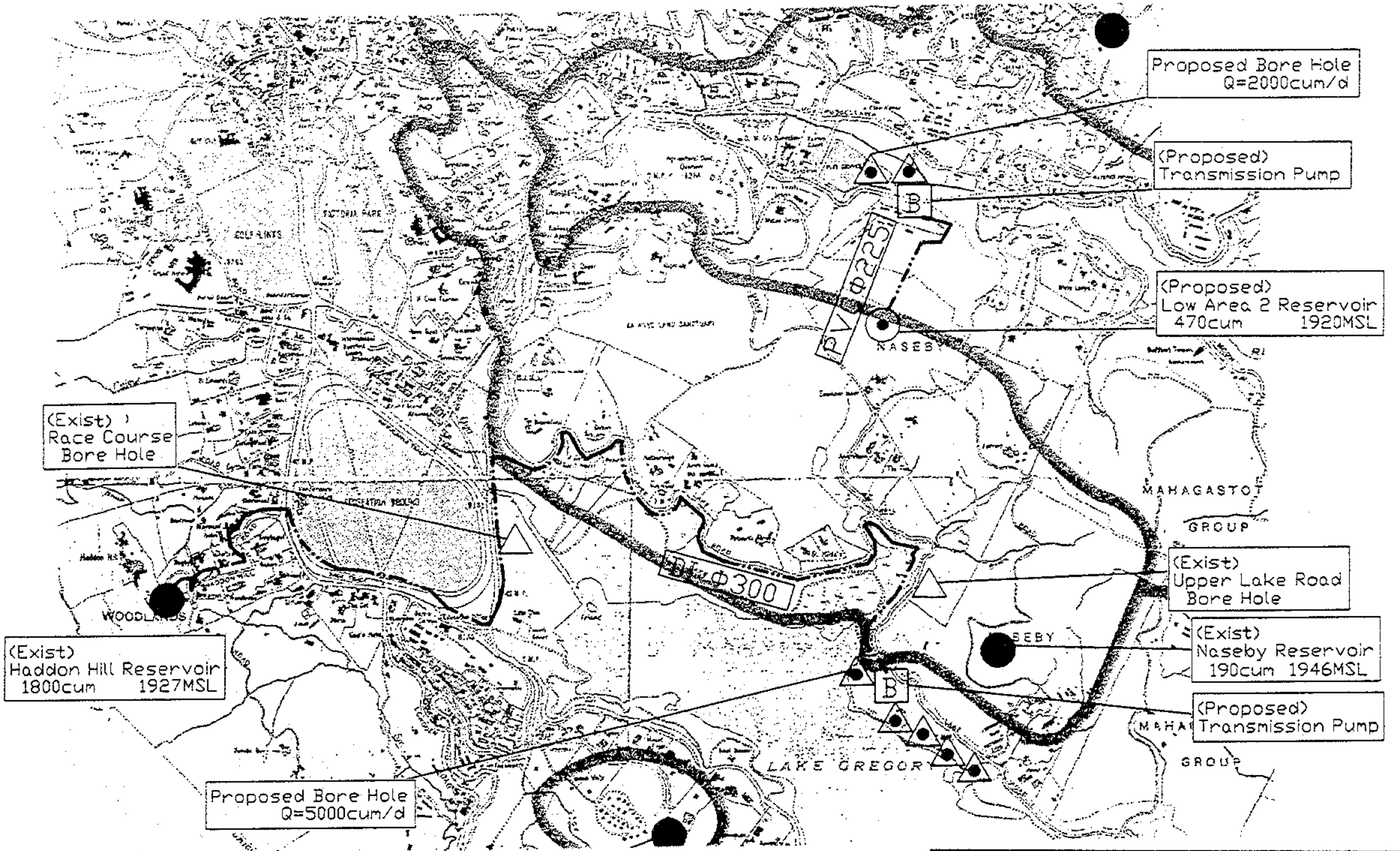


Fig 5.6 Layout of Proposed Wells and Transmission Line

5.4.4 Water Distribution Plan and Transmission Line Requirement

(1) Water Transmission Method

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

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

At present, the existing surface water sources located at Bambarakele, Old Water Field and Pedro are utilized by conveying water via transmission lines to the Haddon Hill Reservoir for the Low Area 1 block.

Previous Tables 5.4 and 5.5 show the relationship between the water sources and reservoirs during the dry season. In this particular subsection, water transmission method during the rainy season mainly for Low Area 1, Low Area 2, Bonavista and Naseby blocks, where groundwater will be utilized during the dry season, are examined.

Since Vijithapura and Unique View are located within the Haddon Hill block and waters are pumped to these reservoirs from branch or distribution lines, no independent transmission is deemed necessary, provided sufficient water is transmitted to the Haddon Hill distribution reservoir. (In addition, the limited size of the service area in these two reservoirs is an additional reason for exclusion from the examination.)

The allocation of water from Bambarakele, Old Water Field and Pedro was determined to be the Haddon Hill reservoir, having an existing transmission line, and to the Bonavista being located in the vicinity of these water sources.

For the Low Area 2 reservoir, Lover's Leap and Gamunu Brewery are the candidate water sources because of their closer distance.

Since those surface water sources are also supplying water to the High Area 1 block, water transmission during the rainy season was established with due consideration to the water distribution of the High Area 1 block.

A comparison of alternatives plans revealed that Low Area 1, Low Area 2, Bonavista and Naseby blocks should be supplied from water sources in Bambarakele and Pedro during the rainy season, as presented in Table 5.7.

The relationship between water sources and reservoirs during the rainy season is shown in Table 5.8, while the layout plan for water transmission by season is shown in Figures 5.7 and 5.8. The utilization of the transmission pump for Naseby Reservoir is described separately in the next section.

(2) Water Transmission Method to Naseby Reservoir

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

As a countermeasure to the above situation, water will be transmitted by gravity to a marginal elevation and then sent by booster pumps for further transmission as shown in Table 5.9.

Table 5.9 Required Transmission Pump to Serve for Naseby Block

Description	Required Equipment
Transmission Pump	Inline Booster Pump 0.42 m^3/min x 25 m x 3.7 kW x 1 unit

(3) Facility Plan for Transmission Pipelines for Water from Surface Water Sources

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

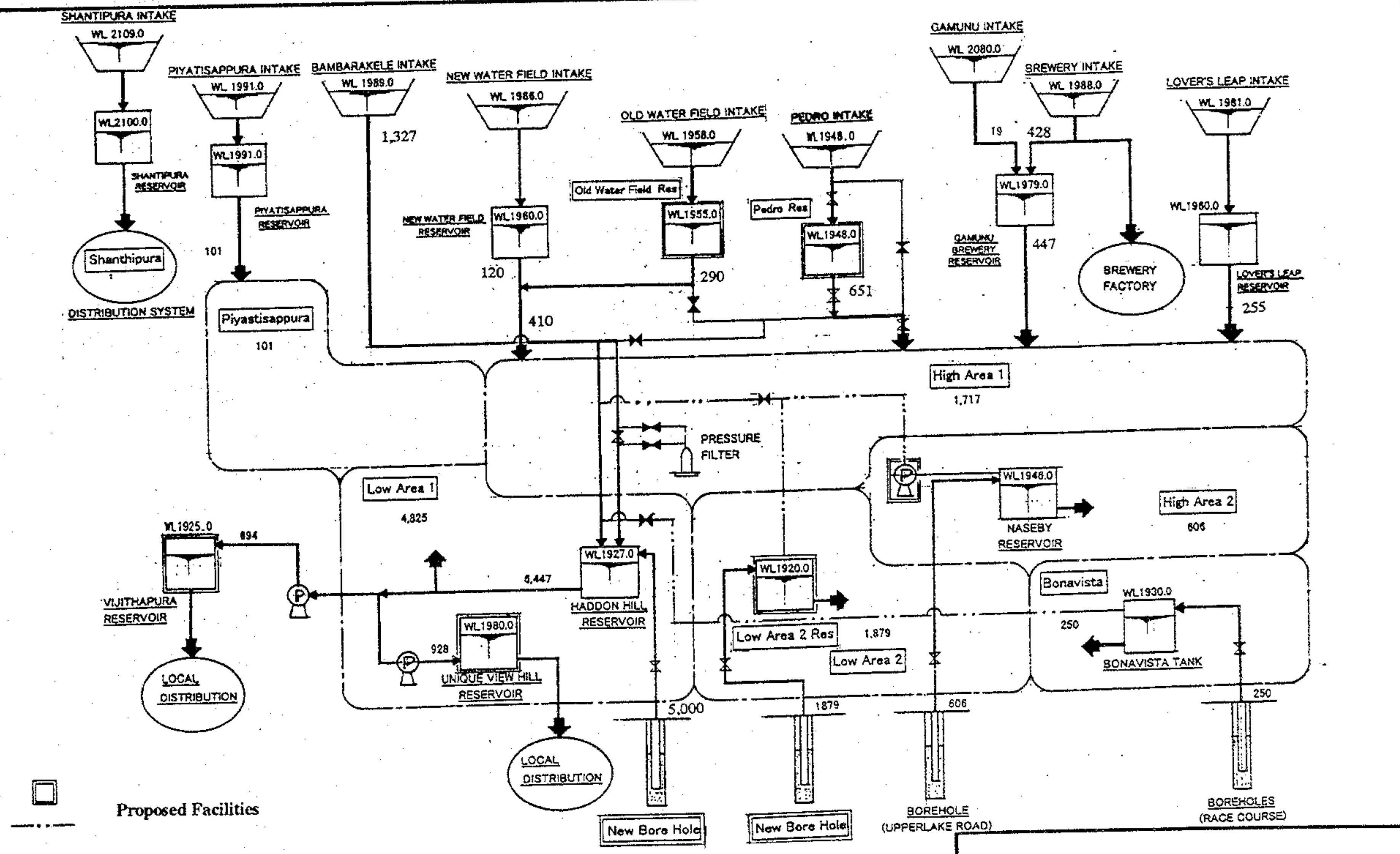
Table 5.7 Comparison of Water Transmission Method in Rainy Season

Water Source	Distribution Reservoir	Problems Relevant to Water Source Capacity	Problems Relevant to Water Distribution in High Area 1	Evaluation
Lover's Leap	Low Area 2	Not feasible because (Water demand of Low Area 2 - 1,879 m^3/day) > (Source capacity of Lover's Leap - 1,615 m3/day)		N.A.
Gamunu, Brewery	Low Area 2	Although water demand of Low Area 2 (1,879 m^3/day) is smaller than source capacity of Gamunu Brewery (2,380 m3/day), it is considered not feasible due to less reliability because Gamunu Brewery owns the water source and utilizes it as large scale consumer and its consumption is unknown.		N.A.
Lover's Leap, Gamunu/ Brewery	Low Area 2, Naseby	Feasible (Water demand - 2,485 m^3/day) < (Source capacity - 3,995 m^3/day)	Not feasible due to less reliability because of unknown intake volume by large-scale consumer (Gamunu Brewery), though water demand (3,661 m^3/day) is smaller than source capacity (3,995 m^3/day) for High Area 1 block. Demand is 2,485+1,176=3,661, if eastern part of High Area 1 were supplied.	NA
Bamba-rakele, Old Water Field	Low Area 1, Low Area 2, Bonavista, Naseby	Not Feasible (Water demand – 9,182 m^3/day) > (Source capacity - 7,908 m^3/day)		NA
Bamba-rakele, Pedro	Low Area 1, Low Area 2, Bonavista, Naseby	Feasible (Water demand - 9,182 m^3/day) ≈ (Source capacity - 9,135 m^3/day) When source capacity becomes smaller than water demand, valve operation can allow to supplement water shortage from neighboring block (though it is not so recommendable).	Western part of High Area 1 shall be supplied from New Water Field and Old Water Field.	Applicable
Bamba-rakele, Pedro, Old W.F	Low Area 1, Low Area 2, Bonavista, Naseby	Feasible (Water demand - 9,182 m^3/day) < (Source capacity - 12,185 m^3/day)	Not feasible that western part of High Area 1 is supplied by New Water Field with a limited capacity. Distribution from Pedro and Old Water Field is not suitable due to its instable water supply.	Semi-applicable

Table 5.8 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)	Water Source: 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 Pedro	1,879		
	Sub Total		1,524	1,879		1,879	0	
6	High Area 2		491	606	Upper Lake Road Borehole	0		
					Bambarakele Pedro	559		
	Sub Total		491	606		559	-47	
7	Bonavista		203	250	Race Course Borehole	0		
					Bambarakele Pedro	250		
	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



Proposed Facilities

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

Fig 5.7 Proposed Flow Diagram in Dry Season

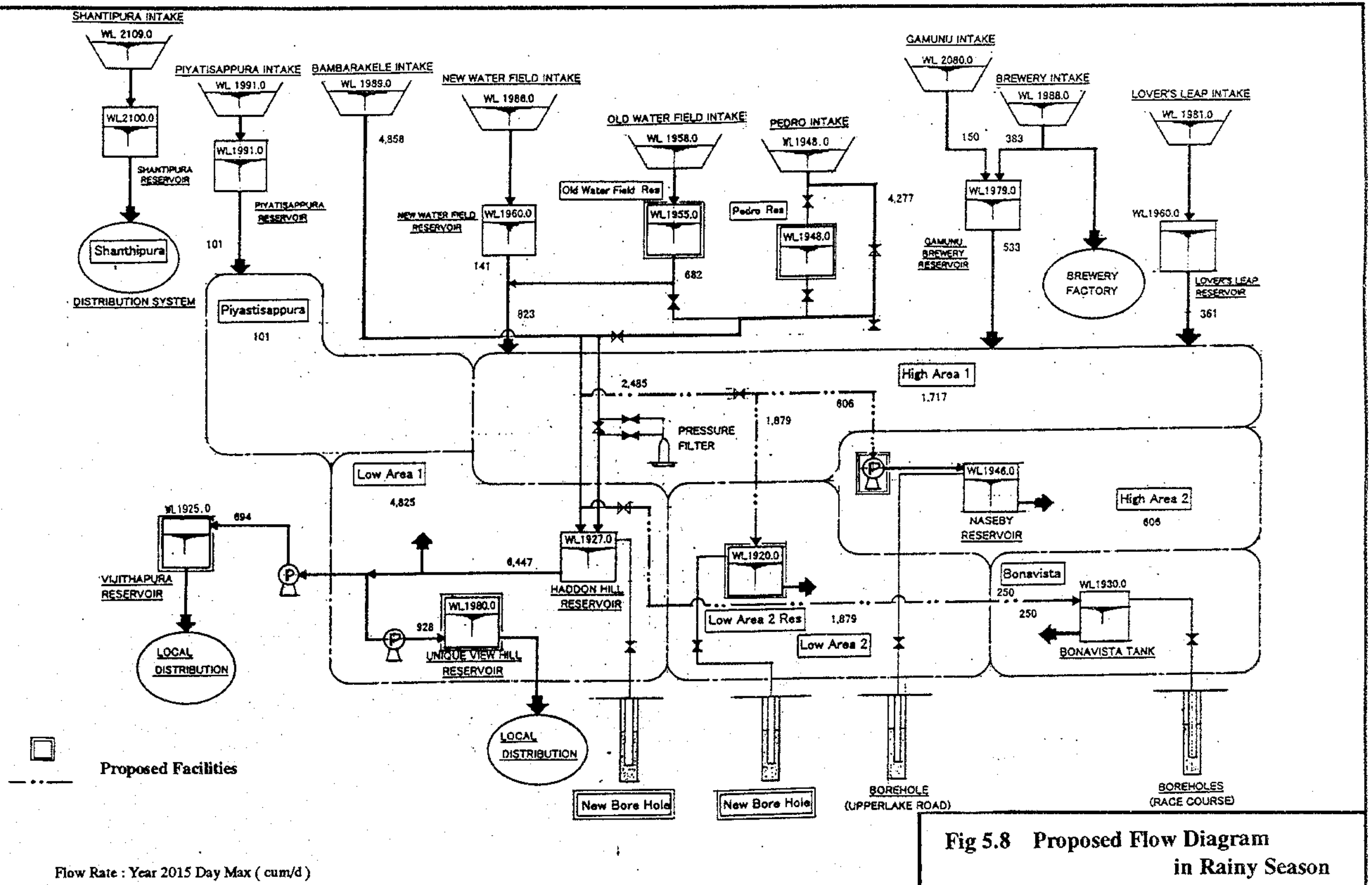


Fig 5.8 Proposed Flow Diagram in Rainy Season

The location and diameter to augment transmission line were determined to attain required dynamic head at respective junction/branch points through hydraulic analysis under the normal condition (maximum daily supply volume) in rainy season (refer to Appendix 5.4)

Available water sources for the Haddon Hill reservoir during the rainy season are Bambarakele and Pedro. Water from Pedro will not be passed through the Pedro reservoir in order to avoid unnecessary head loss.

Locations to augment the transmission lines have been preliminarily designed as shown in Figure 5.9, while magnitude of transmission line augmentation is summarized in Table 5.10.

Table 5.10 Magnitude of Transmission Line Augmentation

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

(4) Utilization of the Existing Filter Tanks

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

At present, the treated water pipe of the filter tanks is directly connected to the distribution main. This may affect the treatment results due to pressure fluctuations. It is recommended that the treated water pipe should not be connected to the distribution main, but isolated by means of the existing isolation valves.

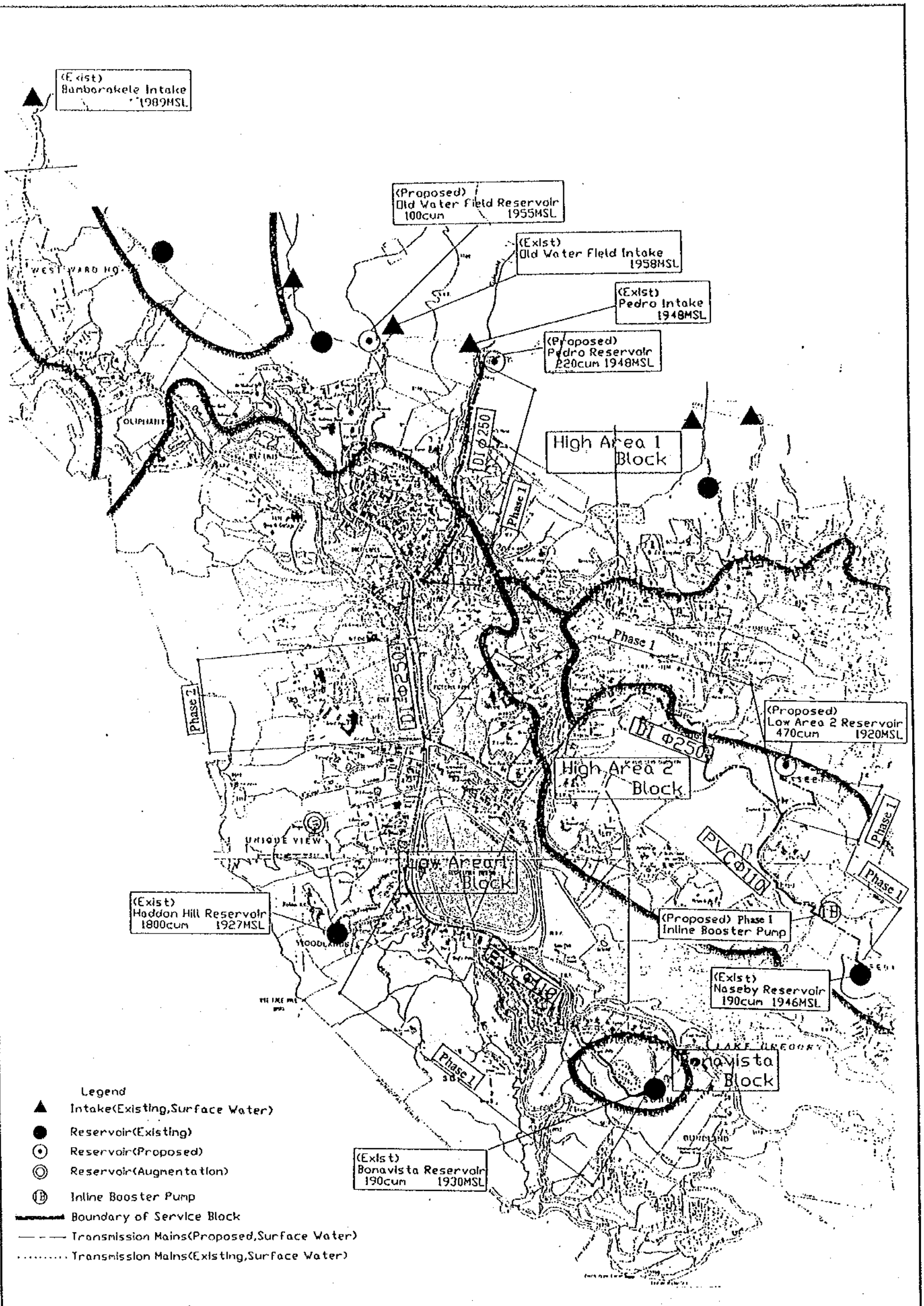


Fig 5.9 Layout of Proposed Transmission Facilities

5.4.5 Plan for Distribution Network

(1) Provision of Appropriate Water Pressure Distribution Network Arrangements

The existing distribution network will cause excessively high/low pressure areas against the water demand in 2015. Improvement of the distribution network will also be required by realignment of the distribution main corresponding to the introduction of new distribution reservoirs, etc.

Required sizes, lengths and pipe materials for the distribution network were determined in order to attain the required dynamic head at respective junction/branch points through a hydraulic analysis for the target year 2015 under normal conditions (hourly maximum supply volume). The analysis results were verified with the water demand in 2005 so as to minimize the initial investment in Phase 1, and confirmed that a part of the distribution system could be constructed in Phase 2. (Refer to Appendix 5.4 for details.)

Locations to augment the distribution network are shown in Figure 5.10, while the required volume of pipe materials is summarized in Table 5.11.

Table 5.11 Magnitude of Distribution Network Augmentation

Pipe Material	Diameter (mm)	Length (m)		
		Phase 1	Phase 2	Total
PVC	ϕ63	50	-	50
PVC	ϕ75	1,460	-	1,460
PVC	ϕ110	1,839	-	1,839
PVC	ϕ160	1,828	1,773	3,601
PVC	ϕ225	1,760	132	1,892
DCI	ϕ250	2,069	-	2,069
Total		9,006	1,905	10,911

In addition to the above, there are several locations which require realignment of the pipe connections corresponding to a rearrangement of the water supply service blocks.

Improvements in the distribution pressure through the above arrangement are summarized in Table 5.12, in which a comparison of dynamic head on the existing distribution network and the improved distribution network under the hourly maximum water demand in 2015 is presented.

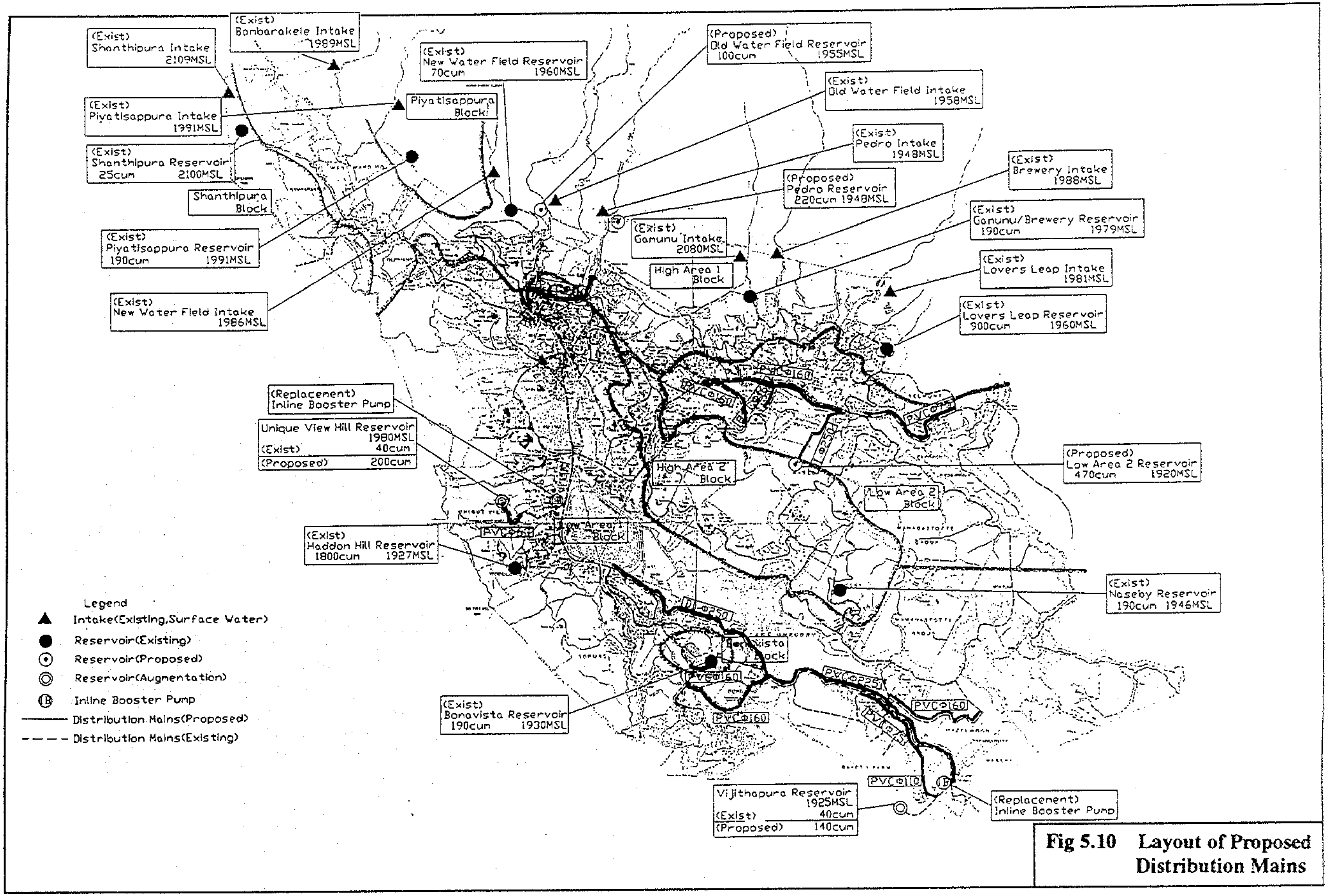


Fig 5.10 Layout of Proposed Distribution Mains

Table 5.12 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 of Water Level at Low Area 2 Distribution Reservoir

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

Static heads were a maximum of 54 m and a minimum of 24 m and approximately 30 m at most of the locations which were deemed to lie within an appropriate range of pressures. Thus, the appropriateness of the water level at the Low Area 2 distribution reservoir was confirmed.

(3) Evaluation of Existing Booster Pump Capacity at Low Area 1 Block

The low Area 1 block is to be served by the Haddon Hill distribution reservoir and is to branch water to Vijithapura and Unique View Hill distribution reservoirs via booster pumps installed in the distribution network.

An evaluation of the existing booster pump capacity was made to verify whether they can cope with the rearranged water distribution blocks and future increases in water demand as follows:

1) Booster pump capacity to serve for Vijithapura distribution reservoir

$Q = 694\ m^3/day = 0.48\ m^3/min.$
Total pumping head
H = 1,930 m amsl – 1,917 m amsl + Loss 6.4 m + Allowance 5 m = 25 m
P = 3.7 kW
Existing booster pump $0.42\ m^3/min.$ x 35 m x 7.5kW
Therefore, existing pump should be replaced with an Inline Booster Pump
$0.48\ m^3/min$ x 25 m x 3.7 kW x 1 unit

Note: Residual pressure at the booster pump was considered for calculation of required pumping head.

2) Booster pump capacity to serve for Unique View Hill distribution reservoir

$Q = 928\ m^3/day = 0.64\ m^3/min.$
Total pumping head
H = 1,980 m amsl – 1,923.7 m amsl + Loss 23.4 m + Allowance 5 m = 85 m
P = 18 kW
Existing booster pump $0.54\ m^3/min.$ x 78 m x 15kW
Therefore, existing pump should be replaced with an Inline Booster Pump
$0.64\ m^3/min.$ x 85 m x 18 kW x 1 unit

Note: Residual pressure at the booster pump was considered for calculation of required pumping head.

5.4.6 Capacity Augmentation of Distribution Reservoir

(1) Distribution Reservoir which requires Capacity Augmentation

Table 5.13 presents the distribution reservoirs with their respective service blocks and capacity balance. In the table, the Low Area 2 distribution reservoir is proposed as a new reservoir to cater for the new service block.

Distribution reservoirs at Old Water Field and Pedro are at present directly supplied from existing water intake facilities and have been augmented to meet the hourly fluctuation of water demand during the dry season.

In addition to the above, the distribution reservoirs at Unique View Hill and Vijithapura blocks require augmentation of their storage capacities to cope with future increase in water demand.

Table 5.13 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

Since the distribution reservoir is to be installed to regulate the hourly fluctuation of water demand, the more the capacity is increased the more the reliability is improved. Retention time at the distribution reservoir is set to keep a minimum of six hours capacity over the maximum daily water demand as follows:

Required capacity of distribution reservoir (m^3)

= Maximum daily water demand (m^3/day) x 6 hr/24 hr

Figure 5.11 shows layout of proposed reservoirs and Table 5.14 shows their required capacities, respectively.

Table 5.14 Distribution Reservoirs to be Augmented

Distribution Res.	Required Capacity (m^3)	Dimensions	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 Tank
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

The difference in water level among water sources in High Area 1 is 31 m (=1979-1948); the highest is at 1.979 m amsl (Gamunu Brewery) and the lowest is at 1,948 m amsl (Pedro).

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

For example, from the water sources in High Area 1, the distribution volume from New Pedro reservoir becomes smaller than that of the Pedro intake facility owing to the lower water level at New Pedro reservoir, while the Pedro intake facility has a larger supply capacity than any other water source.

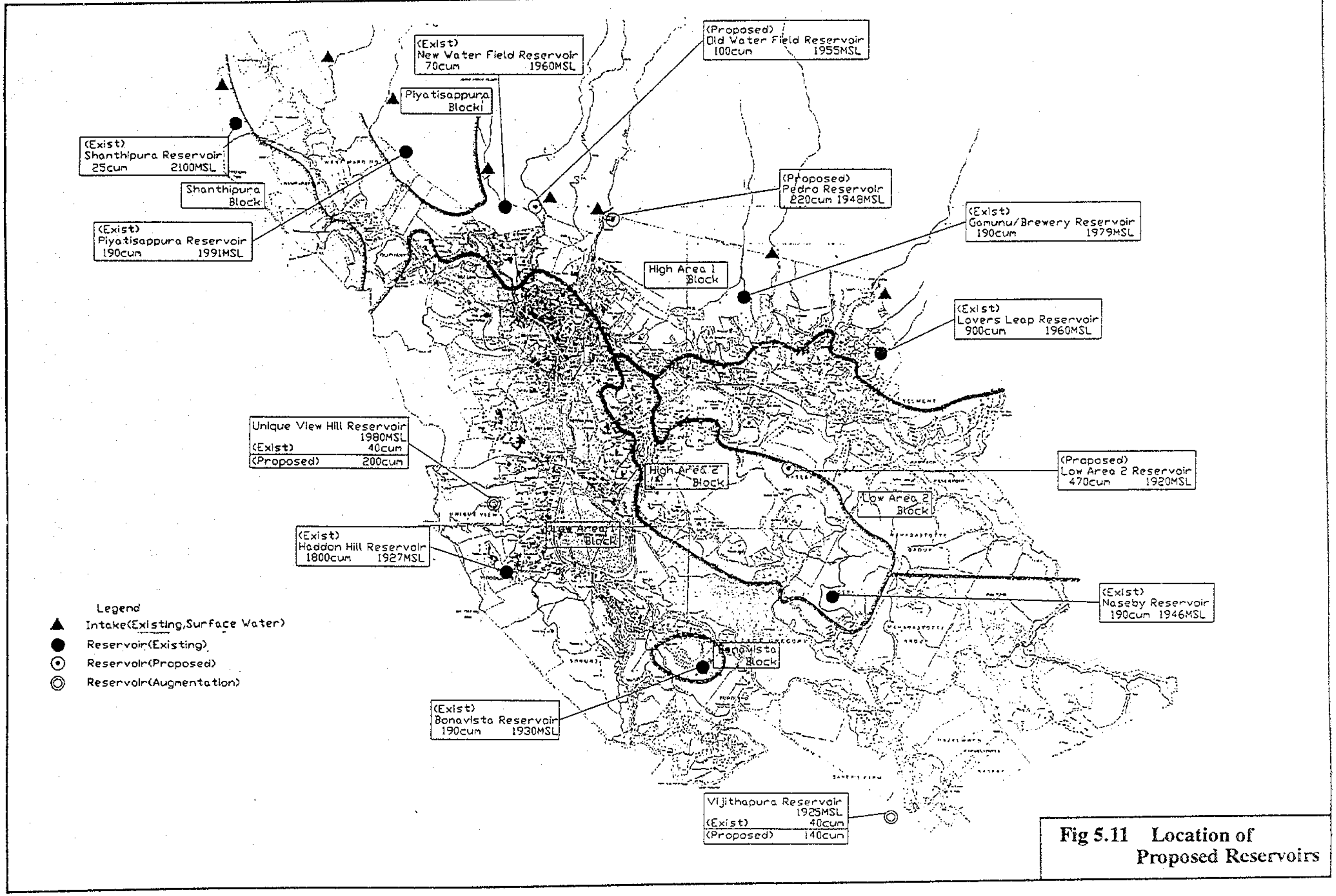


Fig 5.11 Location of Proposed Reservoirs

Considering the above, a hydraulic simulation was carried out assuming the following pre-conditions:

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

Through the hydraulic simulation, water levels at these reservoirs were calculated as shown in Table 5.15.

Table 5.15 Hydraulic Analysis Results on Water Levels at Reservoirs in Dry Season

Distribution Reservoir	New Water Field	Old Water Field	New Pedro	Gamunu Brewery	Lover's Leap
Water Level at Reservoir (m amsl)	1,960	1,958	1,948	1,979	1,960
Water Level of Simulation Results (m amsl)	1,943	1,955	1,948	1,944	1,944
Difference of Water Level (m)	-17.0	-13.0	0.0	-35.0	-16.0
Remarks	Fixed distribution volume	Fixed distribution volume	Fixed water level	Fixed distribution volume	Fixed Distribution volume

Water levels of reservoirs under fixed discharge conditions in High Area 1 block during the dry season are shown in Figure 5.12.

When the water level at the New Pedro distribution 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 the water level at the New Pedro distribution reservoir causes the actual water level in the distribution lines leaving empty conditions in other reservoirs or balanced conditions under lowered water levels.

The above results revealed that even if the required volume is secured at respective reservoirs, the principal function of the reservoir cannot be performed. In other words, flow control at each reservoir will be required by means of valve operation.

Hydraulic simulation has shown that an application of 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. worst conditions was applied for the calculation
c. actually flow can be reduced but no vacuum is expected

Thus, no specific countermeasure is deemed necessary.

5.4.7 Disinfection Facilities

At present, disinfection using chlorine gas and calcium hypochlorite are being introduced under the ADB project. A gas chlorinator is planned to be provided at the Haddon Hill reservoir, while calcium hypochlorite disinfection facilities are being provided at other small reservoirs. Chlorination using a gas chlorinator is appropriate for larger scale facilities, while calcium hypochlorite is suitable for small scale facilities. It is, therefore, recommended that disinfection for new reservoirs be carried out by dosing the raw water with calcium hypochlorite prior to entry into the new service reservoir, Old Water Field and Pedro, Low Area 2. Disinfection by calcium hypochlorite is preferable because it is safer than the other alternatives such as gas chlorination or sodium hypochlorite.

5.5 Development Plan Summary

Facilities to be developed in the project consists of following (see Table 5.16):

(1) Intake and Conveyance

- New Wells
- Conveyance Pipeline

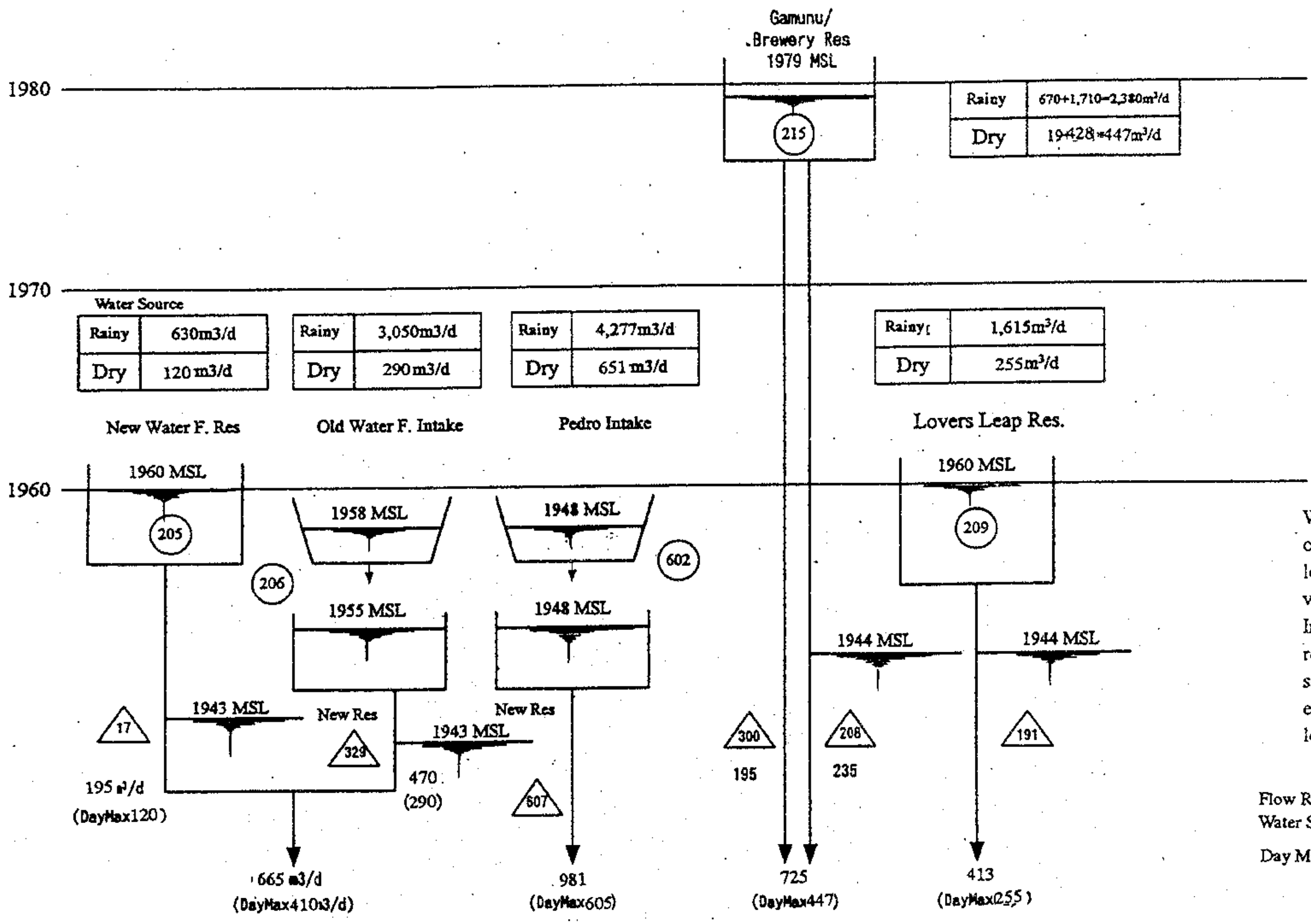
(2) Treatment Facility

- Treatment (chlorination) facility

(3) Transmission and Distribution

- Transmission Pipelines
- Distribution Reservoirs and Pressure Control Chamber
- Distribution Pipeline Network

Layouts of the facilities for the long-term development plan are presented in Figure 5.13.



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 5.12 Dynamic Water Level of Reservoirs without Valve Control

Table 5.16 Proposed Facilities to be Constructed

Facilities				Unit	Phase 1 Quantity	Phase 2 Quantity	Total Quantity
1	Intake Facilities						
	Well and Pump	Well	150 m/piece	pcs	7	0	7
		Pump Equipment	0.7 m3/min. x 58m x 15kW	set	8	0	8
		Electrical Facilities		set	7	0	7
	Conveyance	Conveyance Pipe	PVC φ 160	m	1,240	0	1,240
		Pump Pit	21cum	set	2	0	2
		Pump House	25 m2	set	2	0	2
		Pump Equipment	3.47 m3/min. x 68m x 75kW	set	2	0	2
		Pump Equipment	1.30 m3/min. x 63m x 30kW	set	2	0	2
		Electrical Facilities		set	2	0	2
2	Transmission Pipe Line						
		Transmission Pipe	PVC φ 110	m	2,867	0	2,867
			PVC φ 225	m	700	0	700
			DCI φ 250	m	3,545	488	4,033
			DCI φ 300	m	4,320	0	4,320
		Pump Equipment	0.42 m3/min. x 25m x 3.7kW	set	1	0	1
		Pump Equipment	0.48 m3/min. x 25m x 3.7kW	set	1	0	1
		Pump Equipment	0.64 m3/min. x 85m x 18kW	set	1	0	1
		Pump House	4 m2	set	3	0	3
		Electrical Facilities		set	3	0	3
3	Treatment Facilities						
		Chlorinator		set	3	0	3
		Chlorination House	10 m2	set	3	0	3
4	Distribution Facilities						
		Reservoir	100 m3	set	1	0	1
			220 m3	set	1	0	1
			200 m3	set	1	0	1
			140 m3	set	1	0	1
			470 m3	set	1	0	1
		Distribution Pipe					
			PVC φ 63	m	50	0	50
			PVC φ 75	m	1,460	0	1,460
			PVC φ 110	m	1,839	0	1,839
			PVC φ 160	m	1,828	1,773	3,601
			PVC φ 225	m	1,760	132	1,892
			DCI φ 250	m	2,069	0	2,069

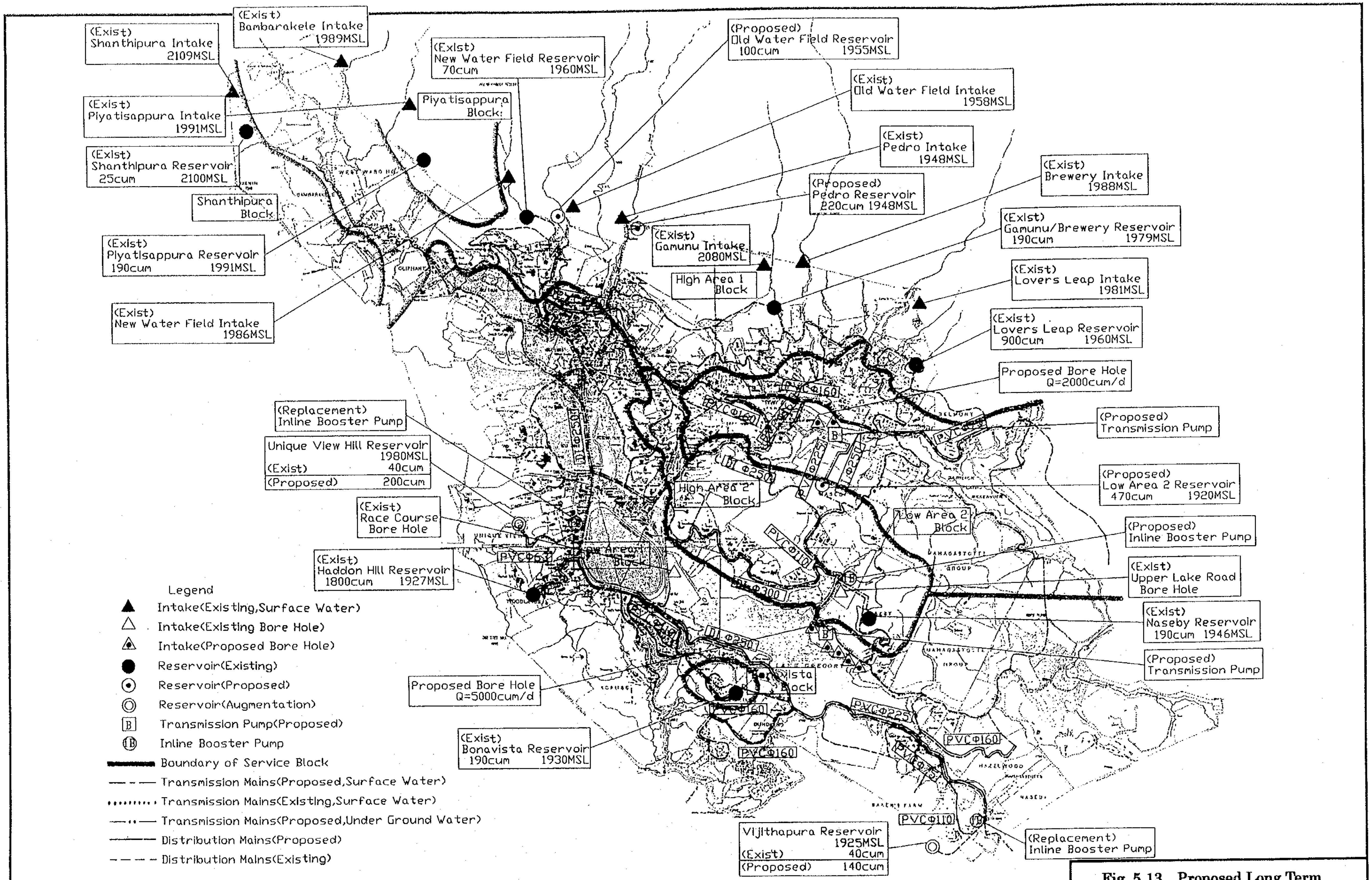


Fig. 5.13 Proposed Long Term Development Plan

5.6 Project Cost

5.6.1 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 %)

5.6.2 Conditions for Cost Estimate

(1) Conditions

1) Basic conditions

Project cost is estimated on the basis of the 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 the suitability of the proposed 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

2) Direct cost

a. Unit prices obtained from the NWSDB and actual contract prices from the Towns South Project were compared and unit costs as of July 1998 were established.

b. Administration cost is separately estimated as the cost of engineering/supervision for international contractor/s in consideration of magnitude of project for the local contractors.

3) Common expenses

Land acquisition costs for new reservoirs are estimated based upon the 0.32 ha required for Phase 1 and 2. The required land should be secured prior to the commencement of construction.

4) Contingency

A total of 15 percent for a contingency fund is included for the project cost both for physical contingency and price escalation.

(2) Scope of work to be implemented under foreign financing

The following works are recommended for implementation under foreign financial assistance.

1) Procurement of engineering services for detailed engineering design and construction supervision.
2) Construction work including procurement of equipment and materials as identified in the preliminary design and project cost estimate.

(3) Scope of work to be implemented by the local counterpart fund

The following works are to be implemented by the counterpart fund of the Sri Lankan Government:

1) Construction of water service connections and meters to be connected to the new distribution pipelines.
2) Land acquisition and relocation of local residents from the proposed construction sites and along the proposed pipeline routes.
3) Construction of perimeter fence at the proposed reservoirs sites.
4) Provision of water quality examination equipment and apparatus.
5) Cost of electricity, fuel, and chemicals during the testing activities of the water works prior to actual operation, except for individual tests of the electrical equipment.

5.6.3 Project Cost

The total cost of the proposed project is estimated at approximately Sri Lankan Rs. 568 million as shown in Table 5.17.

5.6.4 Construction Equipment and Materials

Most of the construction materials are imported from adjacent countries, except sand, gravel, concrete pipe etc. Imported materials are, however, available in the local market in Sri Lanka. Mechanical and electrical equipment must however, be imported from foreign countries.

Local products and imported materials and equipment are listed below. However, the imported materials for civil work are considered to be procured through sales agents and suppliers in Sri Lanka.

(1) Local material

Cement, stone, aggregate, sand, timber, plywood, steel reinforcement bars, structural steel, small PVC Pipe, concrete pipe, steel pipe, road curb, concrete block, brick, AC roof and tiles, pre-cast built wall, fence, road/pedestrian gates, wire nails, gabion mesh, gasoline, diesel, lubricants, admixtures, waterstop, scaffolding, metal forms, guardrail, asphalt, emulsion and other small items.

(2) Imported material

Construction equipment, valves, fittings, ductile iron pipe, truck cranes, vehicles, motorcycles, computers, pumps, motors, transformers, switchgears, disinfection facilities, laboratory equipment, flow meters, and other mechanical and electrical equipment.

5.7 Implementation Program

5.7.1 Implementation Schedule

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

Table 5.17 Estimated Total Project Cost

Unit : Thousand Sri Lankan Rs.

Facilities	Phase 1		Phase 2		Total		Remarks
	Breakdown	Total	Breakdown	Total	Breakdown	Total	
(1) Construction Cost							
1) Intake Facilities		112,499		0		112,499	
Well and Pump	112,499		0		112,499		
2) Transmission Pipe		93,024		4,172		97,196	
3) Treatment Facilities		3,150		0		3,150	
Chlorination	3,150		0		3,150		
4) Distribution Facilities		108,496		7,124		115,620	
Reservoir	64,513		0		64,513		
Distribution Pipe	42,983		6,974		49,957		
House Connection Replaceme	1,000		150		1,150		
5) NRW Reduction Program(Leak Detection)		2,500		0		2,500	
6) Rehabilitation for NRW Reduction		17,000		0		17,000	
7) Administration Cost		17,331		704		18,035	about 5% of others
Sub Total		**354,000**		**12,000**		**366,000**	
(2) Procurement of maintenance equipment		**25,000**		**0**		**25,000**	
(3) Engineering Cost							
1) Detailed Design	19,000		600		19,600		(55%)
2) Construction supervision	16,000		400		16,400		(45%)
Sub Total		**35,000**		**1,000**		**36,000**	about 10% of (1)
(4) Common Expenses							
1) General and Administrative expenses	4,000		2,000		6,000		
2) Land acquisition	6,000		0		6,000		
Sub Total		**10,000**		**2,000**		**12,000**	
(5) Contingency (15%)		**64,000**		**2,000**		**66,000**	
(6) GST (12.5%)		**61,000**		**2,000**		**63,000**	
Total		**549,000**		**19,000**		**568,000**	

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

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
2011-12	Construction
2012	Commencement of operation

The project implementation and disbursement schedule with estimated annual disbursement of project cost is presented in Table 5.19.

5.7.2 Activities in Project Implementation

Construction periods for the major works are estimated in months, as follows:

1) Intake Facilities	Phase 1	Phase 2
- Mobilization	1.0	
- Wells/Well Pumps	20.0	

2) Transmission Facilities	Phase 1	Phase 2
- Mobilization	1.0	1.0
- Civil work	20.0	6.0
Total	21.0	7.0

3) Distribution Facilities	Phase 1	Phase 2
- Mobilization	1.0	1.0
- Civil work	20.0	6.0
Total	21.0	7.0

Table 5.18 Implementation and Disbursement Schedule of Nuwara Eliya Water Supply Project

Item / Phase / Year		Phase 1					Phase 2		
Item		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