No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NATIONAL WATER SUPPLY AND DRAINAGE BOARD
MINISTRY OF HOUSING AND PLANTATION INFRASTRUCTURE
DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

THE DETAILED DESIGN STUDY ON GREATER KANDY WATER SUPPLY AUGMENTATION PROJECT IN THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

VOLUME I

SUMMARY REPORT

MAY 2002

NJS CONSULTANTS CO., LTD.
NIHON SUIDO CONSULTANTS CO., LTD.

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PREFACE

In response to a request from the Government of the Democratic Socialist Republic of Sri Lanka, the Government of Japan decided to conduct a detailed design study on Greater Kandy Water Supply Augmentation Project in the Democratic Socialist Republic of Sri Lanka and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Ikuo Miwa of NJS Consultants Co., Ltd. and consist of NJS Consultants Co., Ltd. and Nihon Suido Consultants Co., Ltd. to Sri Lanka, two times between January 2001 and May 2002.

The team held discussions with the officials concerned of the Government of Sri Lanka, and conducted field surveys at the study area. Upon returning Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Sri Lanka for their close cooperation extended to the teams.

May 2002

Takao Kawakami
President
Japan International Cooperation Agency

May 2002

Mr. Takao Kawakami
President
Japan International Cooperation Agency
Japan

Dear Sir,

Letter of Transmittal

We are pleased to submit herewith the final report for the Detailed Design Study on Greater Kandy Water Supply Augmentation Project in the Democratic Socialist Republic of Sri Lanka.

The Study was completed through the discussions with the Sri Lankan Government officials and the field work during the period from January 2001 to May 2002 and the home work thereafter.

The Final Reports consist of four separate volumes and (draft) tender documents : Volume I - Summary Report which succinctly describes the study and recommendations; Volume II–1: Main Report (1), which covers the review of the previous plans for the Greater Kandy Water Supply Augmentation Project: and Volume II–2: Main Report (2), which covers the details of the detailed design for the above, and Volume III: describes the details of the first phase projects including detailed engineering analysis and relevant.

We hope that the implementation of the proposed projects would greatly contribute to the improvement of water supply services, and sanitary conditions in the study area.

We wish to take this opportunity to express our sincere gratitude to the officials of your Agency, the Ministry of Foreign Affairs, the Ministry of Health, Labour and Welfare, for their kind support and advice. We also would like to show our appreciation to the officials of the Ministry of Housing and Plantation Infrastructure, the National Water Supply and Drainage Board, the JICA Sri Lanka Office, and the Embassy of Japan in Sri Lanka for their kind cooperation and assistance throughout our field survey.

Very truly yours,

Ikuo Miwa
Team Leader
Study Team for the Detailed Design Study
on Greater Kandy Water Supply
Augmentation Project

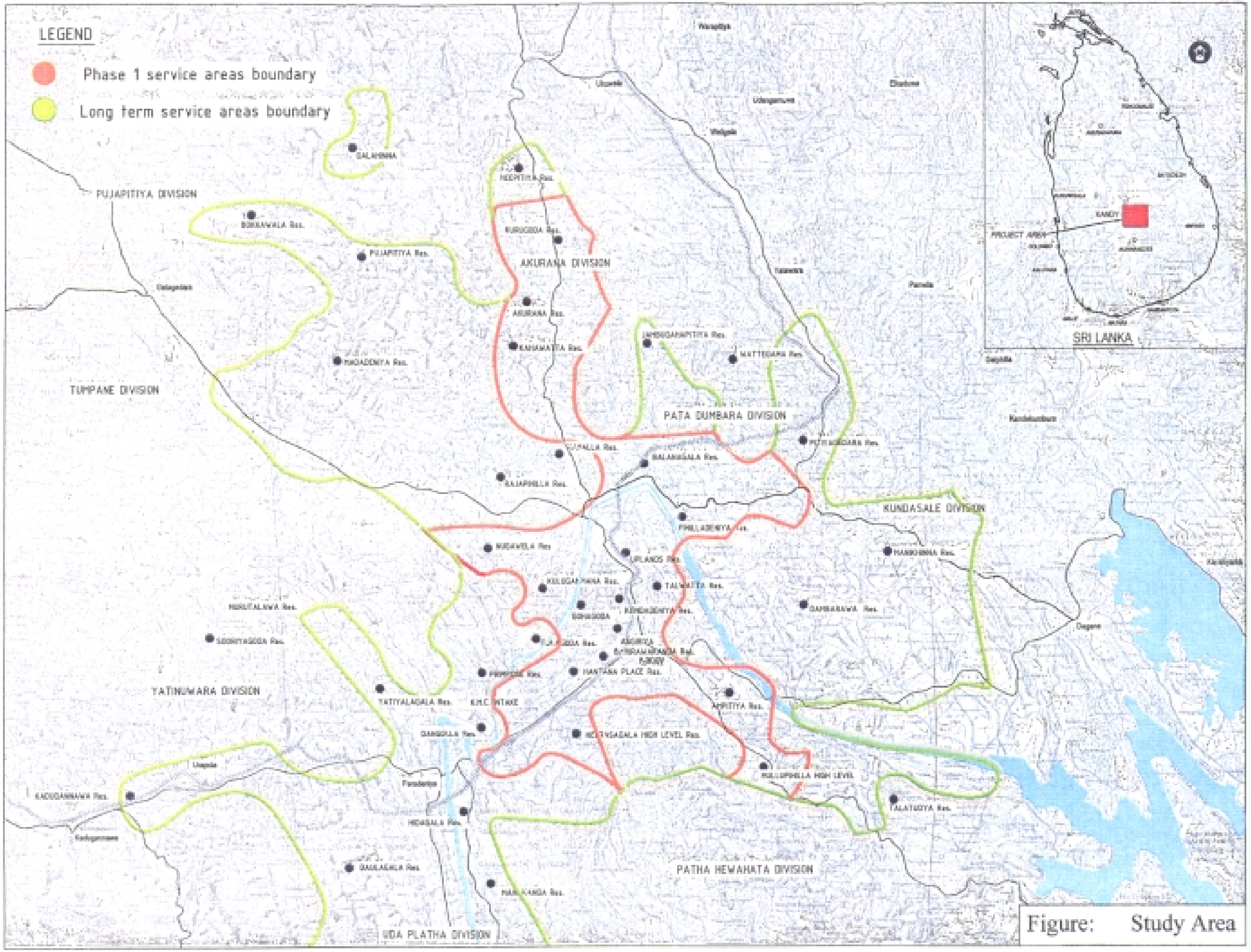

Figure: Study Area

EXECUTIVE SUMMARY

1. Background of the Study

The Greater Kandy (area:460km^2, population: approximately 700,000) with a centre in Kandy City, which is the second biggest city in Sri Lanka, has been recently facing the rapid growth in population. The water demand exceeds the water supply capacity largely and the increase in water supply capacity through the provision of water supply facilities is an urgent matter in the area.

With such a background, the Japan International Cooperation Agency (hereinafter referred to as "JICA") conducted the Study on Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Plan in the Democratic Republic of Sri Lanka (formulation of master plans for water supply and sanitation/sewerage development and feasibility study for the priority projects) since February 1998 and proposed the implementation of the priority projects for water supply (water treatment plant and water distribution system) and sewerage (sewage treatment plant and sewage collection system) in February 1999.

Upon receipt of the report, for the water supply facilities proposed as the priority project in the above study, the Government of Sri Lanka, requested the assistance for the detailed design which directly links to the financial loan by the Japanese.

In response to this request, JICA decided to conduct the detailed design study for the Greater Kandy water supply augmentation project and dispatched the Study Team to Sri Lanka from January 2001 to March 2002. The Study was completed in May 2002 upon submission of the Final Report.

2 Objective of the Study

The objectives of the Study are:

1. To conduct a detailed design of the water supply facilities including the preparation of tender documents, which directly links to the financial loan by Japan Bank for International Cooperation (hereinafter referred to as "JBIC") in response to the request of the Government of Sri Lanka.

   a. Intake facilities
   b. Water treatment plant
   c. Transmission pumping stations
   d. Transmission pipelines
   e. Distribution facilities

2. To pursue technology transfer to the counterpart personnel in the course of the Study.

3. Review of the Previous JICA F/S

(1) BOD_5 Loading Input on the Mahaweli River

There are seven streams entering the Mahaweli River including the Meda Ela in the reach of the confluence with the Meda Ela and the proposed Gohagoda Intake. The sewage flow and mass loading from each stream basin were estimated based on the planning fundamentals defined in the previous JICA study.

(2) Water Quality of the Mahaweli River

The BOD_5 concentration of the Mahaweli River has varied from 3.7 to 4.7 mg/L at the Peradeniya Intake upstream of the confluence with the Meda Ela since 1993 with a drop to 3.7 mg/L in 1998 and 1999. The NWS&DB Laboratory started the water quality surveillance programme since March 2000 and conducted the water sampling once a week. However its results are lack of reliability with problems

According to the investigation by the Study Team, the findings are as follows:

- The BOD_5 concentration was 3.0 mg/L on average in Getambe downstream of the confluence with the Meda Ela, which is considered to be very good taking into account the sampling location downstream of the confluence and the sampling period during the dry season with little rainfall.

- It is 2.8 mg/L in BOD_5 at the proposed Gohagoda Intake 5.0 km downstream of the confluence, which suggests the occurrence of self-purification in the Mahaweli River.

- The conditions of the Meda Ela receiving the wastewater generated in the KMC were 17,500 m^3/day in flow and 13.7 mg/L in BOD_5 on average. The night flow of the Meda Ela was 16,000 m3/day which is regarded as its own flow and the difference of 1,500 m^3/day from the river flow is considered as the wastewater flow and equals to 15.2% of the total wastewater flow generated in the Meda Ela basin. Likewise, the ratio of BOD_5 entering the Meda Ela is 5.7 % of the estimated total BOD_5 loading generated in the basin. It means that most of wastewater infiltrates the ground and some evaporates before reaching to the Meda Ela

- The Asgiriya Stream, which collected the wastewater from the area not to be served by the sewerage had a flow of 670 m^3/day and an average BOD_5 of 3.4 mg/L. The rates to the total wastewater flow and BOD_5 loading generated in the Asgiriya Stream basin were 37% and 1.5%, respectively, similar to the trend in the Meda Ela.

(3) Statistical Analysis of Hydrogeological Data of the Mahaweli River

- The flow of the Mahaweli River is controlled by the operation of the upstream Kotmale Dam and downstream Polgolla Dam and the proposed Gohagoda Intake is situated in the storage zone of the Polgolla Dam.

- The median flow of the Mahaweli River is approximately 2,000,000 m^3/day equivalent to 100 times that of the Meda Ela.

- The frequency that the flow of the Mahaweli River is below the minimum flow of 180,000 m^3/day is 11.3 % per annum, namely 42 days at the Peradeniya Gauging Station. Such days concentrates to March and April.

(4) Water Quality Data of NWS&DB Laboratory

The Mahaweli River is the longest river with the biggest watershed in Sri Lanka and there is little town upstream of the Greater Kandy. Hence, it is considered that the Mahaweli River is hardly polluted artificially. The BOD_5 concentration of such not artificially polluted river is 0.5 to 1.0 mg/l in general. However, there were some extraordinary values in the water quality analysis.

- The past water quality data of the Mahaweli River conducted by NWS&DB RSC-Central Laboratory is in the range of 3.7 to 5.7 mg/L in BOD_5 during the period of 1993 to 2000 and the BOD concentration rose to 5.7 mg/L in 2000 from 3.7 mg/L in 1999.

- There were some extraordinary values especially in BOD_5 in the results of the water quality surveillance program of the Mahaweli River on a weekly basis commenced from March 2003.

- In the first field survey of this Study, the water quality was cross-checked using the same samples of the Mahaweli River between NWS&DB and Peradeniya University. There was obviously a big gap in BOD_5.

For these reasons, the analytical method etc. at NWS&DB Laboratory was studied with some doubt

The study revealed that there were four different points from the ordinary BOD_5 analysis, namely (a) less shaking times of sample bottles, (b) use of ion-exchanged water for distilled water as dilution water, (c) use of DO bottles for BOD bottles inserted a strip of paper to facilitate bottle opening, and (d) application of five times dilution to the samples of the Mahaweli River in principle.

Each factor was identified its extent of influence on the measured BOD_5 concentration in comparison with that regularly analysed. The factors of (a) to (c) has a tendency to give the undervalue, while the factor (d) gives three to six times the actual value, and as a whole the latter completely offsets the former negative factors and raise the BOD_5 concentration. When the sample has a BOD_5 concentration of less than 4 mg/L, ammonium chloride in the dilution solution receives the nitrification by the action of nitrifying bacteria present in the sample and the oxygen demand for this nitrification is added to the measured BOD_5 concentration. It is said that the oxygen demand for such nitrification is 5 mg/L at the maximum. For this reason, the sample receives no dilution in case of a BOD_5 concentration of less than 4 mg/L.

The people near the Mahaweli River have the custom to take bathing and washing in such a water body using soaps. The proposed Gohagoda Intake is located in the stagnant water body of the Polgolla Dam and the water polluted by such bathing and washing flows slowly along the riverbank without mixing. Therefore, the water quality of the sample oftenly reflects such polluted river water due to water sampling within reach from the riverbank. The center of the Suspension Bridge near the entrance of the stagnant water body was selected as the new sampling point that was not affected by such bathing and washing.

The water quality analysis was carried out at the new sampling point using the improved analytical method. The water sampling was done six times every two hours a day in five different weeks. The maximum daily average was 2.57 mg/L in BOD_5 at the river flow of one-fifth the median flow, but others were around 1.0 mg/L indicating that the water quality of the Mahaweli River was good.

(5) Water Pollution Analysis in the Mahaweli River

- The currently-adopted water treatment process is considered to be applicable to the raw water with a BOD concentration of not more than 3 mg/L in Japan and other countries. When the water quality level of the Mahaweli River that is expected to be nearly 1mg/L at present will be deteriorated to 2 mg/L due to the delay in sewerage provision, a BOD5 concentration is simulated at more than 3 mg/L at the proposed Gohagoda Intake. Although the currently-adopted water treatment process is still applicable to such raw water, if being based on the EC standards (not more than 5 mg/L in BOD_5), it is considered to be important to implement the sewage works in order to keep the raw water quality within the desirable level. However there is a little accumulation of water quality data regarding the Mahaweli River and the raw water quality at the proposed Gohagoda Intake will be largely dependent on the development of the Greater Kandy itself. Therefore, it is strongly recommended to conduct continuously the water quality monitoring of the Mahaweli River and the Meda Ela.
- The wastewater entering the Mahaweli River from small streams between the confluence with the Meda Ela and the proposed Gohagoda Intake gives marginal influence on the proposed water source at Gohagoda

(6) Review of M/P and F/S for Sewerage Provision

The major modifications in a sewerage system from the previous JICA study accompanied with the shift of the proposed sewage treatment plant site from Bowala to Gannoruwa due to the strong opposition of the surrounding people.

- Installation of the Bowala in-manhole pump station to lift the wastewater from the Bowala area to the gravity flow trunk sewer.

- Construction of the Getambe Pump Station to pump all the wastewater collected from the KMC to the proposed Gannoruwa Sewage Treatment Plant

- Adoption of the oxidation ditch process for the proposed Gannoruwa Sewage Treatment Plant and setting of its effluent standards of 20 mg/L in BOD_5 and 20 mg/L in SS.

The proposed site for the Gannoruwa Sewage Treatment Plant is currently owned by the Ministry of Agriculture, which has already given his consent to hand over the land for such an use.

(7) Technology Transfer

The technology transfer that is one of objectives of this Study was carried out through (1) the joint works and discussion between the Study Team and NWS&DB Counterpart Team, (2) presentation to the NWS&DB staff who will be responsible for operation and maintenance of the new water supply system after completion of the construction work, (3) JICA group training for waterworks engineering to one of counterparts in Japan and subsequent personal training at the consulting engineering firm and the Osaka Prefectural Government, and (4) technology transfer seminar.

(8) Conclusion

- The service reservoirs in Asgiriya and Gohagoda cover the areas not to be served by sewerage in future, however the influence of the wastewater generated from these areas on the water quality of the proposed Gohagoda Intake is marginal. Hence the Asgiriya and Gohagoda Service Reservoirs should be constructed as proposed in the previous JICA including the relevant transmission and distribution pipes.

- For the conservation of the water supply source, it is important to protect the Mahaweli River itself from water pollution. The construction of a sewage treatment plant is effective for mitigation of mass loading to be discharged into the Mahaweli River for the period of the minimum flow occurred in the drought season. Furthermore, the strong measures against water pollution control should be taken from the long-term viewpoint for the upstream reach of the Mahaweli River.

- The effluent standards of 20 mg/L in BOD5 and 20 mg/L in SS are recommended for a sewage treatment plant adopting the oxidation ditch process.

- The NWS&DB Laboratory must take responsibility to identify continuously the exact water quality of the Mahaweli River based on the improved analytical method and re-selected sampling point so as reflect the real condition of the Mahaweli River.

- The following works are duplicated with the ADB-financed project and shall be excluded from the JICA project.

    Primrose Service Reservoir with a volume of 315 m^3

Clear water transmission pipes to the Dangola Service Reservoir (PVC140mm x 900 m long)

4. Water Demand and Supply

Greater Kandy includes KMC area and parts of ten adjoining Pradeshiya Sabahs, namely Kandy Four Gravets, Akurana, Harispattuwa, Pujapitiya, Kundasale, Patha Dumbara, Patha Hewaheta, Udunuwara, Uda Palatha and Yatinuwara. This area covers about 460 km^2.

The projected total population, the projected service population and the water demands are tabulated in the following table.

Description	2000	2005	2010	2015
Total Population	672,400	717,600	762,900	810,100
Coverage (%)	85.4	85.8	86.4	86.9
Served Population	574,200	615,800	659,400	703,600
Water Demand (m^3/d)	119,474	122,900	133,400	141,600

From above analysis it is seen that the current water demand is 119,474 m^3/d, whereas the current total production is estimated to be approximately 94,000 m^3/d, indicating already a 20 percent short production, which will aggravate further as some of the existing systems will have to be abandoned in the near future due to their unreliable nature of water sources.

The proposed augmentation is scheduled to be implemented in 3 phases, in steps of 36,670 m^3/d in each Phase, and the water balance will be as follows.

Description (m^3/d)	2005	2010	2015
Daily average water demand	122,900	133,400	141,600
Daily max. water demand	147,430	160,040	169,980
Continued existing sources	64,960	64,960	64,040
Deficit over demand in ave.	56,940	67,440	77,560
Deficit over demand in max.	82,470	95,080	105,940
Augmented supply by new plant	36,670	73,330	110,000
Deficit over demand after augmentation in ave.	20,270	(5,890)	(33,440)
Deficit over demand after augmentation in max.	44,800	20,750	(5,060)

Thus, it is seen that in 2005 a significant short supply of water will prevail despite implementation of Phase 1 Project. This will be improved with the implementation of Phase 2 in year 2010 in the daily average demand basis. The full advantage of the Project will only be realised in year 2015 with the implementation of the Phase 3 Project.

5. Proposed Water Supply System

The proposed source for the augmentation system i.e. the Mahaweli River at Gohagoda is acceptable both quantitatively and qualitatively, located at 4.1 km upstream of the Polgolla

Dam. The total designed capacity of the system is 110,000 m^3/d in Phase 3.

After completion of Phase 1 of the Project, water production capacity will be 36,670 m^3/d. However, water intake structure, main part of raw water transmission pipeline, and administrative common facilities will accommodate for Phase 3 capacity of 115,500 m^3/d, including for a five percent loss through the works. Transmission of clear water to Greater Kandy service areas under Phase 1 will be for Kahawatta, Madawala, Uduwawala, Gohagoda, and KMC service areas via Upland, Asgiriya, and Bahirawakanda reservoirs. Likewise, necessary distribution system expansions in the study areas will be covered under Phase 1.

Major facilities/equipment is summarises as shown below:

a) Intake : The designed capacity of intake structure is to be 115,500 m^3/d, Phase 3 and raw water pumps to deliver 38,500 m^3/d (or 446 l/s), Phase 1;

b) Raw water conveyance pipe : Pipes used for raw water transmission main from intake to treatment plant is consist of a 800 mm dia. pressure main up to Balancing Tank and a 1,000 mm gravity main with a total of approximately 1.6 km. The pressure main will accommodate only for the capacity of Phase 1. The gravity main will be for Phase 3.

c) Balancing tank : To be constructed in between raw water intake facility and water treatment plant with a capacity of Phase 3;

d) Treatment plant : Production capacity of 36,670 m^3/d, Phase 1 capacity;

e) Clear water pumps : Deliver 36,670 m^3/d, Phase 1 capacity;

f) Structure for the clear water pumping station, chemical building, administration building, etc. is accommodate for Phase 3;

g) Transmission main from treatment plant to service reservoirs : 41.536 km. of transmission system. DI pipes with diameters from 150 mm to 800 mm and uPVC pipes with diameters from 90 mm to 225 mm will be used;

h) 19 service reservoirs : Primrose service reservoir was excluded due to duplication with ADB Project;

i) Distribution pipelines : 27.98 km of distribution network. uPVC pipes with diameters from 90 to 225 mm and DI pipes with diameters from 100 to 500 mm will be used;

j) Communication and power supply to intake, pumping stations and treatment plant;

k) Plant and equipment necessary for operation and maintenance.

The raw water is taken from the Mahaweli River to the grit chamber through the intake mouth with the bottom elevation at 436.0 m AMSL. The lowest low water level is set at 437.6 m AMSL, 1.6 m above the riverbed. The low water level is set at 438.3 m AMS. The flood water level of the Mahaweli River at Gohagoda is estimated at 441.0 m AMSL. The ground level and motor floor level of the intake facilities is planned at 442.5 m AMSL (1.5 m above the high flood level) and 443.0 m MSL (2 m above the high flood level), respectively.

Raw water pumps lift the raw water up to the balancing tank at 476.0 m AMSL. Then the raw water is introduced by gravity to the receiving well/distribution chamber at the proposed Katugastota site.

The water level at the head end of the plant is set at 451.68 m AMSL at the distribution chamber, which provide sufficient hydraulic energy through the treatment processes up to the clear water reservoir level at 445.82 m AMSL. The planned finish ground level at the Katugastota Water Treatment Plant is 446.5 m AMSL.

Rapid sand filtration is employed as an optimum water treatment system for the Mahaweli River water source taking into consideration of water quality. Coagulation will be achieved though the hydraulic energy by the cascade generated by the weirs provided at the distribution chamber. Three sized vertical baffled channels will provide necessary hydraulic velocity gradient for flocculation varying from 10 to 70 s^{-1}. Horizontal flow sedimentation basins provide a quiescent environment that enables coagulated/flocculated particles of specific gravity heavier than water to settle to the bottom of the tank. Type of filter units will be a constant-rate filter with influent splitting and varying water level. The weirs installed at the entrance of each filter unit will automatically split the settled water evenly to each filter unit. The effluent weirs without any mechanical/electrical equipment will naturally regulate the filtration rate.

All of the equipment and facilities for chemical applications and chlorination are provided in the Chemical Building, which will be constructed near by the Administration Building for easy administration.

A two storey building is planned for administrative facilities as well as for storage, laboratory etc. Operation and maintenance staff members will be accommodated in this building or maintenance building. The layout of the facilities has been done in the most prudent manner, making best use of the orientation and the difference in ground levels of the available land.

Phase 1 Project will cover 11 different service zones through a total of 21 service reservoirs out side KMC area and 8 within KMC area, to facilitate supply of clear water to the Greater Kandy area, namely KMC area and its suburbs to the south, east and west by KMC WTP, and to supplement its short production at KMC's northern boundary, from the proposed Katugastota plant. All the remaining areas are to be served from the Katugastota Plant.

The elevation of the 19 new services varies from 485 to 713 m AMSL. 7 booster pump stations are newly constructed under the Project to enforce the lifting capacity.

6. Implementation Plan and Project Cost

NWSDB will be the agency responsible for the implementation under the supervision of the Ministry of Housing and Plantation Infrastructure.

The same Project Director who headed the PIU during detailed design should continue to supervise the construction works with the assistance of the consultants. The role of the PIU will consist of the management of project, coordination with other divisions of NWSDB and concerned organisations of GOSL, coordination of tendering procedure and implementation of examinations and investigations, which may become necessary under certain circumstances.

A consultancy contract for construction supervision and a construction contract with selected Japanese companies are to be concluded by NWSDB, with JBIC concurrence. The roles of various organizations connected with the implementation are set out in the Implementation Organization.

The selected construction contractor shall be an individual Japanese company with civil, mechanical and electrical capabilities, a joint venture or partnership of Japanese companies qualified in the three fields, a Japanese civil or mechanical/electrical contractor with Japanese or a Sri Lankan mechanical/electrical or civil sub contractor.

The construction period is determined to be 33 months of which 3 months are allocated for operation and maintenance assistance after completion of construction works. Thus the Works are scheduled to be commenced in early 2003 and completed in late 2005.

The total Project cost loaned by JBIC is 4,732 million Japanese Yen including the Civil Works and contingencies, while the estimated cost is approximately 4,995 million Japanese Yen, which exceeds the loaned cost by approximately 263 million Japanese Yen or 5.56 percent against the total of JBIC loan.

The costs for Japanese goods and services are estimated to be 3,123 million Japanese Yen or 58.53 percent of the total estimated costs, which satisfies the eligibility for Procurement Procedure of Loan Agreement.

The cost estimates still include 58.53 percent of Japanese services and goods. There is a possibility that during competitive tendering this difference may be levelled off at some certain percentage and the budgetary allocation would not be disturbed, provided that the Tenderer puts considerable efforts into reducing the price by optimising the procurement rate of Japanese goods to be 50 percent. One example shows that the total project cost estimated is approximately 4,728 million Japanese Yen and 50 percent of Japanese services and goods in assuming lower cost of small pipes and imported reinforcement.

7. RECOMMENDATION TOWARDS PROJECT IMPLEMENTATION

The overall construction period is estimated to be approximately 30 months after the award of contract issued. There are several factors causing for critical delays for the implementation programme such as land acquisition, approvals required from various authorities for buildings, structures and pipe laying, CEB power supply, securing of borrow areas. Hence, these issues need to be resolved expeditiously for the timely completion of the Project.

The activities that are vital for the timely implementation too have been identified for the three Phases. During the pre-construction phase it is mainly the liaison with the concerned authorities, namely RDA, CEA, UDA, Police, KMC and PSs to procure particular building/structure and pipe laying approvals necessary. Liaison with JBIC is necessary both before and after prequalification and tendering with the necessary documentations to receive its concurrence.

NWSDB will have to secure its budget to meet the expenses, which are essential, but left out in the Loan Agreement. These include general administration costs, taxes and duties, land acquisition, compensation and other expenses. In addition, securing of borrow fill areas, sludge disposal sites, garbage removal from the Gohagoda site are as well priority requirements. Likewise, it is unpredictable in advance if the tendering will be successful or not, due to the cost overrun against the loaned amount, NWSDB may have to consider re-tender with adjustment of scope of works, unless otherwise NWSDB would secure the counterpart fund increased.

It should also not be forgotten that although the water quality of the Mahaweli River is currently acceptable as the source of water with the type of treatment proposed, there is a potential risk of the quality of water deteriorating in the future due to enhancement of various activities causing pollution, which will further aggravate during the dry seasons when the flow drops very low.

During the Construction Phase NWSDB has to finalise its organisation set up for the operation and maintenance of the Project after completion. This includes procurement of well experienced and responsible O & M staff, and training them not only in operation of the plant but also in preventive maintenance to guarantee the smooth, efficient and trouble free operation over its full designed lifetime. Apart from it, NWSDB will have to secure the budget necessary to meet the O & M cost after commissioning.

During post construction phase preventive maintenance will play the major role to guarantee the full life span of the Project. The O & M manuals prepared by the consultants and the training given to the staff during pre-construction period will be of immense benefit to achieve the desired objectives. Nevertheless, despite enforcement of proper preventive maintenance procedures, after long years of operation of equipment, facilities and integrated systems may deteriorate, and may require large scale rehabilitation/improvement programmes in order to restore them to their original condition or to upgrade their efficiency. Thus, NWSDB must secure the depreciation budget to meet such costs in future.

Scope of Works of Detailed Design

No.	Description	Original Scope of Works		Proposed Scope of Works	
		Specifications	Nos.	Specifications	Nos.
1.	**Construction of Intake facilities and Raw Water Transmission facilities**			←(no change)	
1)	- Intake structure	38,500 m^3/day	L.S.	←	←
2)	- Pumping station	Q=446 l/s, H=50m	2 sets	←, H=44m	←
3)	- Water conveyance pipeline	DCIP ø 800	2.200m	ø 800, ø 1000	1049m, 442 m
2.	**Construction of Water Treatment Plant**				
	(Coagulation and rapid sand filtering system)	36,670 m^3/d	L.S.	←	←
3.	**Construction of Water Transmission Facilities**				
	- Pump facilities (including one stand by each)				
1)	KMC WTP – Primrose	Q=23 l/s, H=168m	3 sets	Cancelled	
2)	Heerassagala low – Heerassagala middle	Q=12 l/s, H=63m	2 sets	Q=31.7 l/s, H=68 m	←
3)	Heerassagala middle – Heerassagala upper	Q=12 l/s, H=73m	2 sets	Q=8.1 l/s, H=77 m	←
4)	Ampitiya – Elhena	Q=12 l/s, H=55m	2 sets	Q=13.8 l/s, H=45 m	←
5)	Ampitiya – Mullepibilla low	Q=8 l/s, H=78m	2 sets	Q=11.3 l/s, H=145 m	←
6)	Ampitiya – Meekanuwa	Q=9 l/s, H=66m	2 sets	Q=24.8 l/s, H=73 m	←
7)	Kahawatta – Kurugoda	Q=32 l/s, H=75m	2 sets	Q=49.0 l/s, H=65 m	←
8)	Kondadeniya sump – Kondadeniya (augmentation)	Q=45 l/s, H=145m	2 sets	Combined with Upland system	
9)	Kondadeniya – Kulugammana			Q=18.5 l/s, H=64 m	2 sets
10)	Asgiriya Bahirawakanda	Q=78 l/s, H=45m	2 sets	Q=26.3 l/s, H=68m	←
11)	R2 – Hantana Place	Q=18 l/s, H=94 m	3 sets	Q=22.6 l/s, H=102 m	2 sets
12)	Katugastota WTP – Kahawatta	Q=238l/s, H=103m	2 sets	Q=166.5 l/s, H=93m	←
13)	Katugastota WTP – Kondadeniya sump	Q=45 l/s, H=5m	2 sets	Combined with Upland system	
14)	Katugastota WTP – Gohagoda	Q=30 l/s, H=112m	3 sets	Q=68.0 l/s, H=104 m	2 sets
	Katugastota WTP – Upland	Q=282 l/s, H=160m	3 sets	Q=203.71l/s, H=137 m	2 sets
	-Transmission pipelines				
	Service area of Proposed Katugastota Plant	DI ø 150	0 m		0 m
		ø 200	0 m		3,940 m
		ø 250	0 m		4,624 m
		ø 300	4,150 m		4,605 m
		ø 350	700 m		4,309 m
		ø 400	1,400 m		2,020 m

		ø 500	6,350 m		4,390 m
		ø 600	3,080 m		3,272 m
		ø 700	2,950 m		1,850 m
		ø 800	0 m		415 m
		PVC ø 110	1,750 m		0
		ø 225	15,500 m		492 m
		Sub Total Length	**35,880 m**		**29,917 m**
	Service area of KMC	DI ø 150	0 m		1,972 m
		ø 200	1,200 m		4,539 m
		ø 300	0 m		1,782 m
		ø 350	0 m		1,002 m
		PVC ø 90	0 m		149 m
		ø 140	900 m		0 m
		ø 160	8,335 m		767 m
		ø 225	2,280 m		1,457 m
			12,715 m		**11,668 m**
		Total Length	**48,595 m**		**41,585 m**
	- Distribution Pipelines	**Total Length**	**24,000 m**		**27,687 m**
4.	**Construction of Distribution Facilities**				
	- Reservoirs				
1)	Kahalla		323 m^3		600 m^3
2)	Bangalawatta		298 m^3		300 m^3
3)	Pihilladeniya		248 m^3		200 m^3
4)	Kahawatta		1,174 m^3		600 m^3
5)	Kurugoda		535 m^3		600 m^3
6)	Telambugahawatta		124 m^3		500 m^3
7)	Kulugammana (augmentation)		111 m^3		100 m^3
8)	Kondadeniya (augmentation)		384 m^3		200 m^3
9)	Gohagoda		207 m^3		200 m^3
10)	Bahirawakanda (augmentation)		1,595 m^3		600 m^3
11)	Upland		2,728 m^3		2,960 m^3
12)	Primrose (augmentation)		315 m^3	Cancelled	
13)	Heerassagala low		198 m^3		200 m^3
14)	Heerassagala middle		248 m^3		250 m^3
15)	Heerassagala upper		248 m^3		200 m^3
16)	Dangolla (augmentation)		254 m^3		500 m^3
17)	Hantana place		248 m^3		200 m^3

(Continued)

18)	Asgiriya		3,059 m^3		4,100 m^3
19)	Elhena		248m^3		300 m^3
20)	Mullepihilla low (augmentation)		79 m^3		100 m^3
	-Total Volume		**12,624 m^3**		**12,710 m^3**
	- Appropriate distribution networks		L.S.		←
5.	**Procurement of maintenance equipment**				
1)	Water quality analysis equipment		L.S.	←	←
2)	Leakage detection equipment		L.S.	←	←
3)	Truck with loading crane etc.		L.S.	Backhoe	←

THE DETAILED DESIGN STUDY ON
GREATER KANDY WATER SUPPLY AUGMENTATION PROJECT
IN
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

VOLUM I
SUMMARY REPORT

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Abbreviations and Acronyms

1. Unit

cm	centimeter
ft.	foot
g	gram
gpcd	gram per capita per day
ha	hectare (1 ha = 10,000m^2)
hr	hour
kg	kilogram
km	kilometer
km^2, or sq.km	square kilometer
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
l, or L	liter
l/day, or l/d	liter per day
l/sec, or l/s	liter per second
lpcd, or Lpcd	liter per capita per day
m	meter
m/s, or m/sec	meters per second
m^2, or sq.m	square meter
m^3, or cu.m	cubic meter
m^3/d, or cu.m/day	cubic meter per day
m^3/min	cubic meter per minute
m^3/s, or cu.m/sec	cubic meter per second
MCM	million cubic meter
mgd	million gallons per day
mg/l	milligram per liter
mm	millimeter
Mpa	megapascal
ppm	parts per million
Rs.	Sri Lankan Rupee
V	volt

2. Water Quality

BOD_5	Biochemical Oxygen Demand (20°C, 5 days)
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
pH	Hydrogen ion potential
SS	Suspended Solids
TS	Total Solids

3. Organizations

ADB	Asian Development Bank
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CPC	Central Provincial Council
FINNIDA	Finnish International Development Agency
GS	Gramasevaka Divison (local administrative unit)
IBRD	International Bank for Reconstruction and Development (World Bank)

ICC	Interagency Co-ordinating Committee
IDA	International Development Association (soft loan facility of IBRD)
IMF	International Monetary Fund
JBIC	Japan Bank for International Cooperation (Japan)
JICA	Japan International Cooperation Agency (Japan)
KMC	Kandy Municipal Council
MASL	Mahaweli Authority of Sri Lanka
MHUD	Ministry of Housing and Urban Development
MOF	Ministry of Finance
MSL	Mean Sea Level
NJS	Nippon Jogesuido Sekkei Co., Ltd.
NSC	Nihon Suido Consultants Co., Ltd.
NWSDB, or NWS&DB	National Water Supply and Drainage Board
OECD	Organization for Economic Cooperation and Development
PS	Pradeshiya Sabha (local administrative unit)
RDA	Road Development Authority
RSC	Regional Support Center, NWSDB
UC	Urban Council
UDA	Urban Development Authority

4. Others

BOT	Build - Operate - Transfer
BWL	Bottom Water Level
CED	Central Environmental Division
CPI	Consumer Price Index
EAC	Environmental auditing Commission
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
FY	Fiscal Year
GDP	Gross Domestic Product
GL	Ground Level
GNP	Gross National Product
GST	Government Sales Tax
HWL	High Water Level
HH	Household
IEE	Initial Environmental Examination
LWL	Low Water Level
L/S	Lift Station
NGO	Non-Governmental Organization
NRW	Non-revenue Water
ODA	Official Development Assistance
PEU	Project Environmental Unit
P/S	Pumping Station
SLS	Sri Lankan Standards
STP	Sewage Treatment Plant
T.A	Technical Assistance
TWL	Top Water Level
UFW	Unaccounted-For-Water
VAT	Value Added Tax
WID	Women in Development
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant (=STP)

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

1. Background of the Study

The Greater Kandy (area:460km^2, population: approximately 700,000) with a centre in Kandy City, which is the second biggest city in Sri Lanka, has been recently facing the rapid growth in population. The water demand exceeds the water supply capacity largely and the increase in water supply capacity through the provision of water supply facilities is an urgent matter in the area.

With such a background, the Japan International Cooperation Agency (hereinafter referred to as “JICA”) conducted the Study on Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Plan in the Democratic Republic of Sri Lanka (formulation of master plans for water supply and sanitation/sewerage development and feasibility study for the priority projects) since February 1998 and proposed the implementation of the priority projects for water supply (water treatment plant and water distribution system) and sewerage (sewage treatment plant and sewage collection system) in February 1999.

Upon receipt of the report, for the water supply facilities proposed as the priority project in the above study, the Government of Sri Lanka, requested the assistance for the detailed design which directly links to the financial loan by the Japanese.

In response to this request, JICA decided to conduct the detailed design study for the Greater Kandy water supply augmentation project and dispatched the Study Team to Sri Lanka from January 2001 to March 2002. The Study was completed in May 2002 upon submission of the Final Report.

1.2 Objective of the Study

The objectives of the Study are:

1. To conduct a detailed design in order to prepare the tender documents of the following facilities in collaboration with Greater Kandy Water Supply Augmentation Project financed by Japan Bank for International Cooperation (hereinafter referred to as "JBIC") in response to the request of the Government of Sri Lanka.

   a. Intake facilities

b. Water treatment plant
c. Transmission pumping stations
d. Transmission pipelines
e. Distribution facilities

2. To pursue technology transfer to the counterpart personnel in the course of the Study.

1.3 Scope of the Work

In order to achieve the objectives mentioned above, the Study will cover the following:

1. Preliminary study
   a. Collection and analysis of the related data and information
   b. Review on contents of feasibility study, "the Study on Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Plan in the Democratic Socialist Republic of Sri Lanka (1999) "
2. Site investigation
   a. Topographical survey
   b. Level survey
   c. Soil investigation
3. Basic design
4. Detailed design
5. Cost estimation
6. Implementation schedule
7. Preparation of draft pre-qualification documents and drafts tender documents in conformity with "the Guidelines for Procurement under JBIC Loans"

1.4 Formation of the Study

1.4.1 General

The Study was carried out in accordance with the Scope of Work agreed upon between the MHUD (present MH&PI) and JICA on September 2000. The MH&PI had organized the national steering committee and counterpart team, and accomplished the Study in close cooperation with the Study Team. The overall set-up for the implementation of the Study is as shown in Figure 1.1.

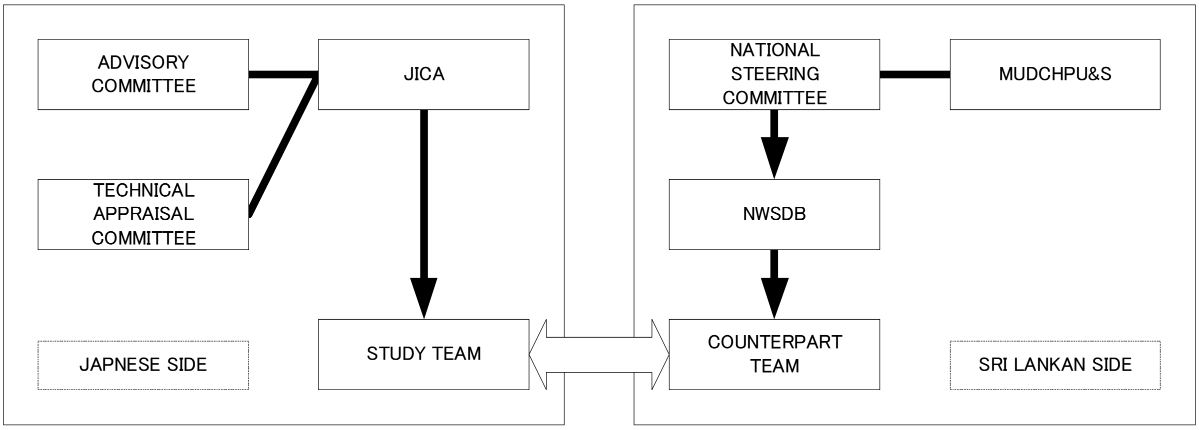


Figure 1.1 Implementation Set-up of the Study

1.4.2 Implementation Set-up of Japanese Side

The implementation set-up of the Japanese side consisted of the Study Team and the Advisory Committee and Technical Appraisal Committee under the general supervision of the JICA headquarters.

The composition of the JICA Advisory Committee is shown below:

Mr. Yoshiki OMURA	Chairperson	Institute for International Cooperation, JICA

The composition of the Technical Appraisal Committee is shown below.

Mr. Junji TADA	Team Leader	IDI
Dr. Toshikatsu OMACHI	Facilities Design	IDI
Mr. Jun IWASAKI	Transmission & Distribution Design	IDI
Mr. Hiroo ODA	Construction Methods & Tender Documentation	IDI

IDI: Infrastructure Development Institute

The composition of the Study Team is shown below.

Mr. Ikuo MIWA	Team Leader	NJS
Mr. Shigeo SAWAI	Water Treatment Plant	NJS
Mr. Yoshihiko SATO	Civil Eng.	NJS
Mr. Shigenori OGAWA	Architectural Eng.	NJS
Mr. Shinichi OSAKA	Mechanical Eng.	NJS
Mr. Akira MIURA	Electrical Eng.	NJS

Mr. Loranjana JAYAWARDENA	Structural Analysis	NSC
Mr. Hideki KONDO	Transmission & Distribution Planning	NSC
Mr. Junichi WATANABE	Distribution Network Analysis	NSC
Mr. Taketoshi Fujiyama	Transmission & Distribution Design	NSC
Mr. Koichi OKAZAKI	Transmission & Distribution Design	NSC
Mr. John M. McGill	Sewerage Planning	NJS
Dr. Kugaprasatham SIVAPRAGASAM	Water Pollution Analysis & EIA	NSC
Mr. Kazuhisa OGAWA	Water Quality & Water Treatment	NJS
Mr. Wijayasiri TILAKUMARA	Sanitary Environment Study	NSC
Mr. Ryosuke ITO	Topographic Survey	NSC
Mr. Akio KABASAWA	Cost Estimation	NJS
Mr. Michael R. SOULSBY	Tender Document Preparation	NJS

NJS: NJS Consultants Co., Ltd.

NSC: Nihon Suido Consultants Co., Ltd

1.4.3 Implementation Set-up of Sri Lanka Side

The implementation set-up of Sri Lanka side consists of the MH&PI, the NWS&DB, NWS&DB counterpart personnel, and the National Steering Committee for the Study composed by representatives from authorities concerned. Overall coordination of the National Steering Committee was handled by the MH&PI.

The National Steering Committee was organized by following representatives of relevant authorities.

Ministry of Housing and Plantation Infrastructure

Mr. A. S. Gunasekera	Secretary
Mr. L. W. Jirasinghe	Additional Secretary (Technical)
Mr. M. I. Abdul Latiff	Deputy Director, water Sector

Ministry of Finance

Mr. J. H. J. Jayamaha	Director, External Resources
Mrs. S. Cooray	Director, External Resources
Mr. A. Ranasinghe	Asst. Director, External Resources
Mr. Shinichiro Omote	JICA Expert, External Resources

Central Provincial Council

Mr. S. B. Wijekoon	Chief Secretary

Kandy Municipal Council

Ms. J. C. Bulumulla	Municipal Commissioner
Mr. P. B. Abeykoon	Chief Waterworks Engineer

National Water Supply and Drainage Board

Mr. M. L. A.M. Hizbullah	Chairman
Mr. S. Weeraratna	General Manager
Mr. W. Wicramage	Addl. G.M.
Mr. S. R. J. R. Senanayake	Addl. G.M., Planning and Monitoring
Mr. K. M. N. S. Fernando	Addl. G.M., XXXXX
Mr. S. A. S. de Silva	Addl. G.M., Regional Operations
Ms. T. P. Lamabadusooriya	D.G.M., Planning and Design
Mr. B. W. R. Barasooriya	D.G.M., RSC-Central
Mr. D. N. J. Ferdinando	A.G.M., Japanese Project Unit
Ms. M. K. Bandara	A.G.M., Planning and Design
Mr. Hirokatsu Asakawa	JICA Expert on Water Supply
Mr. Tamaki Mori	JICA Expert on Sewerage

Counterpart personnel were shown below.

Mr. P. H. Sarath Gamini	Act. Project Director/A.G.M., Planning and Design, NWSDB
Mr. Lester Perera	Deputy Project Director, NWSDB

1.5 Organization of the Reports

The reports of the Study in the English language were compiled in the following five volumes:

Vol. I	Summary Report
Vol. II-1	Main Report (1)
Vol. II-2	Main Report (2)
Vol. III	Data & Attachments

(Draft) Tender Documents

Vol. 1	Pre-qualification Documents and Conditions of Contarct
Vol. 2A	Particular Specifications
Vol. 2B	Standard Specifications (1)
Vol. 2C	Standard Specifications (2)
Vol. 3	Bill of Quantities

Vol. 3	Bill of Quantities (with Price)
Vol. 4B	Drawings (Mechanical and Electrical Equipment)
Vol. 4C	Drawings (Transmission and Distribution Pipes)
Vol. 4D	Drawings (Service Reservoirs)
Vol. 4E	Drawings (Transmission Pipes along the Wattegama Road)

Vol. I, the Summary Report presents an overview of the major study results. Vol. II-1, the Main Report (1) presents the results of the review of F/S as proposed in the previous JICA Report, while Vol. II-2, the Main Report (2) indicates the contents of the detailed design. Vol. III, Data and Attachments contain detailed discussions, appendices, and hydraulic distribution network analysis, process and hydraulic calculations of different facilities and equipment. Etc. The (draft) tender documents compile the documents and drawings prepared by the Study Team, in accordance with the finally adopted contract packages. Out of the tender documents, only Vol. 4E is for the separate contract package of pipe laying works along the Wattegama Road and all others are for Construction Works for Greater Kandy Augmentation Project. The organizational structure of the reports requires to repeat certain portions in different volumes.

CHAPTER 2 PLANNING FUNDAMENTALS

2.1 Locations of Water Supply and Sewerage Facilities

In the previous JICA Report, the water intake is located downstream of the outfall of the proposed sewage treatment plant, which is justified at present from the following reasons:

2.1.1 Topography of Kandy City

The core of Kandy City is surrounded by the triangular mountains, and its entrances are located at each apex of a triangle and at the valley on the eastern mountains. The elevation of each entrance is approximately 520 m north (A10 Road), 540 m east (A26 Road), 580 m south (B39 Road) and 470 m west (A1 Road), respectively. The Meda Ela (Meda River) originates from Kandy Lake, flows southwestwards along the Colombo – Kandy Road (A1) and pours into the Mahaweli River. The urbanization of the City has already expanded to the north, east and south entrances and has been developing southwestwards along the Meda Ela. There are few flat areas with some extent, for example to accommodate a sewage treatment plant, due to its complexity of topography except for the area along Colombo – Kandy Road, which has a relatively gentle slope. The black areas with queer configurations in Figure 2.1 show mostly the valleys or low-lying areas (rarely swamps) and are generally used for paddy fields. It is obvious that there are less valley areas in Kandy city core in comparison with its surrounding areas.

2.1.2 Location of a Water treatment Plant

The location of a water treatment plant is selected in principle based on the approximation between the water source and the water demand area. The farer the distance between the water source and the water demand area, the more the initial investment to water intake and transmission facilities, which lead to the increase in the water rate.

In consideration of the extent available for a water treatment plant, the possible sites were short-listed based on aerial photographs and topographical maps with a scale of 1 to 10,000. The field survey was conducted to assess the adaptability to a water treatment plant, reality in land acquisition and other various aspects and Katugastota site was finally selected for a water treatment plant. Figure 2.1 shows the relative locations of alternative sites and Figure 2.2 presents the present situation of each site using the aerial photograph and topographical map. The results of the comparative study are summarized as shown in Table 2.1.

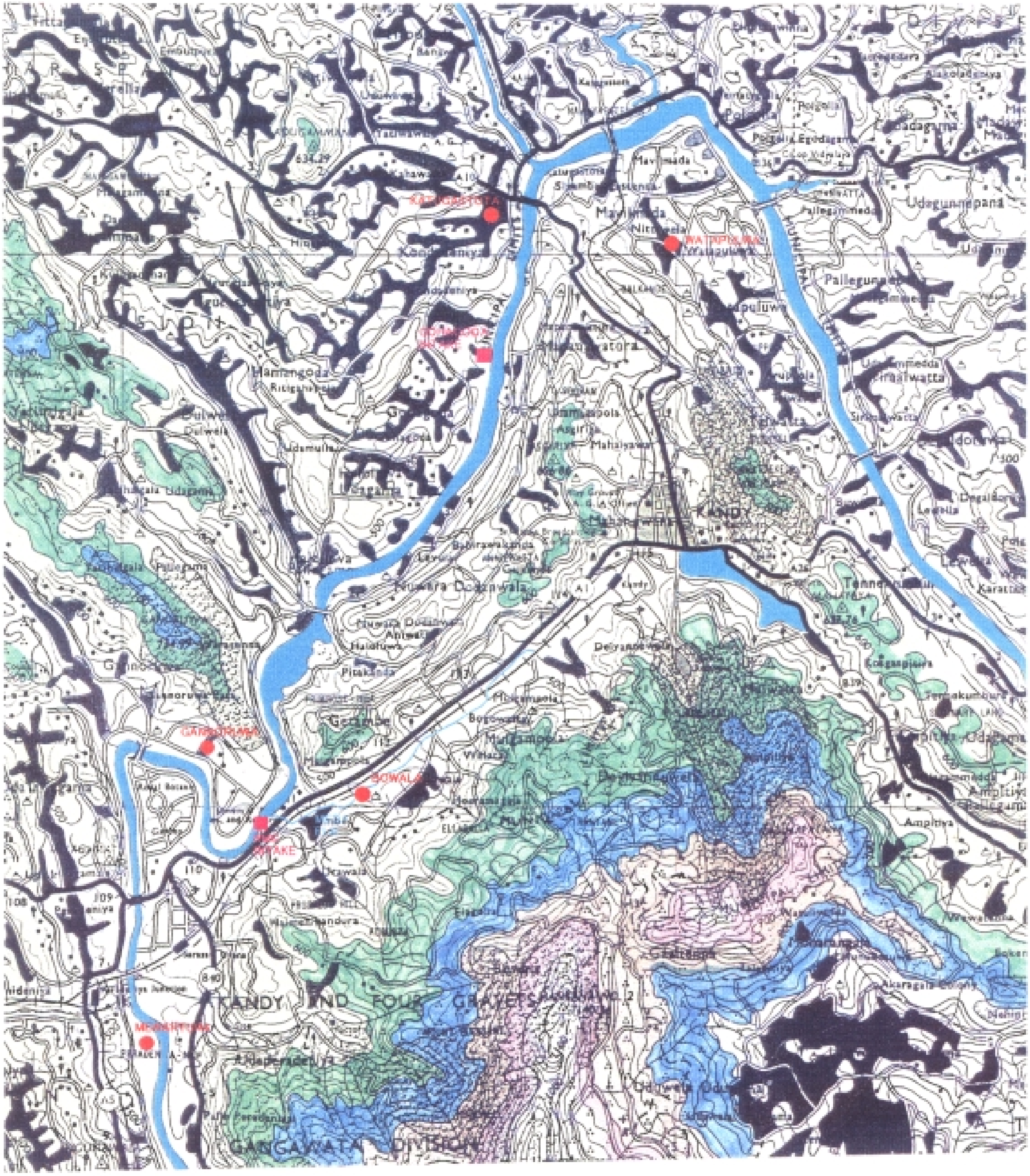
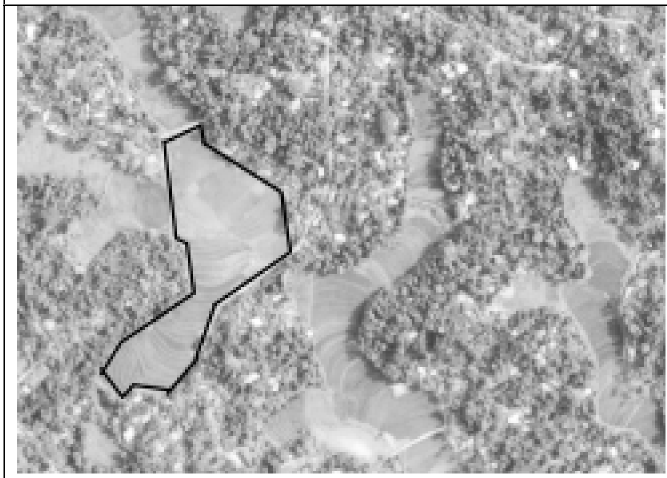
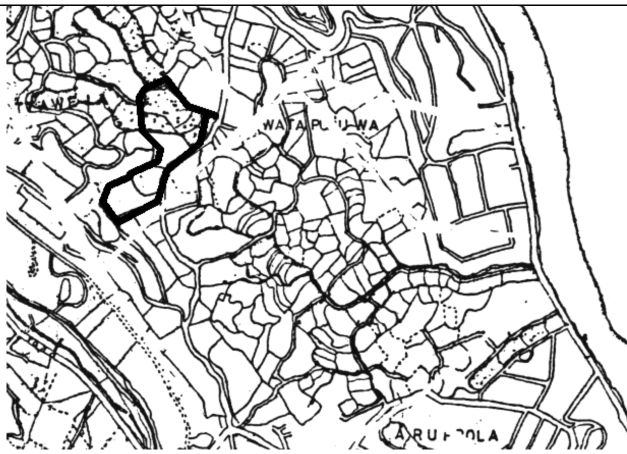


FIGURE 2.1 ALTERNATIVE SITES FOR A WATER TREATMENT PLANT

FIGURE 2.2 SITE ALTERNATIVES FOR A WATER TREATMENT PLANT

Alt. 1 : Watapuluwa





Alt. 2 : Bowala

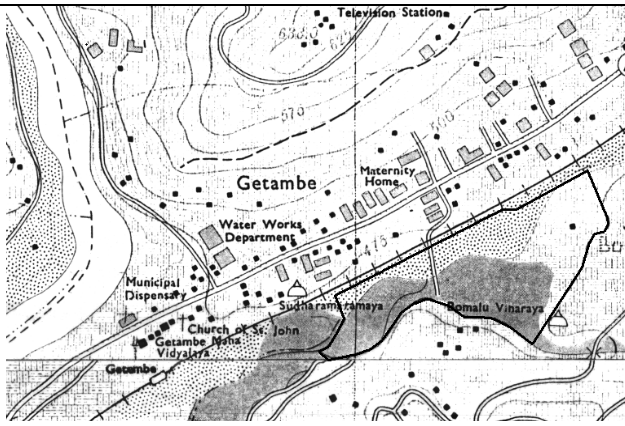
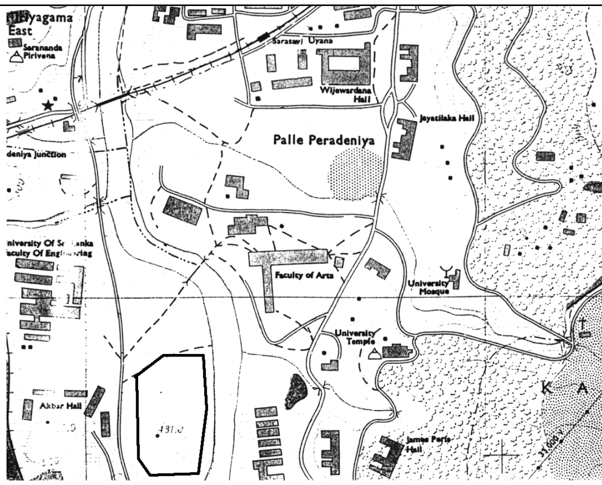
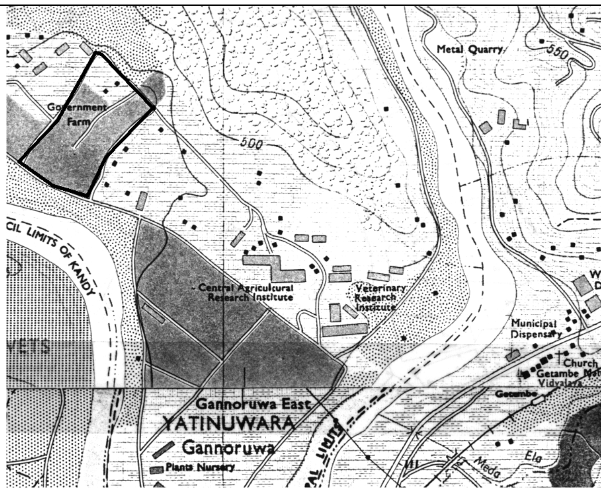


FIGURE 2.2 SITE ALTERNATIVES FOR A WATER TREATMENT PLANT (Cont'd)

Alt. 3 : Mewartura



Alt. 4 : Gannoruwa



Alt. 5 : Katugastota

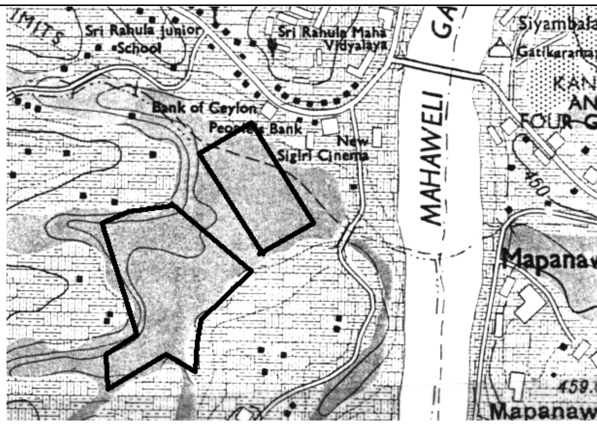


Table 2.1 Comparison of Altertive Sites for A Water Treatment Plant

WRP site	Mewartura	Gannoruwa	Bowala	Katugastota	Watapuluwa
Intake site		Getambe	Getambe	Gohagoda	Polgolla
Landqwner	Peradeniya Univ.	Ministry of Agriculture	Private	Temple	Private
Present land use	Farm	Farm (partly fallow field)	Vacant	Fallow field	Paddy field
Future land use	The Science Park Plan is going on		The legal complex is under construction at the adjoining area. The area has possibility of developmentby UDA.		
Necessity for intake weir	Yes	Yes (The construction of an independent intake weir will be difficult in obtaining the permission from the Mahaweli authoriy due to the zigzag course of the river in this section. It is considered to elevate the existing intake weir for joint use.	Yes (It is considered to elevate the existing intake weir for joint use.)	No	See "Assessment"
Relationship between proposed intake and wastewater	Upstream of the confluence with the Meda Ela	Upstream of the confluence with the Meda Ela	Upstream of the confluence with the Meda Ela	Downstream of the confluence with the Meda Ela	Upstream of the confluence with the Meda Ela and pinga Oya
Extent of site	almost flat area, adequate	almost flat area, adequate	Depressed area, small	almost flat area, The layout is so tight due to existence of the temple in the center.	almost flat area, adequate
Distance from water demand area	Far	Slightly far	Slightly far	Near	Near
Environmental issue	The natural buffer zone is formed by the A5 Road and Mahaweli River. There are two institutions in the corner.	There are quarters in the particular site as well as in the surrounding area. The former requires the resettlement.	Facing the new Colombo - Kandy Road.	Temple in the center of the particular site	
Other specifications		Gannoruwa is the old battle field that the Kandy Kingdom defeated the invaded Portuguese army in 16 A.C.			

Mewartura

There is no possibility of land acquisition due to on-going other project in the particular site

Gannoruwa

(1) The existing KMC intake weir is simply made of the sheet piles that were driven by near the riverbed level and has little effect to raise the river level. In case of raising this existing intake weir so as to function properly and constructing the new intake tower, the Mahaweli Authority may require the elaborate study based on the hydraulic model experiment and the simulation analysis, since the Mahaweli River flows zigzag in this section and get narrow suddenly 600 m downstream of the Getambe Bridge. The 1978 flood occurs before this sudden sectional reduction of the Mahaweli River.

(2) It is necessary to pump up the sludge generated in the water treatment plant to discharge the Mahaweli River down stream of the KMC intake.

Bowala

(1) The previous F/S study revealed that a treatment capacity of 20,000 m3/day was available in the particular site, which is below the Phase I requirement and needs another WTP.

Katugastota (Gohagoda Intake)

(1) The downstream of the suspension bridge becomes the storage zone of the Polgolla Dam in which the fluctuation of the Mahaweli River in quantity and quality is largely mitigated, as it functions as the giant sedimentation tank.

(2) It is possible to take surface water directly from the Mahaweli River by constructing the intake mouth on the riverbank, since a certain river level is kept without a intake weir in the storage zone at the ordinary time.

(3) The Mahaweli River has a flow of approximately 100 times that of the Meda Ela on the median flow and is little affected by the Meda Ela in terms of water quality at the ordinary time.

(4) The proposed Katugastota Water Treatment Plant site has appropriate elevation and slope which make the sludge discharge by a gravity flow possible

Watapuluwa

(1) The Watapuluwa site is located downstream of the confluence of the Meda Ela, Pinga Oya and the watercourse from the Gohagoda garbage dumping site and there is no advantage exceeding the Gohagoda site in water quality.

(2) The surrounding road network requires the development to install the raw water transmission pipes clear water transmission pipes and wastewater discharge pipes due to their present narrowness, which leads to the difficulty in private land acquisition.

(3) When taking surface water from the Polgolla Dam, the type will be the intake tower. When some of ten gates of the Polgolla Dam will be opened to discharge the settled silt for dam maintenance, the partial flow will be induced in the river as well as the drop in water level, which make the water intake unstable.

(4) In case of the intake from downstream of the Polgolla Dam, the intake weir is dispensable due to the difficulty in subsoil water intake, since there is a exposed rocky riverbed.

From the suspension bridge 2.1 km downstream of the confluence with the Meda Ela, the River enters the storage zone of the Polgolla Dam and the proposed Gohagoda intake for the Katugastota Water Treatment Plant is located further 3.4 km downstream of the suspension bridge. The storage zone functions as a giant sedimentation basin to mitigate the fluctuation in quantity and quality of the River flow. It is possible to take water directly through the intake mouth to be constructed on the riverside, as a certain stable river level is kept in the storage zone at the ordinary time. The flow of the Mahaweli River is 23.68 m3/sec (2,046,999 m3/day) at the median equivalent to approximately 100 times the flow of the Meda Ela. Hence, there is little influence of the Meda Ela on the water quality of the Mahaweli River.

In the Master Plan for Greater Kandy Water Supply Augmentation Project, a design flow of 110,000m^3/day is allocated to the nothern Greater Kandy by 58,900 m^3/day and KMC and thesouthern Greater Kandy by 51,100m^3/day. The KMC Water Treatment Plant with a capacity of 33,400m^3/day does not afford to cover the nothern Greater Kandy, therefore almost a half of water intake will have to be transported to the pump station to be located near the proposed Katugastota Water Treatment Plant site for water supply to the particular area in each alternative. In the Gannoruwa Alternative, a half of water intake is pumped to Bahirawakanda, Asgiriya and Uplands Service Reservoirs, while the reminder is conveyed to the above Katugastota Pump Station. In comparison with the Katugasutota Alternative, it is double in length and triple in construction cost and has no economical advantage, as shown in Table 2.2. The Watapuluwa Alternative is also longer and more expensive than the Katugastota Alternative.

As a conclusion, it is recommended to construct the intake facilities at the Gohagoda site and transmit the raw water to the Katugastota Water Treatment Plant by pumping.

Table 2.2 Construction Cost Comparison

DI	Size	Unit Cost	Watapuluwa Alternative		Gannoruwa Alternative		Katugastota Alternative	
	Dia. (mm)	(Rs.)	(m)	(Rs.1000)	(m)	(Rs.1000)	(m)	(Rs.1000)
Pressure	250	8,550	4,750	40,613	750	6,413	4,750	40,613
	400	15,040	1,150	17,296	2,900	43,616	2,070	31,133
	500	20,044	3,710	74,363	3,280	65,744	3,710	74,363
	600	23,206	920	21,350			570	13,227
	700	30,184	1,750	52,822	430	12,979	1,400	42,258
	800	43,127	400	17,251	16,490	711,164	650	28,033
	900	50,608	360	18,219				
Gravity	900	50,608	1,490	75,406	2,030	102,734		
	合計		14,530	317,320	25,880	942,650	13,150	229,627

Note: The cost includes the pipe laying cost for the raw water and clear water transmission pipelines to the proposed Katugastota Pump Station for water supply to northern Greater Kandy, but excludes the construction cost of the water intake and water treatment oplant, which are common to each alternative.

2.1.3 Location of a Sewage Treatment Plant

The sewerage system is designed in principle based on the gravity flow and collect the sewage in the form similar to the flow of the Meda Ela and its tributaries to the sewage treatment plant running on the New Colombo – Kandy Road in parallel with the Meda Ela. The Bowala site that was studied initially in the previous JICA study is situated along the Meda Ela and was provably only one possible place for a sewage treatment plant in the Kandy city core. When this place was cancelled by the strong opposition of the surrounding residents, but not the landowner, the NWS&DB was forced to look for the alternative sites outside the city core (see Figures 2.3 and 2.4).

Downstream of the Polgolla Dam

To protect the wastewater from being discharged into the Meda Ela, namely, not to discharge the wastewater upstream of the proposed Gohagoda Intake, it is necessary to find the site for a sewage treatment plant across the northern, eastern or southern pass mentioned above and discharge the STP effluent to the downstream of the Polgolla Dam. However, the land with an extent enough for a sewage treatment plant is only available at the valley in Watapuluwa near the Polgolla Dam, to which the sewage has to go over the northern pass on the A10 Road with an elevation of 520 m. As an elevation of the

As a conclusion, it is recommended to construct the intake facilities at the Gohagoda site and transmit the raw water to the Katugastota Water Treatment Plant by pumping.

Table 2.2 Construction Cost Comparison

DI	Size	Unit Cost	Watapuluwa Alternative		Gannoruwa Alternative		Katugastota Alternative	
	Dia. (mm)	(Rs.)	(m)	(Rs.1000)	(m)	(Rs.1000)	(m)	(Rs.1000)
Pressure	250	8,550	4,750	40,613	750	6,413	4,750	40,613
	400	15,040	1,150	17,296	2,900	43,616	2,070	31,133
	500	20,044	3,710	74,363	3,280	65,744	3,710	74,363
	600	23,206	920	21,350			570	13,227
	700	30,184	1,750	52,822	430	12,979	1,400	42,258
	800	43,127	400	17,251	16,490	711,164	650	28,033
	900	50,608	360	18,219				
Gravity	900	50,608	1,490	75,406	2,030	102,734		
	合計		14,530	317,320	25,880	942,650	13,150	229,627

Note: The cost includes the pipe laying cost for the raw water and clear water transmission pipelines to the proposed Katugastota Pump Station for water supply to northern Greater Kandy, but excludes the construction cost of the water intake and water treatment oplant, which are common to each alternative.

2.1.3 Location of a Sewage Treatment Plant

The sewerage system is designed in principle based on the gravity flow and collect the sewage in the form similar to the flow of the Meda Ela and its tributaries to the sewage treatment plant running on the New Colombo – Kandy Road in parallel with the Meda Ela. The Bowala site that was studied initially in the previous JICA study is situated along the Meda Ela and was provably only one possible place for a sewage treatment plant in the Kandy city core. When this place was cancelled by the strong opposition of the surrounding residents, but not the landowner, the NWS&DB was forced to look for the alternative sites outside the city core (see Figures 2.3 and 2.4).

Downstream of the Polgolla Dam

To protect the wastewater from being discharged into the Meda Ela, namely, not to discharge the wastewater upstream of the proposed Gohagoda Intake, it is necessary to find the site for a sewage treatment plant across the northern, eastern or southern pass mentioned above and discharge the STP effluent to the downstream of the Polgolla Dam. However, the land with an extent enough for a sewage treatment plant is only available at the valley in Watapuluwa near the Polgolla Dam, to which the sewage has to go over the northern pass on the A10 Road with an elevation of 520 m. As an elevation of the

Getambe Pump Station to which the wastewater will be concentrated is 470 m, it means to pump backwards the wastewater collected from an elevation of 535.5 m by an elevation gap of 65 m, which is wasteful from the energy-saving viewpoint. In the city core, a variety of underground public utilities are congested along the main roads, there is little room to install the 500 mm force main additionally beside the ordinary sewers. Furthermore, the road network has not yet been developed in the Watapuluwa area which has only the width for vehicles just to come and go . The many steep and winding roads will be another trouble for sewer laying.

Right Bank of the Mahaweli River

On the right bank of the Mahaweli River that the Meda Ela joins, the mountains are close to the Mahaweli River and there is no proper sites for a sewage treatment plant between the Getambe and Katugastota Bridges. The possible site is located behind the veterinary hospital in Getambe, which is the depressed area with a steam connecting to the Mahaweli River 200 m away. The filling of the land is required to protect the site from flooding, however even though done so, its extent is still small and it is necessary to consider the separate treatment of sewage and sludge at the different sites. The biggest disadvantage of the site is that there are the university hospital and dormitories, temple and residents around the site, which may cause the strong opposition of residents and stakeholders at the time of project implementation.

Left Bank of the Mahaweli River

There are three alternative sites on the left bank of the Mahaweli River as described below.

The Mewartura site is the farm of the Faculty of Agriculture, Peradeniya University and is surrouded by A5 Road and the Mahaweli River which form the natural buffer zone. It has enough space and good condition for a sewage treatment plant. However, the site is located 4.6 km away from the Getambe Pump Station and has necessity to extend its effluent pipe to at least the downstream of the Getambe Bridge to avoid the effluent discharge at the upstream of the KMC intake. In addition, the Science Park Project is planned at the particular site and there is no possibility of land acquisition.

The Gonnoruwa site, which is owned by the Ministry of Agriculture and used for a pilot firm, has a flat area sufficient for the arrangement of sewage treatment facilities. The site for a sewage treatment plant always faces the opposition of its surrounding residents unavoidably, but this site is surrouded by mountains north and other pilot farms, residents living in quarters inside or near the site are workers for those pilot farms and there is little involvement of the general people. Another importance is that the land is owned by the governmental agencies and has high possibility of land acquisition.

The Gohagoda site is next to the KMC garbage-dumping site and near the proposed Gohagoda Intake, but due to the difference in basin, the effluent of a sewage treatment plant will be discharged 0.4 km downstream of the intake. The site slopes to the north as a whole but not necessarily even. The site may involve a part of the dumping site and in such a case, it is necessary to excavate the previously dumped garbage for disposal at the other site. The environmental problems incidental to the operation of a sewage treatment plant may be offset by those of the garbage-dumping site. The residents inside and adjoining the site are mostly squatters and it is reportedly possible to require their evacuation. The site is about 9.9 km away from the Getambe Pump Station and requires the river crossing over the Mahaweli River. (For the river crossing at the Mewartura and Gannoruwa sites, the suspension on the Getambe Bridge which is currently under expansion is possible.)

The features of each alternative site are summarized in Table 2.3. Taking into account the construction cost to convey the sewage from the Getambe Pump Station to the particular site and the effluent to the receiving water body, and the operation cost of the Getambe Pump Station, the financial burden is obviously too heavy for the Watapuluwa site and likewise for the Gohagoda site. The Mewartura site of Peradeniya University is excluded from the consideration due to no possibility of land acquisition. The reminders are the Getambe site on right bank of the Mahaweli River and the Gannoruwa site on the left bank. The sewage treatment site is unavoidable to face the opposition of its surrounding residents, however for the Gannoruwa site there will be less involvement of the general people, since it is surrounded by mountains and farms with a sufficient extent and its construction and maintenance costs are least in the alternative sites. The Gannoruwa site is, therefore, the best selection.

The landowner of the Gannoruwa site or the Ministry of Agriculture consented on 25 October 2002 to that the site would be used for a sewage treatment plant.

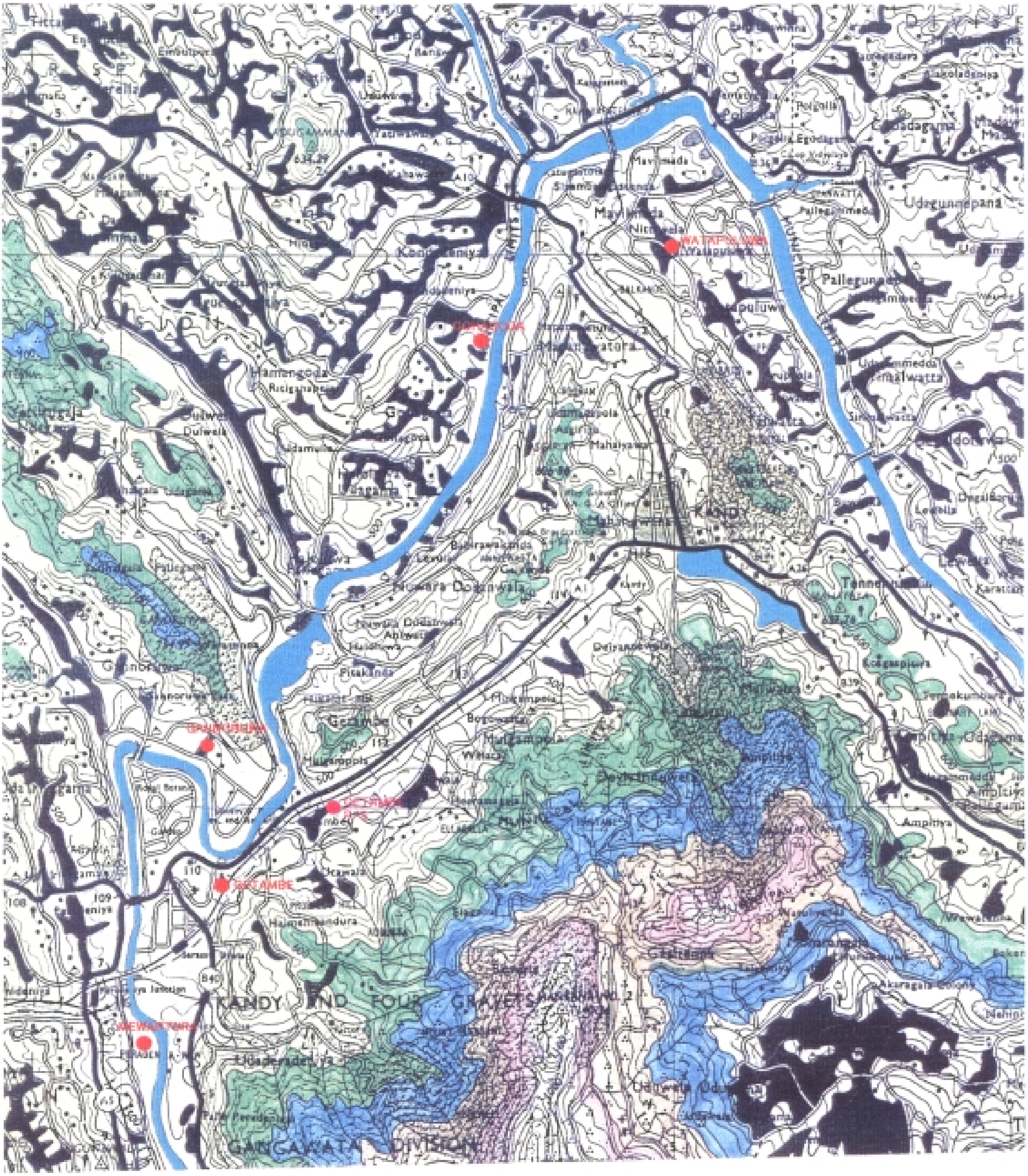
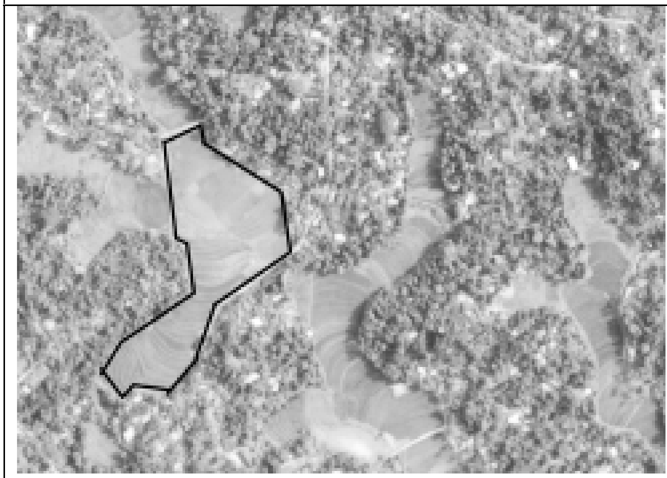
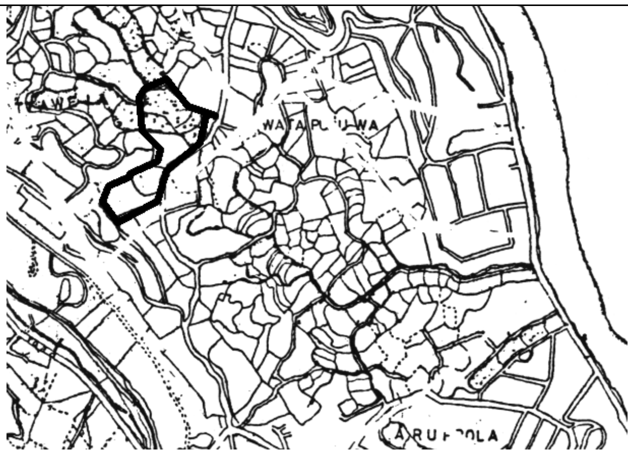


FIGURE 2.3 ALTERNATIVE SITES FOR A SEWAGE TREARMENT PLANT

FIGURE 2.4 SITE ALTERNATIVES FOR A SEWAGE TREATMENT PLANT

Alt. 1 : Watapuluwa





Alt. 2 : Getambe

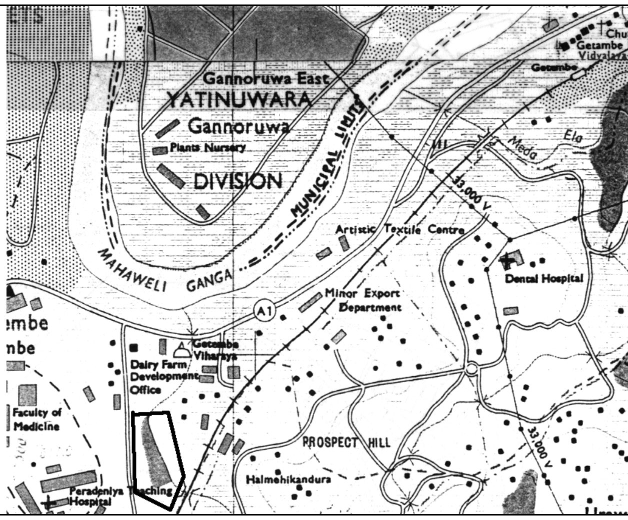
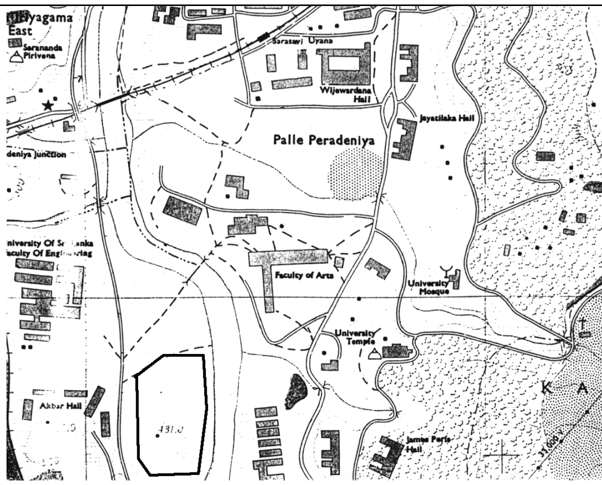
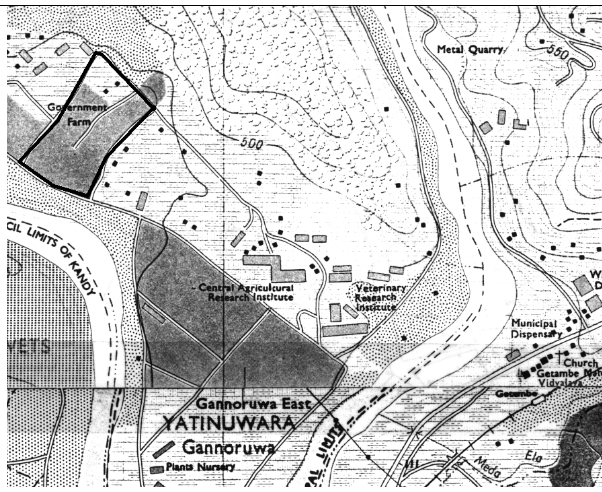


FIGURE 2.4 SITE ALTERNATIVES FOR A SEWAGE TREATMENT PLANT (Cont'd)

Alt. 3 : Mewartura



Alt. 4 : Gannoruwa



Alt. 5 : Gohagoda

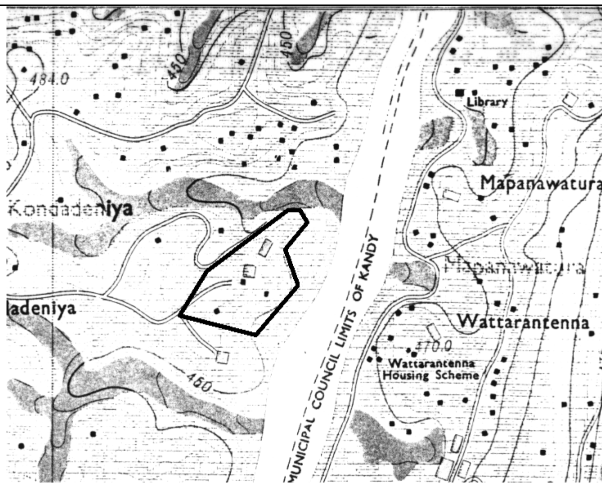


Table 2.3 Comparison of Altertive Sites for A Sewage Treatment Plant

WRP site	Watapuluwa	Getambe	Mewartura	Gannoruwa	Gohagoda
Landqwner	Private	Ministry of Agriculture	Peradeniya Univ.	Ministry of Agriculture	KMC
Present land use	Paddy field	Vacant	Farm	Farm (partly fallow field)	
Future land use			The Science Park Plan is going		
Nearest Water Body	Downstream of Polgolla Dam	Upstream of KMC Intake	Upstream of KMC Intake	Upstream of KMC Intake	Downstream of proposed Gohagoda Intake
Extent	Almost flat, adequate	Depressed area, small	Almost flat, adequate	Almost flat, adequate	Slope
Surrounding Environment		Surrounded by the temple, university hospital and dormitories and residences	The natural buffer zone is formed by the A5 Road and Mahaweli River. There are two institutions in the corner.	There are quarters in the particular site as well as in the surrounding area. The former requires the resettlement.	The environmental problems will be offset by those of the adjoining garbage dumping site.The discharge point of the STP's effluent is 0.4 km downstream of the proposed Gohagoda Intake.
Length and Max. Elevation of theRoute from the Getambe P/S	7.1 km, approx. 520 m AMSL	2.0 km, approx. 480 m AMSL	5.6 km, approx. 490 m AMSL	1.4 km, approx. 477 m AMSL	9.9 km, approx. 480 m AMSL
Distance from the STP to the discharge point	1.4 km	0.2 km	4.6 km	0.8 km	0.1 km
Environmental issue		The temple was eager for the particular site acquisition.		Residents in the quarters have to follow the decision of the Ministry of agriculture regarding the land	It is possible to remove most residents due to squtters
Other specifications		Requirement for land filling due to the depressed area. No river crossing over the Mahaweli River		Gannoruwa is the old battle field that the Kandy Kingdom defeated the invading Portuguese army in 16 A.C.	There are some possibilities that the site include partly the garabage dumping site, which require the replacement of the ground soil and the new dumping site of surplus soil including the garbage.

Table 2.3 Comparison of Altertive Sites for A Sewage Treatment Plant (Cont'd)

WRP site	Watapuluwa	Getambe	Mewartura	Gannoruwa	Gohagoda
Construction Cost (Rs. million)	Force main ϕ 500mm x 6.4 km 128.3 Gravity sewer ϕ 825mm x 0.7 km 16.4 Effluent pipe ϕ 825mm x 1.4km 32.8 Total 177.5	Force main ϕ 500mm x 2.0 km 40.1 Effluent pipe ϕ 825mm x 0.2km 4.7 Total 47.8	Force main ϕ 500mm x 5.6 km 112.2 Effluent pipe ϕ 825mm x 4.8km 112.4 Total 224.6	Force main ϕ 500mm x 0.9km 18.0 ϕ 350mm x 0.2km 2.4 Gravity sewer ϕ 825mm x 0.4km 9.4 Effluent pipe (Force Main) ϕ 825mm x 0.8km 16.0 Total 45.8	Force main ϕ 500mm x 9.9 km 198.4 Effluent pipe ϕ 825mm x 0.2km 4.7 Total 203.1
O&M Cost 14hr x 30d x (Rs. Thousand/mo.)	203 kw x 2 (one stand-by) 400	65 kw x 2 (one stand-by) 127	120 kw x 2 (one stand-by) 234	58 kw x 2 (one stand-by) 113	130 kw x 2 (one stand-by) 254
Evaluation	Taking into account the total cost of Rs. 463.2 million for pipe laying and Rs. 686 thousand/mo. for power, the financial burden of this site is too heavy.	The strong opposition of surrounding residents is expected and even though obtaining their consent, environmental measures at the STP is severest. The land-saving treatment process is required but sludge handling has to be done in other place.	There is no possibility of land acquisition due to the on-going other project	The site extent and surrounding condition is good and the construction and O&M costs are cheapest	Taking into account the total cost of Rs. 463.2 million for pipe laying and Rs. 686 thousand/mo. for power, the financial burden of this site is too heavy. As the garbage dumping site will be used in future, the negotiation which part is available for the

2.2 Water Supply Service Population

(1) KMC (Kandy Municipal Council)

The Study on Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Plan was initiated by JICA in February 1998 and completed by January 1999. Subsequently (December 2000), Engineering Consultants Limited, supported by ADB, prepared the report titled Feasibility Study of Water Supply Augmentation & Distribution at Kandy. In both feasibility reports, projected water supply service population in KMC to the year 2020 was developed as shown in Table 2.4.

Table 2.4 Projected Water Supply Service Population

Item	2000	2005	2010	2015	2020
JICA projection	144,000	153,000	162,000	171,000	181,000
ADB projection	135,750	144,846	154,573	164,954	176,032

All available population data was collected to evaluate the above projections, but only insignificant changes to the data on which the original JICA projections were based were found. The JICA projection was therefore adopted for the purposes of the current project.

(2) Outside KMC

Data on water supply service connections in the year 2000 (from January to December) for 19 water supply schemes was obtained from NWSDB (See Appendix 2.1, Vol. II-1). Ten of these schemes will be included in the proposed phase 1 water supply improvement project. The service population in the year 2000 was estimated by multiplying the number of service connections by the population per service connection factors given in Table 2.5. The numbers of service connections applied for but not yet connected, including those for housing estates, were taken into consideration in the projection. A comparison of the water supply service population in the year 2000 as estimated under the NWSDB and JICA projections are presented in Table 2.6.

Table 2.5 Population per Service Connection

Category	Population (pers./conn.)
Domestic	5.6
Commercial	10.0
Standpost	55.0
Other	10.0

Table 2.6 Service Population in the Year 2000 for Phase 1 Water Supply Schemes

Water Supply Scheme		NWS&DB Projection				JICA Projection
		Service Connections			Population	
		In service	Backlog	Total		
(1)	Alawathugoda	1,057	1,333	2,390	15,956	18,953
(2)	Akurana	1,149	3,778	4,927	32,417	27,378
(3)	Balanagala	1,605	651	2,256	14,946	17,802
(4)	Polgolla	1,449	2,029	3,478	23,355	17,805
(5)	Kulugammana	1,828	1,042	2,870	17,340	16,394
(6)	Kondadeniya	1,105	98	1,203	7,711	9,998
(7)	Gohagoda	1,921	30	1,951	12,542	15,793
(8)	Ampitiya	1,668	980	2,648	15,730	18,831
(9)	Mullepihilla	171	161	332	2,339	
(10)	Hantana	488	0	488	3,327	6,418
計		12,441	10,102	22,543	145,663	149,372

An inspection of Table 2.6 reveals that the total served populations for the NWSDB and JICA projections are very similar (within 2.5 percent), although there are variations of up to 20 percent for individual water supply scheme service areas. There are a number of reasons for these variations.

1) The same population per service connection figures has been applied to every water supply scheme without taking into account individual area characteristics.

2) The boundaries of the water supply schemes and the JICA Feasibility Study service area are not the same.

3) Applications for service connections from outside of the proposed water supply service area have been included in the totals, for example the Akurana and Polgolla areas.

4) The JICA projection includes some population presently served by groundwater from individual wells while it is understood that the NWSDB projection does not, which accounts for some of the difference between the two projections.

If the service population estimated by NWSDB is adjusted for the factors noted above the two projections become very close indeed.

(3) Total Served Population

Based on the previous discussion, the projected service population presented in the JICA Feasibility Study has been adopted for the purposes of this investigation, as shown in Table 2.7. The existing and proposed service area has been subdivided into subareas that will be served by individual reservoirs and the projected population served by each reservoir is estimated as shown in Appendix 2.2, Vol. II-1.

Table 2.7 Target Water Supply Service Population in Greater Kandy

Area	2000	2005	2010	2015	2020
Kandy Municipal Council (KMC) (A)	144,000	153,000	162,000	171,000	181,000
Outside KMC					
Kandy Four Gravets (Part)	58,000	62,000	67,000	71,000	77,000
Harispattuwa, Akurana & Pujapitiya (Part)	138,000	150,000	161,000	173,000	184,000
Kundasale (Part)	87,300	93,800	99,500	106,000	113,000
Patha Dumbara (Part)	42,900	46,000	48,400	51,600	54,700
Patha Hewaheta (Part)	8,600	9,400	10,600	12,000	14,000
Udunawara, Yatinuwara & Udu Palatha	95,400	101,600	110,900	119,000	126,200
Subtotal (B)	430,200	462,800	497,400	532,600	568,900
Total (A) + (B)	574,200	615,800	659,400	703,600	749,900

2.3 Projected Water Demand

(1) KMC

The water demand projections from the JICA and ADB Feasibility studies are compared in Table 2.8. Both projections are divided into three categories of service, but the definitions of these categories are not the same. Although the differences in category definition make it impossible to compare the projections on a category by category basis, the total water demands projected for each target year compare favorably.

4) The JICA projection includes some population presently served by groundwater from individual wells while it is understood that the NWSDB projection does not, which accounts for some of the difference between the two projections.

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Kundasale (Part)	87,300	93,800	99,500	106,000	113,000
Patha Dumbara (Part)	42,900	46,000	48,400	51,600	54,700
Patha Hewaheta (Part)	8,600	9,400	10,600	12,000	14,000
Udunawara, Yatinuwara & Udu Palatha	95,400	101,600	110,900	119,000	126,200
Subtotal (B)	430,200	462,800	497,400	532,600	568,900
Total (A) + (B)	574,200	615,800	659,400	703,600	749,900

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(1) KMC

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Table 2.8 Projected Water Demand in KMC

	2000	2005	2010	2015	2020
JIC Aprojection					
(1) Domestic	14,570	16,500	18,610	20,730	—
(2) Non-domestic	8,352	9,333	10,530	11,799	—
(3) NRW	16,560	14,535	13,122	10,773	—
Total	39,482	40,392	42,282	43,263	—
ADB Projection					
(1) Domestic	26,924	28,732	30,661	32,721	34,918
(2) Non-domestic	750	800	854	911	972
(3) NRW	9,578	10,083	10,620	11,190	11,797
Total	37,252	39,615	42,135	44,822	47,687

NRW = Non-revenue Water

It is significant to note that water demand for the floating population that visit Kandy during special festivals has been excluded from Table 2.8.

As indicated in Table 2.8, the total water demand of each target year is almost the same for both the ADB and JICA projections (within 2 to 3 percent). The water demand projections developed in the JICA Feasibility Report have therefore been adopted for the purposes of this study.

(2)Outside KMC

A record of water consumption and NRW (December 2000) for 34 water supply schemes was obtained from NWSDB (See Appendix 2.3, Vol. II-1). Existing water production capacity is inadequate for existing, let alone future water demands making it difficult to use this data as an indicator of actual demand. A comparison of the water use shown by the NWSDB data with the estimated water demands given in the JICA Feasibility Report is presented in Table 2.9.

Table 2.9 December 2000 Water Demand Outside KMC (m^3/d)

	NWS&DB Projection	JICA Projection
Domestic	23,170	33,556
Non-domestic	10,255	12,906
NRW	20,558	33,556
Total	53,984	80,018

The NWSDB estimate of water demand reflects the current situation where supplies are inadequate and distribution system pressures range from low to negative, a situation that will naturally result in reduced water consumption. Implementation of the proposed water supply improvement project is expected to provide the service area with an adequate supply at greatly increase distribution system pressures, which is expected to result in a substantial increase in per capita water use over present levels. The JICA Feasibility Study water demand projection has therefore been adopted as a basis of design for the proposed water supply improvement facilities.

(3) Total Projected Water Demand

A summary of total projected water demand in Greater Kandy is shown in Table 2.10. Details of estimated water demand in Greater Kandy by reservoir tributary service area are given in Appendix 2.4, Vol. II-1.

Table 2.10 Projected Water Demand in Greater Kandy

(Unit: m^3/d)

	2000	2005	2010	2015
KMC				
Domestic	14,544	16,524	18,630	20,691
Non-domestic	8,352	9,333	10,530	11,799
NRW	16,560	14,535	13,122	10,773
Total	39,456	40,392	42,282	43,263
Outside KMC				
Domestic	33,556	38,156	44,766	52,253
Non-domestic	12,906	14,689	17,965	21,631
NRW	33,556	29,619	28,352	24,500
Total	80,018	82,464	91,083	98,384
Total				
Domestic	48,100	54,513	63,425	72,808
Non-domestic	21,258	24,158	28,448	33,603
NRW	50,116	44,185	41,492	35,236
Total	119,474	122,856	133,365	141,647

CHAPTER 3 EXISTING DSTRIBUTION SYSTEM

The relevant data on the existing distribution network were collected from NWSDB and KMC, which will be used to identify the service area of each reservoir taking into account the elevation of a reservoir, topography, available road, etc. in the next stage.

3.1 Relationship with ADB Project in KMC

The Feasibility Study of Water Supply Augmentation & Distribution at Kandy was completed in December 2000 under the ADB assistance and the detailed design stage has commenced in April 2001 five months behind the original schedule.

Although the ADB project basically accepts the contents of the previous JICA Report, there are some overlaps caused by the emergency of the works as follows:

(1) Primrose Reservoir

The construction of the Primrose Reservoir (volume: 315 m3) and its related pump replacement at the KMC Water Treatment Plant are overlapped between the ADB and JICA projects. The existing Primrose Reservoir made of steel panels has a serious leakage and requires for its reconstruction as soon as possible. For this reason, its reconstruction is scheduled in Phase 1 under the ADB project that will start the construction from June 2001. From the viewpoint of efficient available land use and emergency of the works, it is proposed that the Primrose Reservoir will be constructed with a combined capacity of existing and new reservoirs under the ADB project and be excluded from JICA project. However, as to the pump replacement at the KMC Water Treatment Plant, the replacement of impellers are supposed under the ADB project and it is necessary for a mechanical engineer to check whether such a replacement will meet the capacity requirement.

(2) Transmission Pipes to Dangola Reservoir

The existing pipe to the Dangola Reservoir is used for both purpose of water transmission and distribution resulting in insufficient water transmission to the existing Dangola Reservoir. The ADB project has a plan to separate the water transmission from the water distribution through the installation of new transmission pipes to the Dangola Reservoir in Phase 1. Therefore, it is suggested to exclude the installation of transmission pipes to the Dangola Reservoir from the JICA project and to undertake the construction of the new

Dangola Reservoir (volume: 254 m3) and its related connection work under the JICA project.

3.2 Other Water Supply Scheme

Through the data collection and field survey, it is found that some reservoirs were newly constructed since the previous JICA study as shown in Table 3.1. The volume requirement of each reservoir will be readjusted in consideration of the service area by reservoir to be identified in the next stage.

The capacity of the Polgolla Water Treatment Plant was expanded by 500 m3/day, but this will be abandoned up to 2005 and have no influence on the overall scheme

CHAPTER 4 POLLUTION INPUTS TO THE MAHAWELI RIVER

4.1 General

One of the objectives of the current investigation is to evaluate the impact of existing and future wastewater discharges on the Mahaweli River upstream of the proposed Gohagoda Intake. There are two major sources of wastewater of interest to this investigation:

- The Asgiriya and Gohagoda reservoir service areas are not included in the wastewater collection and treatment system that is proposed for the Kandy area. Part of the Asgiriya Reservoir service area drains directly to the Mahaweli River and parts of it drains indirectly to it via the Asgiriya and Dodamwela Channels. Part of the Gohagoda Reservoir service area also drains directly to the Mahaweli River and portions drain indirectly via the Dulwela and Y. Udagama Channels. In Asgiriya reservoir service area, the housing has been gradually constructed, while the Gohagoda reservoir service area remains rural. Both service areas are almost exclusively residential in nature except for a few hotels and schools which would in any case produce only domestic wastewater.

- Those portions of the area drained by the Meda River with relatively high population densities and concentrations of commercial activities will be served by a proposed Master Plan for wastewater collection and treatment facilities. The sewerage system is to be developed in two stages, a priority project, which is the subject of the current investigation, covering the city center commercial area, the area around Kandy Lake, the Hantana Housing Scheme, the General Hospital, the railroad station the central market, the prison and the soccer stadium. Stage two will cover the balance of the Master Plan sewerage service area. The remainder of the Meda River tributary area, which is mountainous in nature and the housing has been developped gradually, is not be included in the sewerage service area.

For convenience, the nine areas that drain to the Mahaweli River above the proposed water supply intake described above have been designated Areas A through I, as listed in Table 4.1 and illustrated in Figures 4.1 and 4.2.

4.2 Population

The Asgiriya Reservoir service area and the Meda River tributary area are mostly contained within the Kandy Municipal Council. The Gohagoda Reservoir service area is contained within the Harispattuwa D. S. Division. The projected population growth rates for these D.

S. Divisions is shown in Table 4.2. The population projections presented in the 1999 report were based on 1997 data. The 1997 data has not been updated in the meantime, although a countrywide census is in course of preparation (2001). The 1997 data was therefore adopted for the purposes of this investigation. A summary of projected populations within the areas of interest tributary to the Mahaweli River is presented in Table 4.3. Details of 1997 area, population, number of families, family size and population density for GN Divisions lying wholly or in part within the Master Plan sewerage service are given in Appendix 4.1. Details of projected population in the Asgiriya Reservoir service area, the Gohagoda Reservoir service area and the Meda River tributary area are presented in Appendix 4.2, Vol. II-1. Projected populations for these areas were obtained by applying the population growth rates noted above to the 1997 population data.

Table 4.1 Areas Tributary to Mahaweli River Above Proposed Water Supply Intake

Asgiriya Reservoir service area
Area A: Directly tributary
Area B: Indirectly tributary via Asgiriya Channel
Area C: Indirectly tributary via Dodamwela Channel
Gohagoda Reservoir service area
Area D: Directly tributary
Area E: Indirectly tributary via Dulwela Channel
Area F: Indirectly tributary via Y. Udagama Channel
Meda River Tributary Area
Area G: Sewerage service area (Phase I)
Area H: Sewerage service area (Phase II)
Area I: Outside Master Plan sewerage service area

Population densities within these areas vary from 71.1 persons per hectare for the area to be served by the priority sewerage project to 14.3 persons per hectare for the Gohagoda reservoir service area (see Table 4.4).

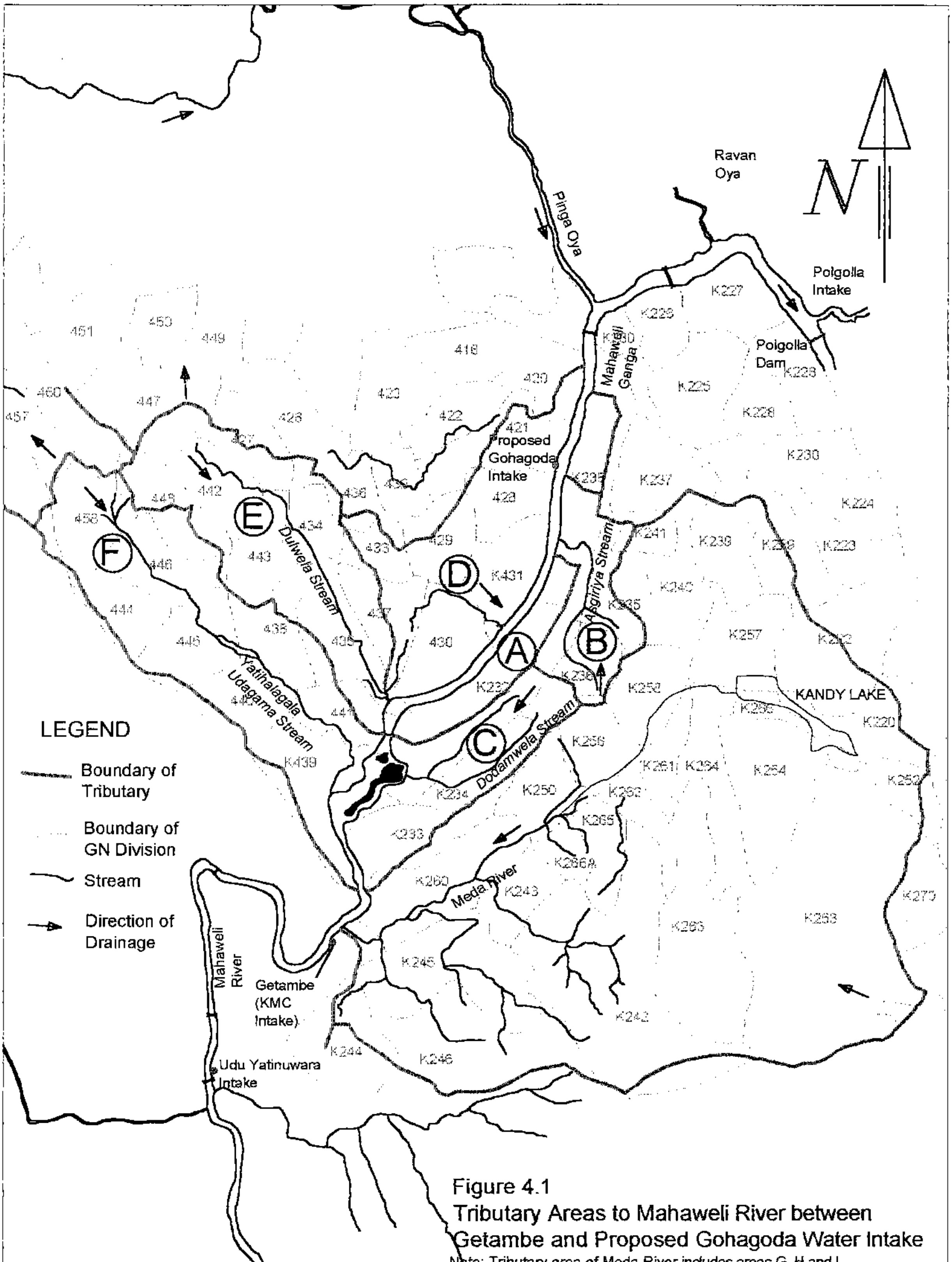


Figure 4.1
Tributary Areas to Mahaweli River between Getambe and Proposed Gohagoda Water Intake

Note: Tributary area of Meda River includes areas G, H and I.
Area G is the Master Plan sewerage Service Area. Area H is the Priority Sewerage Service Area within Area G. Area I is the tributary area outside the Master Plan Sewerage Service Area. (Refer Figure 1.1)

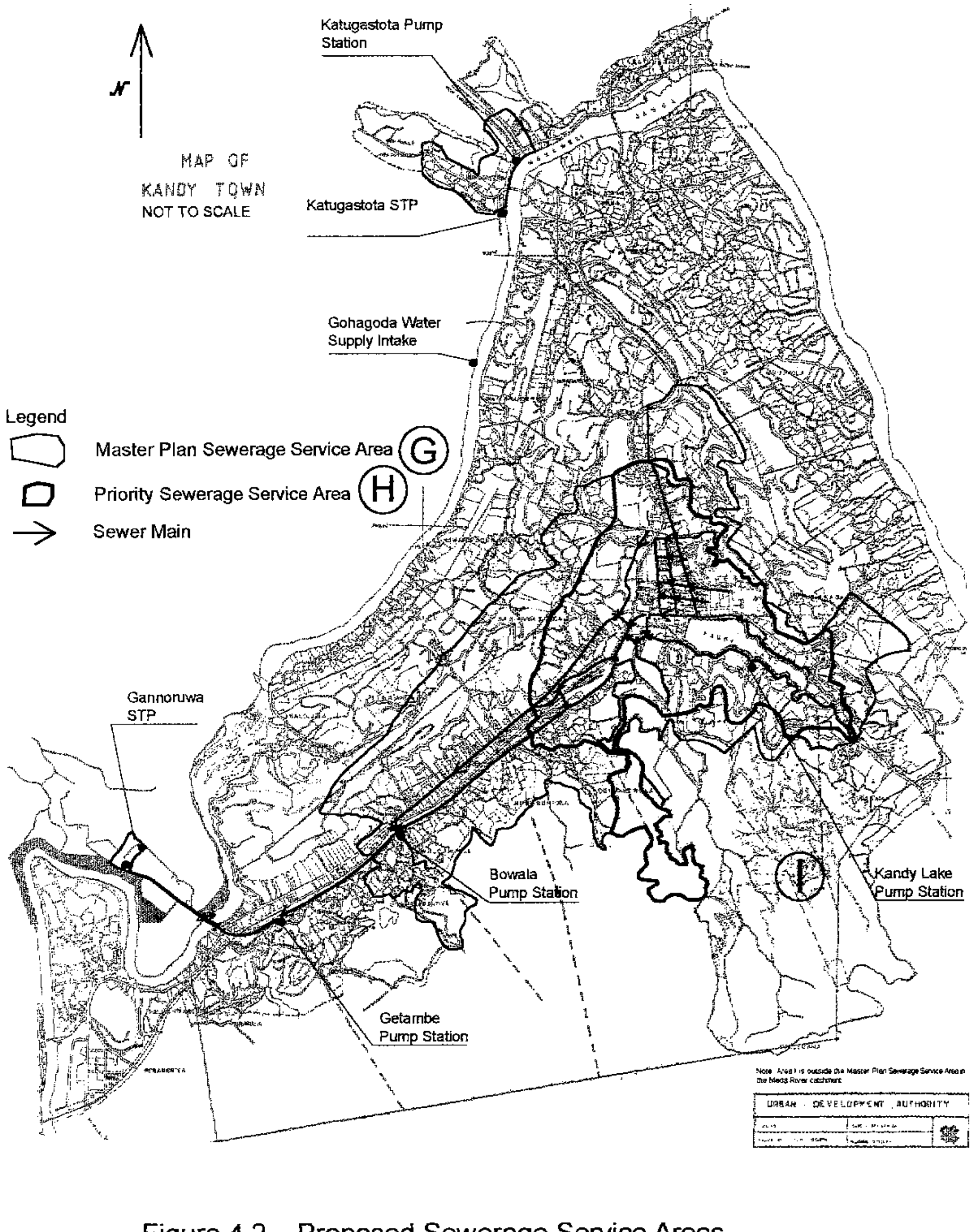


Figure 4.2 Proposed Sewerage Service Areas

Table 4.2 Population Growth Rates

Area	Division	Growth Rate From 1997 (%)		
		2001	2005	2015
Asgiriya Reservoir service area	Kandy Municipa Council	6.14	11.32	24.81
Gohagoda Reservoir service area	Harispattuwa	6.63	12.39	28.24
Meda River drainage area	Kandy Municipa Council	6.14	11.32	24.81

Table 4.3 Projected Population

Area	1977	2001	2005	2015
Asgiriya Reservoir service area				
A: Directly tributary	771	817	858	962
B: Indirectly tributary via Asgiriya Channel	4,596	4,879	5,117	5,737
C: Indirectly tributary via Dodamwela Channel	4,833	5,130	5,381	6,032
Subtotals	10,200	10,826	11,356	12,731
Gohagoda Reservoir service area				
D: Directly tributary	3,264	3,465	3,631	4,073
E: Indirectly tributary via Dulwela Channel	4,939	5,240	5,496	6,163
F: Indirectly tributary via Y. Udagama Channel	5,135	5,449	5,716	6,409
Subtotals	13,338	14,154	14,843	16,645
Meda River Tributary Area				
G: Within Master Plan sewerage service area	39,841	42,285	44,352	49,724
H: Within Priority sewerage service area	17,302	18,363	19,260	21,595
Balance Master Plan sewerage service area	22,539	23,922	25,092	28,129
I:Outside Master Plan sewerage service area	21,573	22,897	24,017	26,925
Subtotals	61,414	65,182	68,369	76,649
TOTALS	84,952	90,162	94,568	106,025

Much of the Gohagoda and Asgiriya reservoir service areas and the areas tributary to the Meda River that will be included in the proposed sewerage system service area are relatively steep. Comparison of housing densities shown on a 1987 topographic map of these areas with present field observations indicates that a considerable amount of development has occurred in the intervening period, and the substantial number of new buildings currently under construction suggest that development is ongoing. Maintenance of residential wastewater disposal systems is presently very limited in KMC. There are approximately 22,000 households in the KMC area, but KMC records indicate that only 360 septic tank cleaning operations were carried out during the year 2000. Although data is not available on the number of households with septic tanks versus pit latrines, field observations suggest that at least half of the structures in the proposed sewerage service area are equipped with septic tanks. The existing maintenance capability is only adequate for about 2,000 households with septic tanks. It is understood that plans to upgrade septic tank maintenance capabilities are under consideration by KMC authorities.

Typical household and business plumbing systems in the study area divert "black" wastewater from toilets into septic tanks and "grey" wastewater from washing and bathing into surface drains that commonly connect to storm water drainage systems which in turn ultimately drain to local streams and the Mahaweli river. Both septic tanks and latrine pits are typically constructed in such a manner as to allow liquid to soak into the surrounding soil. The steepness of much of the study area terrain and the relatively small lot sizes suggests that infiltration beds are in general small or non-existent. Field observations indicate that many residences and businesses located adjacent to streams discharge grey water directly to the streams, and the closeness of the septic tanks and latrine pits of these establishments to the waterways could result in relatively high proportions of nutrients reaching the streams.

4.3 Unit Wastewater Quantities

Unit wastewater quantities that were developed in a previous report were adopted for the purposes of this investigation, as summarized in Table 4.4.

Table 4.4 Unit Wastewater Quantities

(Unit: lpcd)

Year	Domestic	Non-domestic	Infiltration	Total
1997	78	79	28	185
2001	82	85.5	30	197.5
2005	86	92	32	210
2015	97	138	42	277

4.4 Wastewater quantities

A summary of estimated wastewater quantities generated in areas tributary to the Mahaweli River upstream from the Gohagoda intake is presented in Table 4.5. It is important to note that the unit wastewater quantities discussed above are based on the assumption that water supply is equal to demand. In areas where present supplies are limited by inadequate water production or distribution facilities, the actual amount of wastewater generated will be less than the amounts given in Table 4.5.

Table 4.5 Wastewater Quantities

(Unit: m^3/d)

Area	1977	2001	2005	2015
Asgiriya Reservoir service area				
A: Directly tributary	60	67	74	93
B: Indirectly tributary via Asgiriya Channel	358	400	440	556
C: Indirectly tributary via Dodamwela Channel	377	421	463	585
Subtotals	795	888	977	1,234
Gohagoda Reservoir service area				
D: Directly tributary	255	284	312	395
E: Indirectly tributary via Dulwela Channel	385	430	473	598
F: Indirectly tributary via Y. Udagama Channel	401	447	492	622
Subtotals	1,041	1,161	1,277	1,615
Meda River Tributary Area				
(Within Master Plan sewerage service area)	6,255	7,083	7,895	11,685
G: Sewerage service area (Phase I)	2,716	3,076	3,428	5,075
H: Sewerage service area (Phase II)	3,539	4,007	4,467	6,610
I: Outside Master Plan sewerage service area	1,683	1,878	2,065	2,612
Subtotals	7,938	8,961	9,960	14,297
TOTALS	9,774	11,010	12,214	17,146

NOT INCLUDING INFILTRATION

4.5 Unit Mass Loading Rates

According to the scope of work for this project, the water quality constituents of interest to this investigation are pH, BOD5, COD, T-N, T-P and coliforms. PH and coliform concentrations are primarily of concern to design of the water treatment works and are determined by direct water quality measurements in the Mahaweli River. Previous studies have established common average values for the constituents of interest contained in domestic wastewater based on the data in Japan, as follows:

Constituent	Unit Mass Loading Rate (g/capita/day)
BOD_5	57
COD_{Mn}	28
SS	43
T-N	12
T-P	1.2

A unit mass loading rate for BOD5 of 40 g/capita/day for tropical countries was used in the previous JICA report and has been adopted for use in the present analysis. Wastewater quality data on domestic and non-domestic sources collected during a previous study indicated that non-domestic wastewater from the study area has approximately half the strength of domestic wastewater. Based on this information, estimated unit mass loading rates and concentrations for wastewater in the study area were derived as summarized in Table 4.6.

Table 4.6 Wastewater Quality

Source	Unit Wastewater Quantities (lpcd)	Unit Mass Loading Rates (g/capita/day)				
		BOD	COD	SS	T-N	T-P
Domestic	97	40.0	28	43	12	1.2
Non-domestic	138	28.5	19.9	30.6	8.5	0.9
Infiltration	42	0	0	0	0	0
Total	277	68.5	47.9	73.6	20.5	2.1

4.6 Mass loading rates

A summary of the mass loading rates generated in the study area is presented inTable 4.7. Breakdown of BOD is indicated in Table 4.10 and other details are shown in Appendix 4.3、Vol.II-1.

Table 4.7 Total Mass Loading Rates Generated in the Study Area (kg/day)

	1977	2001	2005	2015
BOD	4,534	4,813	5,047	5,657
COD	3,171	3,367	3,530	3,959
SS	4,872	5,171	5,423	6,081
T-N	1,358	1,443	1,512	1,695
T-P	139	146	153	171

CHAPTER 5 WATER QUALITY OF THE MAHAWELI RIVER AND ITS TRIBUTARIES

5.1 Available Water Quality Data for the Mahaweli River

Water quality of Mahaweli River between Getambe and proposed water intake site at Gohagoda is of primary concern for this study. Figure 5.1 shows that stretch of Mahaweli River. Existing water supply intake is located at Getambe and the distance between Getambe Intake and proposed Gohagoda intake is 5.5 km along the river. Major tributaries to Mahaweli River in this stretch are Meda Ela (stream), Dodamwela Ela (stream), Asgiriya Ela (stream) and others.

5.1.1 NWSDB Monitoring Program

Water quality monitoring of Mahaweli River has been carried out on a weekly basis by the NWSDB from March 2000 at five locations as follows:

① Peradeniya Intake (Upstream of confluence with Nanu Oya and Udu/Yatinuwara Intake)

② KMC Intake (at Getambe upstream of Meda Ela confluence)

③ Downstream of Meda Ela Confluence

④ Proposed Gohagoda Intake Site

⑤ Polgolla Intake

Details of the monitoring and the data are presented in Appendix 5.1.
This program is on going and the following observations are made on the monitoring program.

- ***Sampling***

Sampling is carried out at the bank of the river and not necessarily from the main flow of the river. Mahaweli River is wide and develops several channels of flow when flow is low. It is desirable that the samples are collected from the main flow. For example, at Peradeniya samples can be collected from top of the footbridge. Sampling location after the confluence of Meda-Ela is at the right-bank of the river where the flow is mainly divided into two and mixing of Mahaweli River and Meda Stream is not complete. For this reason, two locations are proposed for monitoring.

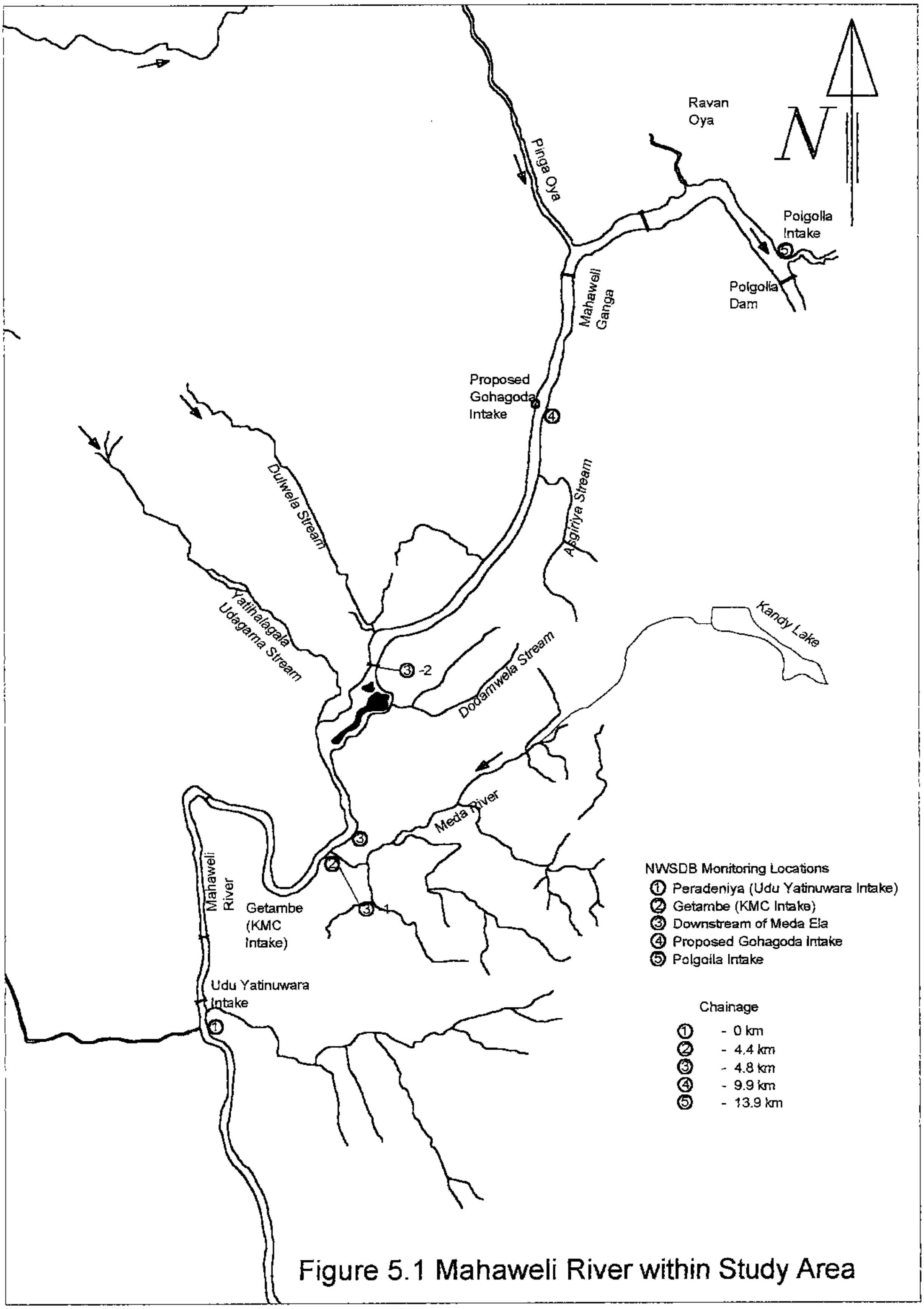


Figure 5.1 Mahaweli River within Study Area

1) Meda Ela (at the Colombo Road Bridge prior to confluence with Mahaweli River, shown as ③-1 in Figure 5.1)

2) At the suspension bridge which is 2.1 km downstream from the confluence of Meda Stream over Mahaweli River (shown as ③-2 in Figure 5.1).

Sample is collected by immersing a sample bottle in the river. Collected sample is used for testing of all parameters at the laboratory including pH, DO and bacteriological parameters.

- Inadequate equipment for field measurement (pH, and DO are not measured at site. pH must be measured at the site. DO should either be measured at the site or be fixed at the site for determination at the laboratory).

5.1.2 Other Sources of Data

For the year 1993 monthly monitoring at Peradeniya and at Tennekumbura were available as reported in the F/S Study. Sampling and analysis is carried out by IFS (Institute of Fundamental Studies). Tennekumbura is downstream of Polgolla Dam and is outside the area of this study. Table 5.1 shows the results.

Table 5.2 and 5.3 shows the summary of analysis carried out during the previous study JICA (F/S) in the Mahaweli River.

Prior to the commencement of NWS&DB RSC-Central Laboratory monitoring program described in the preceding sub-section, BOD_5 data for Peradeniya Intake measured by Regional Laboratory of NWSDB is available and is summarised in Table 5.4 and Figure 5.2. Raw data is presented in Appendix 5.2, Vol. II-1.

Table 5.1 Water Quality of the Mahaweli River at Peradeniya During 1993

Month	pH	EC μ S/cm	T-P, ppb	Dissolved-P, ppb	NO_3-N, ppb	BOD_5, mg/L
Jan.	7.27	68	21	ND	74	1.75
Feb	7.75	76	16	02	85	1.80
Mar	7.91	89	15	09	107	2.75
Apr	7.67	88	12	ND	87	2.30
May	7.00	108	05	01	43	2.05
Jun	7.57	52	09	ND	71	1.05
Jul	7.39	40	04	03	60	1.50
Aug	7.42	65	06	01	43	0.90
Sep	7.84	74	08	--	49	1.30
Oct	7.36	81	04	02	46	0.90
Nov	7.21	72	04	05	127	1.85
Dec	7.25	98	06	04	106	0.95

(Source: EIA Report, Table 6.6, and Unpublished Data from Institute of Fundamental Studies (IFS))

Table 5.2 Water Quality of Mahaweli River in 1998

Parameter	Getambe Intake		Polgolla Intake		Gohagoda Proposed Intake	
	Min	Max	Min	Max	Min	Max
Turbidity (NTU)	4.4 11.5	46.3 47.1	2.7 11.7	50 54.3	10	15
pH	6.2 5.5	7.5 7.2	6.5 5.2	8.2 7.2	6.8	6.9
EC (μs/cm)	61.4 43.3	81.7 57.1	59.8 50.7	84.5 59.2	52	63
Alkalinity (mg/L)	24.2 8	39.3 22	26.6 16	39.9 35	20	21
Chloride (mg/L)	4.2 2.1	7.8 4.2	5.0 2.7	9.3 5.0	1.99	2.55
Free NH_3 (mg/L)	0 0.08	0.2 1.00	0 0.06	0.19 0.29	ND	0.46
Nitrite (mg/L)	0 0.08	0.27 0.27	0 0.08	0.96 0.13	0.13	0.19
Nitrate (mg/L)	1.28 0.17	3.02 4.19	1.52 1.32	4.97 2.53	3.52	4.79
Fluoride (mg/L)	0.05 0.02	0.2 0.10	0.04 0.02	1 0.33	0.15	0.16
Phosphate (mg/L)	0.32 0.91	1.1 4.04	0.64 1.58	1 6.85	1.51	2.15
Sulfate (mg/L)	1.13 1.3	3.41 2.4	1.21 0.7	2.68 5.8		0.7
T-Coliform /100 ml	400 100	>1000 >1000	160 200	960 >1000	100	1100
E.coli /10 ml	70 20	>1000 >1000	40 60	340 480	32	260
Mn (mg/L)	0.06 0	0.22 0	0.06 0	0.25 0	0	0
T-Iron (mg/L)	0.4 0	0.6 3.42	0.2 1.8	1 1.94	0	0

Source : JICA (1998 Volume 2, Main Report, Table 15.5)
Note : Upper row in each item is for wet season (July to September 1998)
Bottom row in each item is for dry season (March to May 1998)

Table 5.3 Water Quality of Mahaweli River in 1998

Parameter	Peradeniya	Getambe	Polgolla Dam	Proposed Gohagoda Intake
pH	6.4 - 7.1 5.4 - 5.7	6.2 - 7.1 5.0 - 5.5	6.4 – 6.8 5.4 – 5.6	7.4
Electrical Conductivity (µS/cm)	63 - 64 49 - 68	61 - 64 51 - 57	69 – 200 260	111
COD (mg/L)	24 - 32 8	24 - 32 8 - 32	24 – 48 8 – 32	17
BOD_5 (mg/L)	3.0 - 3.2 3.2 - 4.2	2.0 - 5.7 1.2 - 1.7	3.4 – 5.5 3.2 – 6.4	1.2
DO (mg/L)	5.3 - 7.5 7.3 - 7.5	2.2 - 5.8 7.2 - 7.9	1.0 – 4.9 3.4 – 4.5	7.6
SS (mg/L)	130 - 142 10 - 60	130 - 175 10 - 110	143 – 188 20 – 30	113
Chloride (mg/L)	4.1 - 5.5 3.2 - 4.3	4.0 - 4.6 3.5 - 4.2	4.0 – 4.9 17.9 - 7.1	6.9
Sulfate (mg/L)	1.9 - 2.3 1.2 - 2.1	2.1 - 3.3 1.6 - 1.8	2.1 – 2.6 1.4 – 1.6	1.5
T-Nitrogen (mg/L)	3.7 - 4.3 3.6 - 9.9	2.2 - 5.3 5.1 - 11.0	4.5 – 4.9 12.3 - 2.5	6.27
T-Phosphorus (mg/L)	1.3 - 1.5 0.2 - 0.7	0.8 - 0.8 0.6 - 0.9	1.4 – 1.7 0.7 – 1.1	1.19
T-coliform CFU/100 mL	2.5 - 10 17 - 24	1 – 8 13 – 22	1 – 10 22 – 17.5	26
E.coli CFU /100 ml	10 – 50 60 - 120	7 – 15 80 – 110	2 – 100 100 – 120	120
Zn (mg/L)	0.02 0.02	0.01 0.02	0.01 - 0.02 0.01 - 0.02	

Source: JICA (1998 Volume 2, Main Report, Table 15.6)
Note: Upper row in each item is for wet season (July to September 1998)
Bottom row in each item is for dry season (March to May 1998)

At Peradeniya, which is upstream of the reach, yearly variation of BOD_5 and NO_3-N is as summarised in Table 5.4.

Table 5.4 Water Quality of Mahaweli River at Peradeniya

Year		1993		1994	1995	1996	1997	1998		1999	2000
BOD_5, mg/L	Max.	2.8	4.4	5.2	5.5	8.8	6.7	4.2	5.2	6.2	21.0
	Median	1.6	4.2	4.1	4.3	4.7	4.1	3.2	3.7	3.7	5.7
	Min.	0.9	3.9	3.7	3.7	3.5	2.8	2.5	2.7	2.7	3.7
NO_3-N, mg/L	Max.	0.13						N/A			13.3
	Median	0.07						N/A			1.2
	Min.	0.04						N/A			0.2
T-P, mg/L	Max.	0.78						1.5			0.78
	Median	0.28						0.99			0.28
	Min.	0.03						0.23			0.03
No. of data		12	5	12	12	12	12	6	12	12	43
Period		Monthly	Aug. to Dec.	Monthly	Monthly	Monthly	Monthly	Apr. & Aug.	Monthly	Monthly	Mar. to Dec.
Source		EIA of JICA F/S	NWSD B	NWSD B		NWSD B	NWSD B	JICA F/S	NWSD B	NWSD B	NWSD B

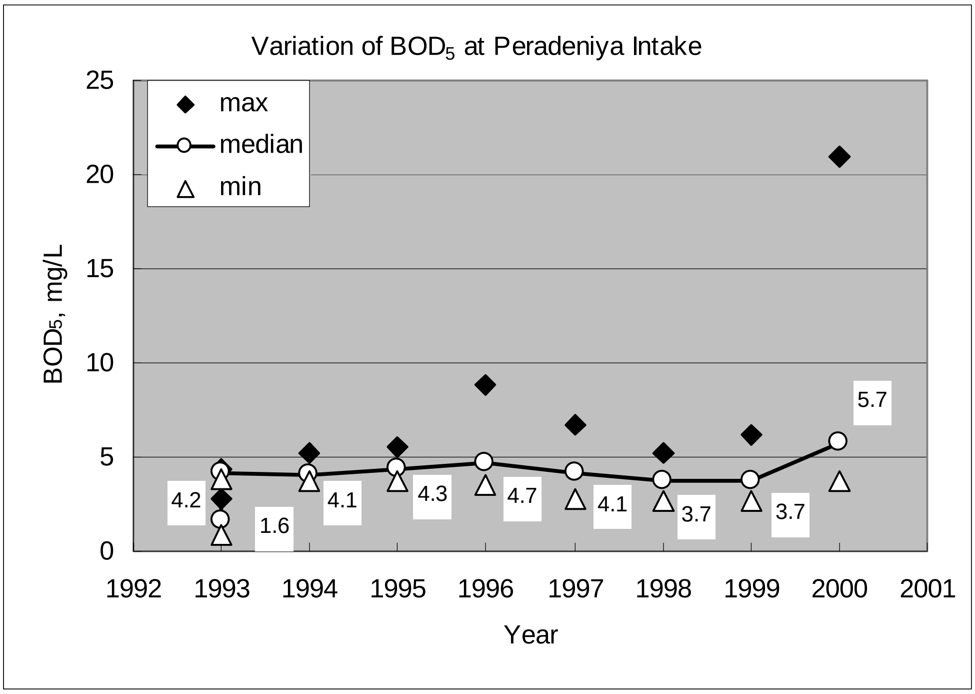
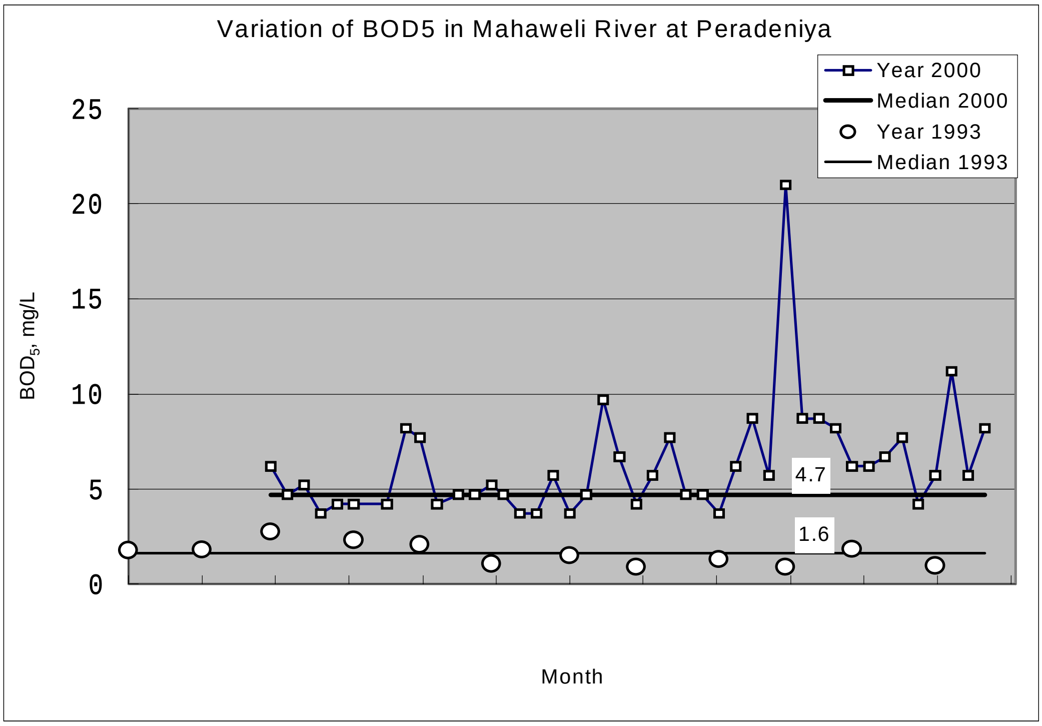


Figure 5.2 Yearly Change in BOD_5 of the Mahaweli River at the Peradeniya Intake



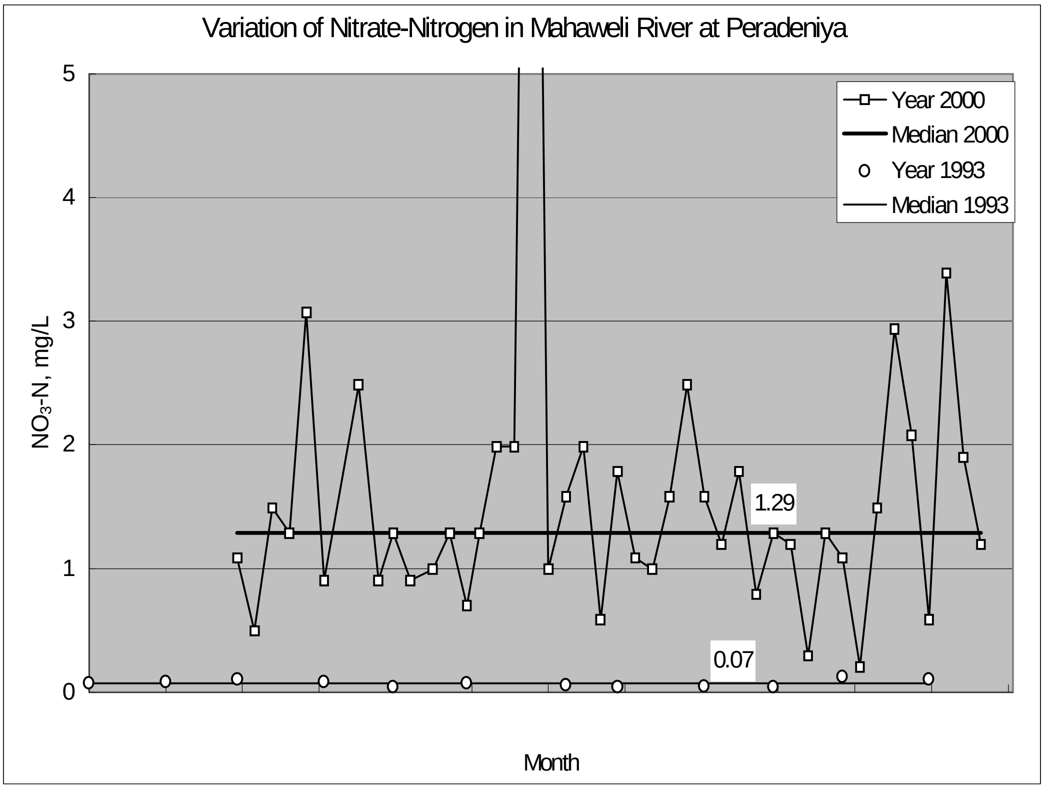


Figure 5.3 Change in BOD_5 and NO_3-N of the Mahaweli River at the Peradeniya Intake

BOD_5 data at Peradeniya shows difference depending on where analysis is made. Especially, difference is marked between the data obtained by NWS&DB RSC-Central Laboratory and IFS for the year 1993. Respective values are 4.2 mg/L and 1.6 mg/L, which is 2.6 mg/L of difference. There are no other sources of data available neither to verify this difference nor to verify the current BOD_5 level.

Data obtained by NWSDB is also shows a marked increase in BOD_5 concentration of 2 mg/L (median value for 1999 is 3.7 mg/L while that for year 2000 is 5.7 mg/L). Considering the median flow of Mahaweli River (2,046,000 m^3/d at Peradeniya for 1990-1999) this amounts to an increase of approximately 4,000 kg BOD_5/d or an equivalent increase of waste from approximately 80,000 population at Peradeniya, which is highly unlikely, assuming that the unit mass loading rate is 50 g BOD_5/capita/day.

Possible cause of this unusual increase of BOD_5 at Mahaweli River at Peradeniya lies with the sampling and analysis methods.

There are four laboratories in Kandy area capable of carrying out BOD_5 analysis and several others in Colombo. Laboratories in Kandy area are as follows:

- NWS&DB RSC-Central Laboratory
- Department of Chemistry, University of Peradeniya
- Faculty of Engineering, University of Peradeniya
- Institute of Fundamental Studies (IFS)

There is a need to standardise laboratory measurements among these laboratories and with laboratories in Colombo, analysing parallel samples.

5.2 Water Quality and Flow Investigation in This Study

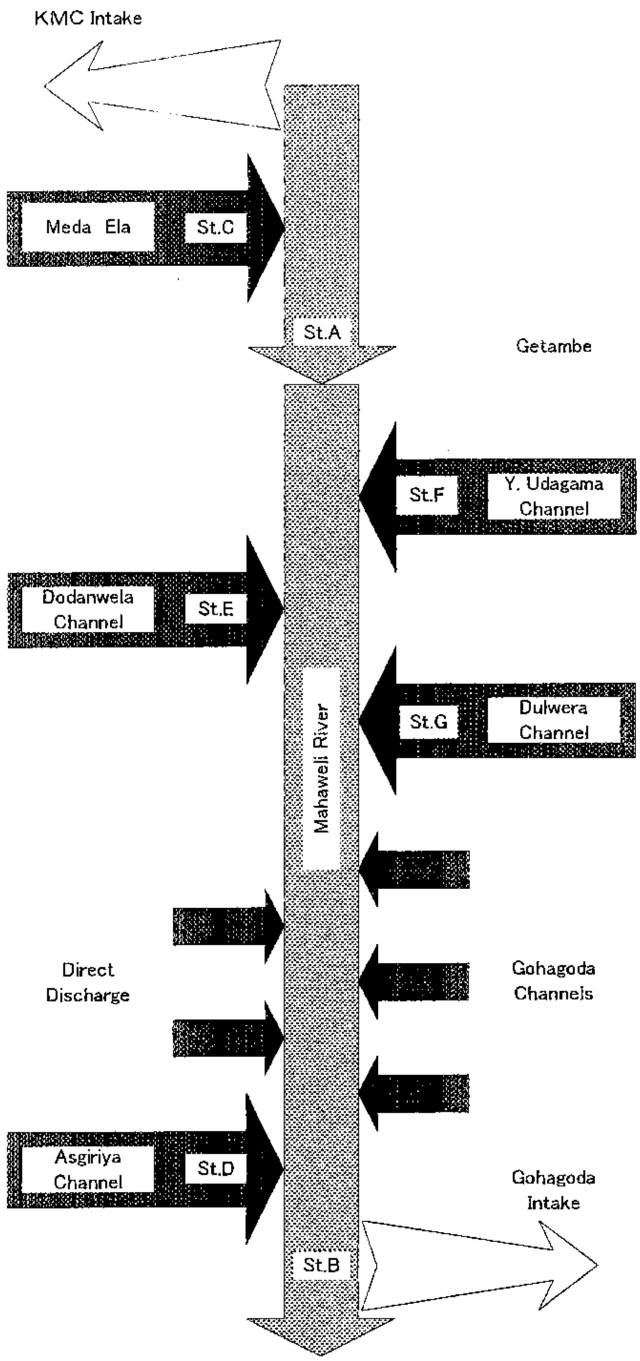
5.2.1 Monitoring Program

The Study Team carried out water quality analysis and river flow measurement examination to clarify the present relationship among the pollutant loading of the selected points as schematised in Figure 5.4. The water sampling was conducted on 2, 9, and 18 March 2001 at the following locations on the Mahaweli River and its tributaries. The examined water quality parameters were temperature, pH, suspended solids (SS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (T-N), total phosphorous (T-P), and T-coli and F-coli. A total of 174 samples were analysed from each sampling station as shown in Table 5.5.

- St. A Mahaweli River 500 m downstream of the confluence of the Meda Ela (hereinafter referred to as "Getambe")
- St. B Mahaweli River around the proposed Gohagoda Intake ("Gohagoda")
- St. C Meda Ela 100 m upstream of the confluence of Mahaweli River ("Meda Ela")
- St. D Asgiriya channel at the cascade bottom near the confluence of the Mahaweli River ("Asgiriya")
- St. E Dodanwela channel 100 m upstream of the confluence of the Mahaweli River
- St. F Dulwera channel at the crossing of National Road B
- St. G Y. Udagama channel at the crossing of National Road B

In connection to the water quality at Getambe (St. A), Gohagoda (St. B), Meda Ela (St. C), and Asgiriya (St. D), flow measurement was conducted from 9 March to 10 April 2001 as shown in Table 5.6 to estimate major pollutant loading. River flow measurement at survey points, Getambe (St. A) and Gohagoda (St. B) was conducted three times in deferent days and the frequency of flow measurements were every six hours and at survey point Meda Ela (St. C) and Asgiriya (St. D) were every two hours for 24 hours. The flow rate was estimated by (measured flow rate at 10 sub-sections) x (sectional areas which is computed based on the measured widths and depths).

Figure 5.4 Selected Sampling Stations



5.3 Summary of Water Quality Analysis and Flow Measurement in This Study

The results of the water quality analysis and flow measurement at the Mahaweri River and its tributaries conducted by the Study Team are shown in Table 5.5 and Figure 5.5, which are summarised as follows:

(1) The water quality of the Mahaweli River at Getambe is 15.8 mg/L in SS, 3.0 mg/L in BOD and 18.2 mg/L in COD on median. The BOD concentration recorded the lowest value in the past annual average since 1993 in spite of its location downstream of the confluence with the Meda Ela and the dry weather condition

(2) At the proposed Gohagoda Intake, the BOD concentrations are different in cross-sectional locations, namely 3.4 mg/L on the left bank, 3.1 mg/L in the middle and 3.6 mg/L on the right bank on average, while 3.6 mg/, 2.9 mg/L and 3.1 mg/L on median, respectively.

(3) The water quality at Gohagoda is 10.8 mg/L in SS, 2.8 mg/L in BOD and 22.0 mg/L in COD on average. SS and BOD values are lower than those at Getambe.

(4) The BOD concentration of the Meda Ela is low as 13.7 mg/L on average in comparison with high COD concentration of 86.8 mg/L. The BOD/CODCr ratio is 0.16, which is rather deviated from the experienced value of 0.4 to 0.8 for domestic wastewater.

(5) At the Meda Ela the rates of mass loading entering the Mahaweli River to the estimated mass loading generated within its reach are 8.7% for SS, 5.7% for BOD and 51.2% for COD.

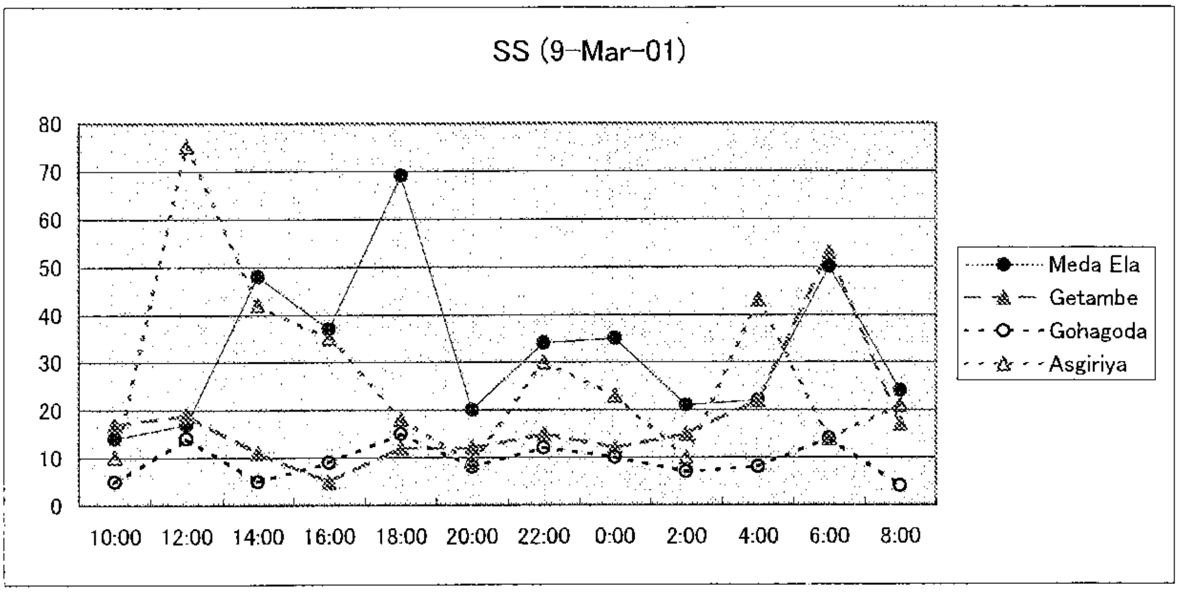
(6) The own flow of the Meda Ela is estimated at 16,000 m^3/day, while the sewage inflow to the Meda Ela at 1,500 m^3/day. The sewage flow generated within the Meda Ela reach is predicted at 9,871m^3/day, only 15.2% out of which is collected by the Meda Ela. It suggests that most of sewage infiltrates the ground and some evaporates into the air before reaching to the Meda Ela or its tributaries.

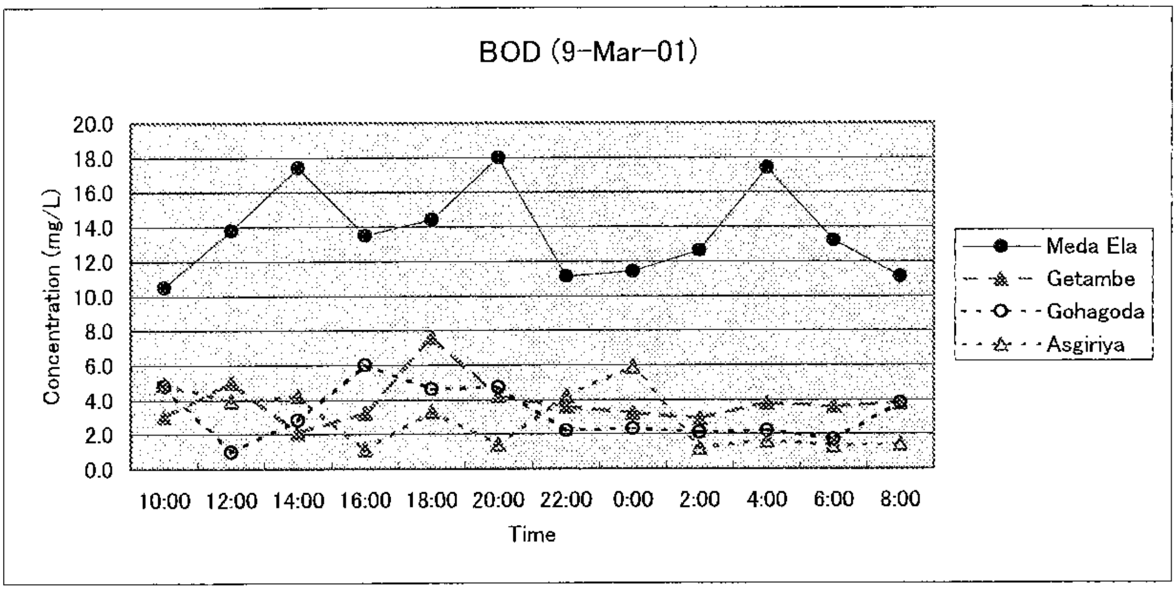
(7) At the Asgiriya Channel, the sewage inflow is observed and the BOD concentration varies 1.1 to 6.0 mg/L with an average of 3.4 mg/L. The rate of BOD mass loading entering the Mahaweli River to the estimated mass loading generated within its reach is only 1.5%.

(8) Other small streams joining the Mahaweli River between Getambe and Gohagoda have less affect on the proposed Gohagoda Intake than the Asgiriya Channel in quantity and quality.

Table 5.5 Results of Water Quality Analysis on the Mahaweli River

Date		Tair (°C)	Twater (°C)	pH	SS (mg/L)	BOD (mg/L)	CODCr (mg/L)	T-N (mg/L)	T-P (mg/L)	T-Coli (1/100mL)	F-Coli (1/100mL)
Meda Ela											
2-Mar-01	Max	32	30	7.7	23	17.4	180	12.98	1.19	71,000	32,000
	Min	18	22	6.3	6	10.4	8	4.71	0.46	10,100	4,700
	Ave	26	25	7.0	12	13.7	64	8.63	0.73	28,800	11,500
9-Mar-01	Max	32	29	7.6	69	18.0	188	12.36	1.14	52,300	23,600
	Min	22	22	6.5	14	10.5	44	4.56	0.42	2,400	200
	Ave	26	25	7.2	33	13.7	110	7.99	0.80	19,200	7,600
Overall	Max	32	30	7.7	69	18.0	188	12.98	1.19	71,000	32,000
	Min	18	22	6.3	6	10.4	8	4.56	0.42	2,400	200
	Ave	25.7	24.6	7.1	22.5	13.7	86.8	8.31	0.76	24,000	9,500
	Median	24.0	24.0	7.1	19.0	13.2	72.0	7.84	0.80	19,600	6,350
Getambe											
2-Mar-01	Max	29	26.5	7.4	24	6.0	32	2.86	1.06	7,200	3,800
	Min	20	21	6.4	12	1.2	8	0.98	0.34	2,800	200
	Ave	25	24	7.0	15	3.4	16	1.84	0.57	4,800	1,300
9-Mar-01	Max	33	25	7.8	53	7.6	24	2.76	1.06	32,300	12,700
	Min	22	22.5	7.0	5	2.1	8	1.34	0.38	3,800	100
	Ave	26	24	7.3	18	3.8	16	1.89	0.60	11,500	3,800
18-Mar-01	Max	34	28	7.5	29	5.4	32	2.86	0.96	17,000	6,500
	Min	22	22	6.9	4	0.7	8	1.34	0.56	3,500	800
	Ave	26	24	7.2	15	1.7	23	1.96	0.71	7,200	2,500
Overall	Max	34	28	7.8	53	7.6	32	2.86	1.06	32,300	12,700
	Min	22	22	6.9	4	0.7	8	1.34	0.38	3,500	100
	Ave	25.7	24.2	7.1	15.8	3.0	18.2	1.90	0.63	7,800	2,500
	Median	24.5	24.0	7.1	13.0	3.0	16.0	1.86	0.61	6,100	1,400
Gohagoda (Sample at rhe Left Bank and Composite Sample)											
2-Mar-01	Max	32	29	7.6	24	5.1	32	3.50	1.06	11,700	4,200
	Min	18	24	6.2	6	1.8	10	1.56	0.34	2,600	100
	Ave	25	26	7.1	12	3.7	20	2.23	0.57	5,200	1,600
9-Mar-01	Max	32	27	7.7	15	6.0	64	2.56	0.98	20,000	8,800
	Min	22	23	6.9	4	1.0	8	1.34	0.40	4,200	200
	Ave	26	25	7.3	9	3.2	28	1.98	0.59	7,700	2,000
18-Mar-01	Max	34	25	7.5	16	3.7	28	2.46	0.96	16,700	7,800
	Min	22	22	6.6	5	0.4	8	1.26	0.48	2,400	100
	Ave	26	24	7.1	11	1.6	18	1.86	0.68	7,200	1,600
Overall	Max	34	27	7.7	16	6.0	64	2.56	0.98	20,000	8,800
	Min	22	22	6.6	4	0.4	8	1.26	0.40	2,400	100
	Ave	25.9	25.0	7.2	10.8	2.8	22.0	2.02	0.61	6,700	1,700
	Median	25.0	25.0	7.2	10.0	2.3	20.0	1.92	0.58	5,650	1,200
Asgiriya											
2-Mar-01	Max	32	28	7.8	46	6.0	124	4.34	1.06	17,200	16,000
	Min	19	21	7.1	17	1.2	8	1.26	0.34	7,100	300
	Ave	26	24	7.6	28	4.0	33	2.25	0.50	10,500	5,000
9-Mar-01	Max	34	26	8.1	75	5.9	124	2.56	1.10	26,700	11,400
	Min	22	21	7.4	9	1.1	8	1.12	0.44	3,800	200
	Ave	26	23	7.8	28	2.9	49	1.60	0.63	11,800	3,900
Overall	Max	34	28	8.1	75	6.0	124	4.34	1.10	26,700	16,000
	Min	19	21	7.1	9	1.1	8	1.12	0.34	3,800	200
	Ave	25.9	23.4	7.7	27.8	3.4	40.7	1.92	0.57	11,200	4,500
	Median	25.5	23.5	7.7	24.0	3.4	32.0	1.69	0.50	9,700	3,000
Dodanwela											
18-Mar-01	12:20	29	25	7.2	16	1.2	24	1.69	0.84	7,400	3,300
	20:20	28	25	7.0	10	3.2	32	3.06	0.78	11,200	3,300
Dulwera											
18-Mar-01	11:30	32	23	7.5	20	0.4	32	1.69	1.02	9,700	2,100
	19:30	30	27	7.2	30	0.6	32	1.42	0.96	9,400	2,100
Y. Udagama											
18-Mar-01	11:50	29	25	7.2	20	1.4	24	1.42	1.12	13,000	6,600
	19:50	28	25	7.0	28	1.2	32	1.69	1.04	13,100	6,800





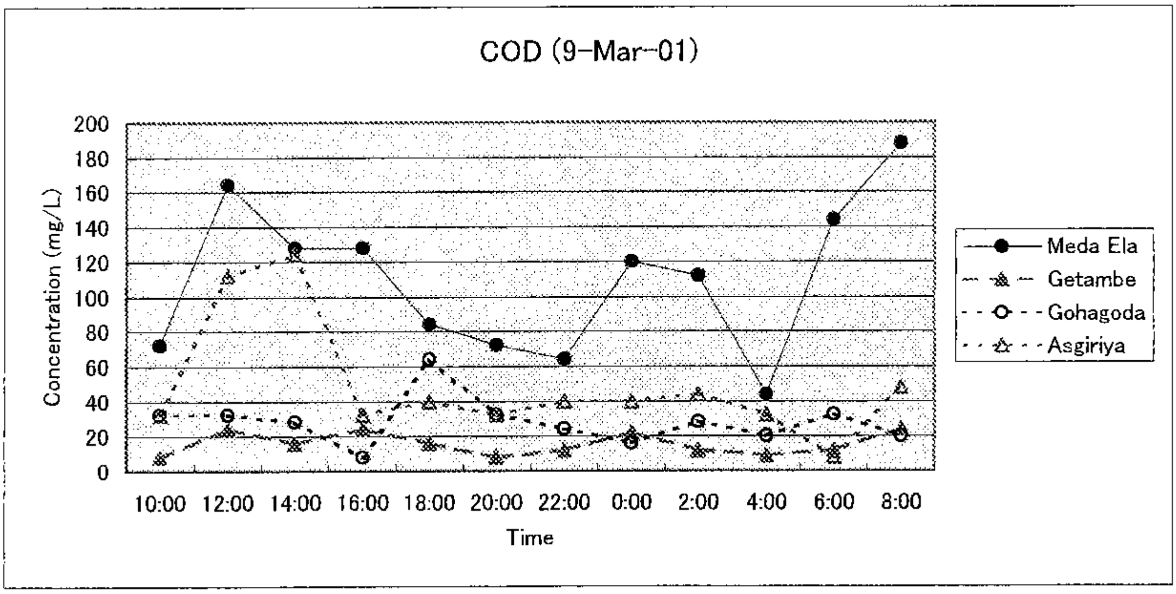


Figure 5.5 24-Hour Water Quality Examination (9 March 2001)

5.4 Study on the Laboratory of NWS&DB RSC-Central

The Mahaweli River is the longest river with the biggest watershed in Sri Lanka and there is little town upstream of the Greater Kandy. Hence, it is considered that the Mahaweli River is hardly polluted artificially. The BOD5 concentration of such not artificially polluted river is 0.5 to 1.0 mg/l in general. However, there were some extraordinary values in the past water quality analysis.

- The past water quality data of the Mahaweli River conducted by NWS&DB RSC-Central Laboratory is in the range of 3.7 to 5.7 mg/L in BOD5 during the period of 1993 to 2000 and the BOD concentration rose to 5.7 mg/L in 2000 from 3.7 mg/L in 1999.
- There were some extraordinary values especially in BOD5 in the results of the water quality surveillance program of the Mahaweli River on a weekly basis commenced from March 2003.
- In the first field survey of this Study, the water quality was cross-checked using the same samples of the Mahaweli River between NWS&DB and Peradeniya University. There were obviously a big gap in BOD5.

For these reasons, the analytical method etc. at NWS&DB Laboratory was studied with some doubt

5.4.1 Analytical Method

The results of the Mahaweli River Water Quality Monitoring Program started in March 2001 by NWS&DB have also shown the abnormal values on the weekly basis and threw doubt both on the analytical method and sampling points

The analytical methods and glasses and instruments used for the analysis of parameters such as pH, SS, BOD5, COD, NH4-N, PO4-N and E coli. were checked and it reveals that for the BOD5 analysis the following manner is different from the ordinary manner generally accepted.

(1) It is desirable to shake the bottle about 30 times for adequate mixing after pouring the sample and dilution solution in the bottle and plugging it. But the practice of NWS&DB is only three times.

(2) NWS&DB uses the DO bottle for the BOD analysis due to its unavailability with inserting a strip of paper at the bottle mouth so as to facilitate the plug removal.

(3) It is common to use the distilled water for dilution in the BOD analysis, but NWS&DB uses the ion-exchanged water due to no distilled-water product unit.

(4) The dilution rate is changed in accordance with the estimated BOD_5 concentration of the sample and The dilution rate of NWS&DB, however, is usually five for the samples of the Mahaweli River.

To identify how much the above factors affect on the BOD5 concentration individually, the comparative tests are done for verification. Table 5.6 shows the affect of shaking times (above (1)), while Tables 5.7 and 5.8 indicate the affects of other factors (above (2) to (4)). The results of a series of tests are summarized as follows:

(1) Less shaking times has tendency to reduce the BOD_5 concentration but its affect is a little (Table 5.6).

(2) The use of ion-exchanged water instead of distilled water acts so as to reduce the BOD_5 concentration but its affect is a little (Sample B in Table 5.8).

(3) It is considered that there is no change in the BOD_5 concentration using the DO bottle for the BOD bottle as long as the sealing is complete. However the insertion of a strip of paper at the bottle mouth leads to the sucking of a inside water by the capillary phenomenon for evaporation and instead the oxygen supply by the air invasion, which makes the BOD_5 concentration lower. In the test, the formation of approximately 1 cm in diameter air bubble was observed and the influence varies 0.2 to 1.1 mg/l in the BOD_5 concentration (Sample C in Table 5.8).

(4) For a BOD_5 concentration of less than 4mg/l the sample receives no dilution in general, since the ammonia chloride contained in the dilution solution is nitrified by the action of nitro bactor in the sample at the low BOD_5 concentration, resulting in the overvalued BOD_5 concentration. The BOD_5 increase derived this nitrification is 5 mg/L at the maximum. In case of the sample from the proposed Gohagoda Intake, the analysed value was three to six times the actual one (Sample D in Table 5.8).

As a conclusion, although only the excessive dilution rate results in the overvalued BOD5 concentration, the magnitude of its affect exceeds largely those of other factors acting reversely. It is, therefore, considered that the analytical results of NWS&DB give the values larger than the actual ones as a whole.

Table 5.6 Affect of Shaking Times for DO Fixation on BOD_5 Concentration

Shaking Times		First Trial			Second Trial		
		1	2	Average	1	2	Average
NWS&DB	3 times	7.78	7.82	7.80	8.14	7.86	8.00
Standard	30times	7.82	7.84	7.83	8.16	8.18	8.17

Table 5.7 Affects of Other Factors（Meda Ela）

Factor	Standard/ Recommendation	Regular Analysis	NWS&DB		
		Sample A	Sample B	Sample C	Sample D
Type of water	Distilled water	Yes	No (Ion-exchanged water)	Yes	Yes
Type of bottle	Water-sealed incubation bottle	Yes	No (DO bottle)	No (Do bottle with a inserted strip)	Yes
Dilution rate	No dilution	Yes	Yes	Yes	No (50 times)
Shaking times	30 times	Yes	Yes	Yes	Yes
BOD_5	7 Feb. 2002	10.1	10.2	9.5	9.0
	12 Feb.2002	7.2	6.99	6.92	8.6
Remarks					No nitrification of NH_4-N in dilution solution

Table 5.8 Affects of Other Factors（Proposed Gohagoda Intake）

Factor	Standard/ Recommendation	Regular Analysis	NWS&DB		
		Sample A	Sample B	Sample C	Sample D
Type of water	Distilled water	Yes	No (Ion-exchanged water)	Yes	Yes
Type of bottle	Water-sealed incubation bottle	Yes	No (DO bottle)	No (Do bottle with a inserted strip)	Yes
Dilution rate	No dilution	Yes	Yes	Yes	No (5 times)
Shaking times	30 times	Yes	Yes	Yes	Yes
BOD_5	7 Feb. 2002	1.44	1.26	0.33	4.05
	12 Feb.2002	0.79	0.65	0.57	4.70
Remarks					Nitrification of NH_4-N in dilution solution

5.4.2 Sampling Point

The people near the water bodies have the custom to take bathing and washing in the water body using soaps. The proposed Gohagoda Intake is located in the stagnant water body of the Polgolla Dam and the water polluted by such bathing and washing flows slowly along the riverbank without mixing. Therefore, the water quality of the sample oftenly reflects such polluted river water due to water sampling within reach from the riverbank. The new sampling point was selected, which was the center of the suspension bridge 3.4 km upstream of the proposed Gohagoda Intake, in order to avoid the influence of such bathing and washing. The Mahaweli River enters into the rapids at 500 m downstream of the confluence with the Meda Ela and the Suspension Bridge is located at the entrance of the stagnant water body of the Polgolla Dam just after the rapids (see St. 3-2 in Figure 5.1).

Table 5.9 Water Quality of the Mahaweli River at the Center of the Suspension Bridge

(unit: mg/L)

Date	Sampling Point	Sampling Time						Ave.
		8:00	10:00	12:00	14:00	16:00	18:00	
02/02/08 11.00 m^3/s	Suspen. Bridge	0.8	0.8	0.9	1.0	1.0	1.3	0.97
02/04/04	Peradeniya	2.0	3.2	2.0	2.2	3.0	2.7	2.52
5.20 m^3/s	Suspen. Bridge	2.8	3.5	2.4	2.6	2.0	2.1	2.57
02/04/11	Peradeniya	0.9	0.5	0.6	1.1	0.7	0.7	0.93
18.50 m^3/s	Suspen. Bridge	0.9	1.3	0.9	0.8	1.1	0.8	1.11
02/04/17	Peradeniya	1.8	0.8	0.9	1.2	0.8	2.2	1.39
33.60 m^3/s	Suspen. Bridge	0.7	0.7	0.7	0.8	0.6	0.8	0.90
02/04/24	Peradeniya	0.5	0.6	0.5	1.5	0.4	0.7	0.89
36.50 m^3/s	Suspen. Bridge	0.5	0.4	0.4	1.0	0.8	0.7	0.83

Note:
The sample of 8 Feb. 2002 was analysed by the JICA Study Team and others by NWS&DB based on the improved analytical method.
The analysis by the JICA Study Team was in compliance with the Standard Method.
The analysis by NWS&DB uses the ion-exchanged water for distilled water as dilution water and DO bottles for BOD bottles, which is the best method that can be done using the available equipment in the Laboratory. The results may give slightly lower BOD concentration than the actual one but it is practicably no problem.
The figures below the date shows the flow of the Mahaweli River measured at the Peradeniya Gauging Station.

As shown in this results , the past water quality data of the Mahaweli River is rather lack of reliability and it is reasonable to consider that the BOD concentration will be in the range of 1 to 3 mg/L at present.

The Mahaweli River enters into the steep mountainous area upstream of the Greater Kandy. Therefore there is little possibility that the upstream area will be developed and the Mahaweli River will be polluted thereby. It is not too much to say that the future water quality of the Mahaweli River is dependent on the development of the Greater Kandy itself

CHAPTER 6 EFFECT OF POLLUTANT LOADS ON GOHAGODA WTP INTAKE

6.1 General

Purpose of this chapter is to forecast and evaluate water quality of Mahaweli River at proposed Gohagoda Intake for various scenarios. Information on pollutant load generation and release to receiving water in the Study Area, and water quality of Mahaweli River and its tributaries presented in the preceding two chapters will be utilised for these forecasts. Mahaweli River stretch under consideration is between Getambe where water intake of KMC is located and Gohagoda, where the proposed water intake will be located. Figure 6.1 shows the Mahaweli River and its tributaries. Major tributaries in the reach are:

Right Bank

1. Meda River
2. Dodamwela Stream
3. Asgiriya Stream

Left Bank

4. Yatihalagala Udagama Stream (shown as Y. Udagama Stream)
5. Dulwela Stream

6.2 Characterization of the River Reach

6.2.1 Topography

Tributaries to Mahaweli River in this reach are shown in Figure 6.1.

Mahaweli River flows along a mild slope between Peradeniya and Getambe. Average riverbed slope between Udu Yatinuwara Intake in Peradeniya (464 m above MSL) and KMC Intake at Getambe (460.5 m above MSL) is approximately 0.83 m/km. Thereafter, river flow becomes rapid through rocky riverbed for about 1.5 km downstream near the confluence with Y. Udagama Stream. Average riverbed slope is approximately 7 m/km. Further downstream, average riverbed slope becomes milder and is approximately 4 m/km for another 2.5 km. Thereafter, effect of Polgolla Dam on slowing the river flow and the accumulation of silt is evident. Between Polgolla Dam and suspension bridge, the Mahaweli Authority is monitoring riverbed levels.

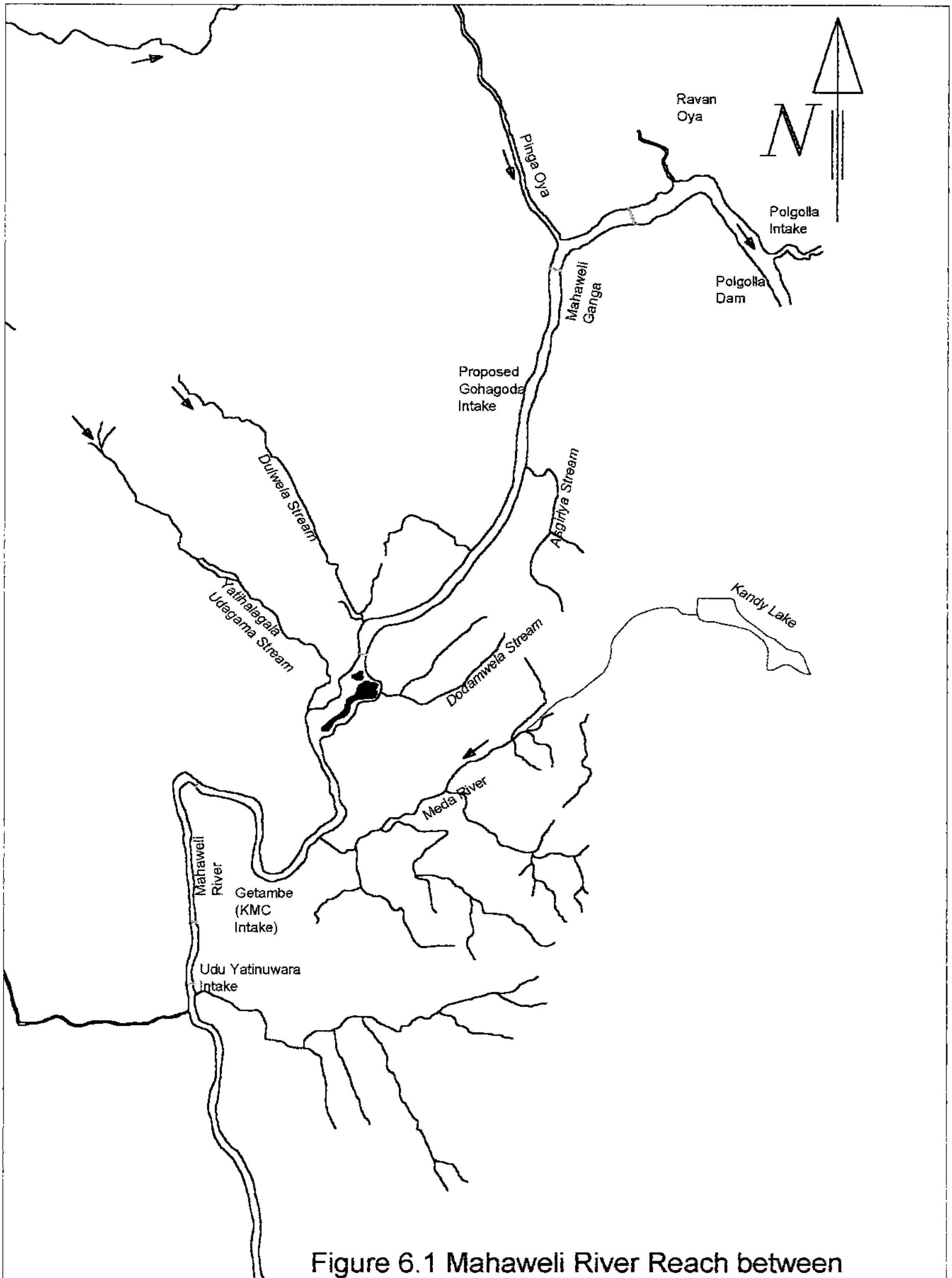


Figure 6.1 Mahaweli River Reach between Getambe and Proposed Gohagoda Water Intake

6.2.2 River Flow

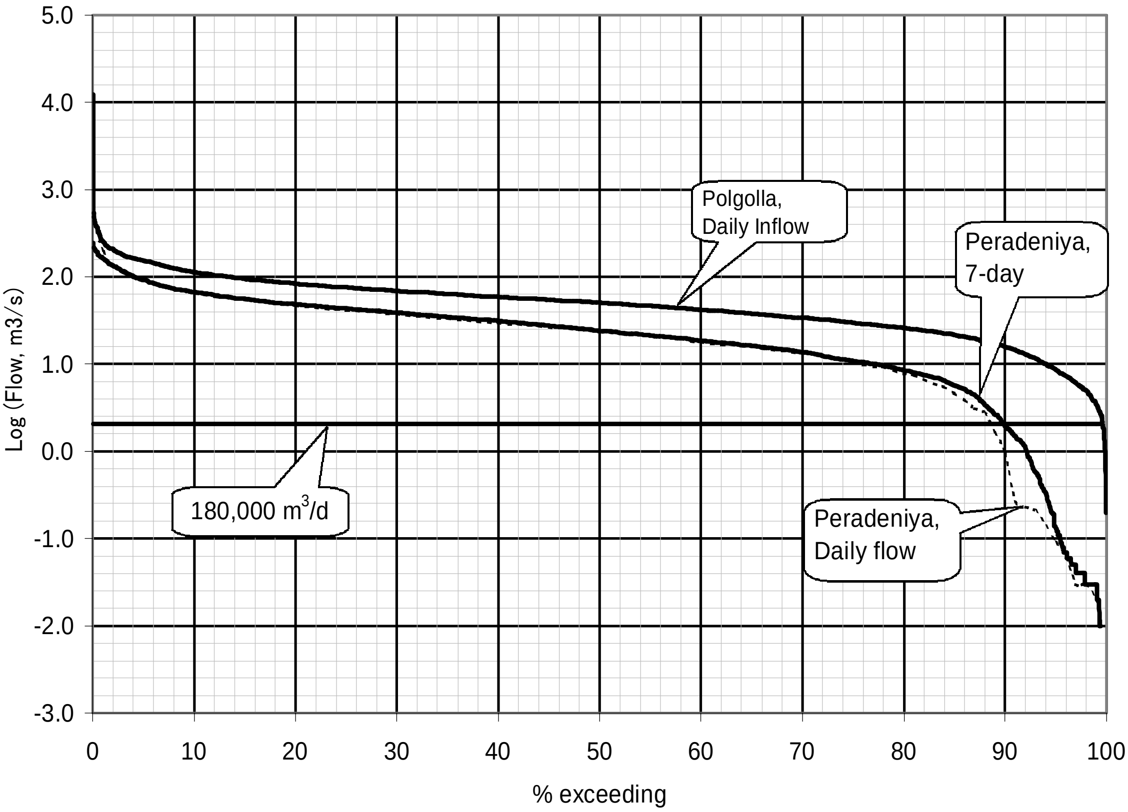
Flow of Mahaweli in the reach under consideration is regulated by the operation of Kotmale Dam and Polgolla Dam. River flow is monitored at Peradeniya Gauging Station by Irrigation Department daily and inflow to Polgolla Dam is estimated based on downstream release and flow for power generation.

Figure 6.2 shows the frequency of daily flow as recorded at Peradeniya Gauging Station (tributary area 1,168 km^2) between October 1990 and September 1999, 7-day average flow and inflow to Polgolla Reservoir (tributary area app. 1,292 km^2). Median value of flow at Peradeniya is 23.68 m^3/s or 2,046,000 m^3/d. For 7-day average, median flow is 24.57 m^3/s or 2,122,900 m^3/d.

Storage volume of Polgolla Reservoir is 4.1 MCM at normal operating level (at 440.7 m above MSL, surface area of 1.2 km^2) and the minimum storage volume is 2.0 MCM at 438.9 m above MSL (surface area of 0.7 km^2). Average retention time in Polgolla Reservoir is around 2 days based on the median flow at Peradeniya (23.68 m^3/s or 2,046,000 m^3/d) and the storage volume at normal operating level. However, silt removal of Polgolla Reservoir has never been carried out and the actual retention time can much lower than two days.

Proposed water intake at Gohagoda is 5.5 km downstream of KMC Intake at Getambe and within the Polgolla Reservoir under normal conditions. There is no other existing water intake within the river reach under consideration. KMC Intake at Getambe is located downstream of Peradeniya River Gauging Station. Intake capacity is 33,400 m^3/d.

Figure 6.1 Flow in Mahaweli River at Peradeniya and Inflow to Polgolla



Note : Mahaweli Flow at Peradeniya is for 1989/10/01 to 1999/9/30) – Data Source : Irrigation Department
Daily inflow to Polgolla 1990/01/01 to 2000/12/31 – Data Source : Mahaweli Authority of Sri Lanka

6.2.3 Pollutant Sources

Man-made activities and natural processes in the tributary areas to Mahaweli River contribute to the pollution of Mahaweli River and the pollutants reach through its tributaries. Some of the areas drain directly to Mahaweli River through storm drains most are unlined such as those between Dodamwela Stream and Asgiriya Stream (Area A) and that from the Gohagoda Area (Area D).

Major tributary is Meda River that drains major part of KMC and adjacent areas in the south and east. Table 6.1 shows the characteristics of tributaries.

Table 6.1 Characteristics of Tributaries to Mahaweli River

Tributary	Tributary Area, km^2	Average Population Density*, person/ha	Description
Meda River	19.31	36.2 (41.5)	Includes KMC area and its surroundings in the south east
(Gannoruwa STP service area)	6.74	67.4 (77.1)	Residential/commercial and institutional area. There are two existing communal STP's for Hantana and for the General Hospital. However, Hospital treatment plant is not functioning and the Hantana treatment plant is not functioning as intended.
(Outside Sewerage service Area)	12.57 (= 19.31-6.74)	19.6 (22.4)	Rural area
Dodanwela Stream	1.65	33.4 (38.2)	Residential area with a few small hotels/ inns.
Asgiriya Stream	1.18	33.7 (38.5)	Residential area with a few small hotels/inns. A hotel is in this tributary facing the Mahaweli River.
Y. Udagama Stream	4.28	13.7 (15.7)	Rural area
Dulwela Stream	3.25	15.4 (17.6)	Rural area
Asgiriya Area	0.70	11.8 (13.5)	Residential area draining directly.
Gohagoda Area	2.86	12.9 (14.8)	Residential and agricultural area with rural setting.
Total	33.23		

Note: Population density shown is for year 2001 and that in parenthesis is for year 2015.
Refer Appendix 3.2 for the description of environmental sanitation systems in the tributary areas other than that of Meda River.

There are two water intakes in the Mahaweli River upstream of the river stretch under consideration. They are Peradeniya University Intake and Udu Yatinuwara Intake. Treated effluent from Peradeniya Teaching Hospital that is located upstream of KMC Intake and is discharged to Meda River. However, when the treatment plant is not functioning it is discharged upstream of KMC Intake through a stream.

6.2.4 Model

Purpose of the modelling is to simulate water quality of Mahaweli River for different scenarios such as increase in water supply or discharge of wastewater effluent.

Simple one-dimensional steady-state model will be used. Open channel flow of Mahaweli River during low flow is assumed without the effect of Polgolla Reservoir, i.e at the lowest water level of Polgolla Reservoir. However, during normal flow conditions water quality in the Polgolla Reservoir will be affected by interactions within the reservoir.

Water quality constituents, mainly BOD_5 and DO are calculated based on dilution and first-order decay process.

Physically, river reach is divided into 500 m sections between Getambe and Proposed Gohagoda Water Intake. Figure 6.3 shows the schematic of computational model. It consists of two basic elements namely junction element and computational element. Inflow and extraction are allowed at the junction element. Simple mass balance is applied to obtain the flow and concentrations at the exit of junction element. Degradation processes of non-conservative contaminants and others, such as organic matter, are modelled to occur in the computational element. Point inflows are assigned to the junction element immediately downstream of their physical confluence with river. Following processes are modelled.

Organic matter: First-order reaction is used to describe deoxygenation of ultimate carbonaceous BOD in the river. BOD removal due to sedimentation, scour and flocculation is neglected.

Dissolved oxygen: Oxygen balance in the river depends on the capacity of river to reaerate itself. Source of oxygen is due to dissolved oxygen in the incoming flow and atmospheric reaeration. Sink of oxygen is due to biochemical oxidation of organic matter. Supply of oxygen due to photosynthesis and demand due to nitrogenous organic matter, sediment demand and algal respiration is neglected.

Total phosphorous: Removal of total phosphorous due to sedimentation is described by a first-order decay mechanism.

Faecal and Total Coliforms: Die-off of fecal and total coliforms is described by a first-order reaction.

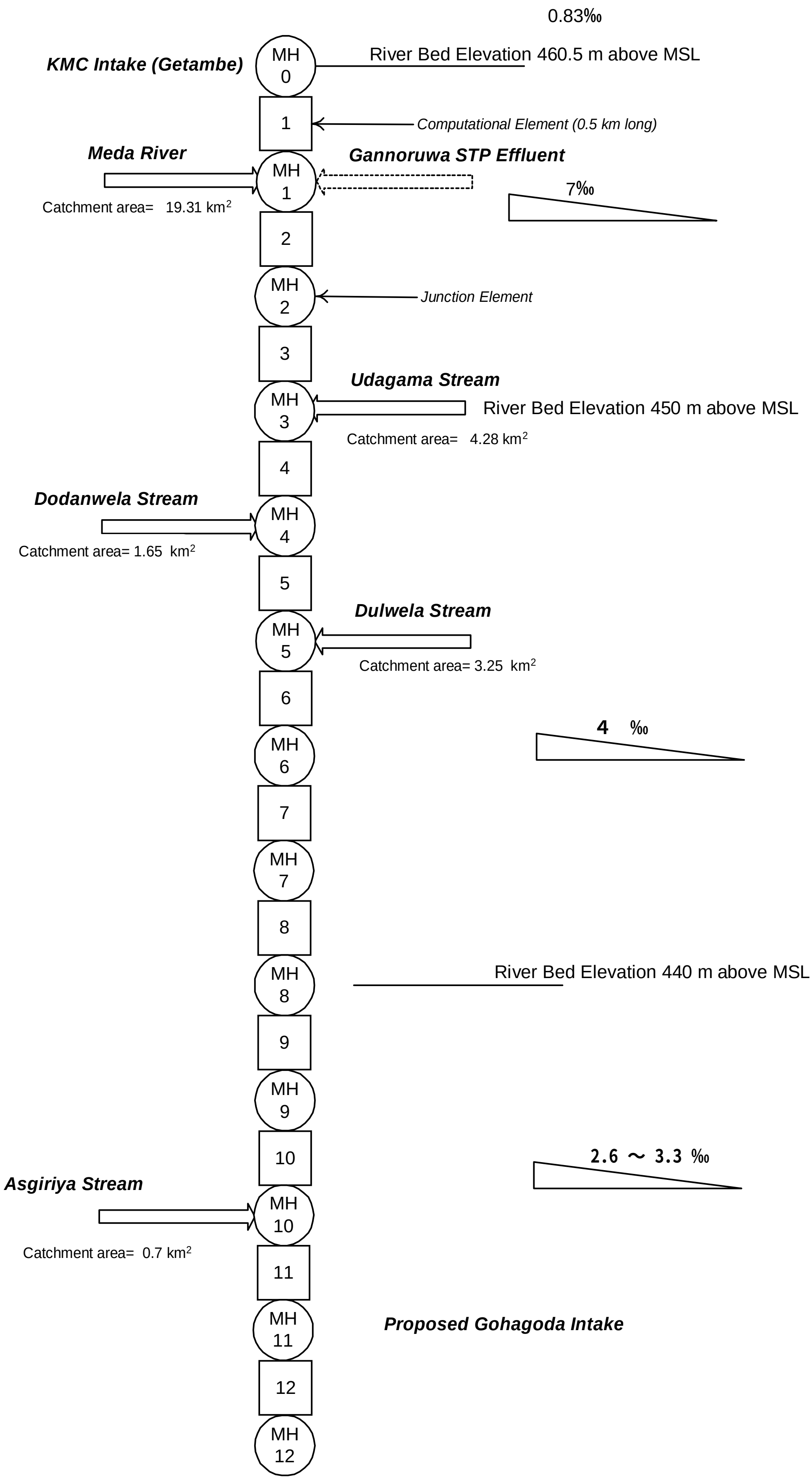


Figure 6.3 Schematic of Mahaweli River between Getambe and Proposed Gohagoda Intake

Appendix 6.3 shows the details of the water quality model used.

6.3 Forecast of Water Quality

Simulation of water quality requires input of several parameters and conditions. As discussed in the previous chapters, collection of regular data has commenced recently and requires refinement. Several assumptions are made with the available information.

6.3.1 River Flow

Extreme conditions in water quality occur during dry weather when the river flow is low and the analysis will be made for this condition assuming steady flow conditions.

Dry weather flow for analysis is generally based on the minimum flow for prospective use of river depending on economic considerations. Mahaweli River downstream of KMC Intake is used for consumptive uses namely irrigation and water supply.

Minimum weekly inflow of Mahaweli River to Polgolla Dam is determined to be 180,000 m^3/d except for extremely dry weather conditions. Mahaweli Authority, which regulates the flow of Mahaweli River has permitted NWSDB to abstract 180,000 m^3/d.

Minimum flow of Mahaweli River is taken as 180,000 m^3/d in the stretch between Getambe and proposed Gohagoda Intake for analysis.

Water quality can also deteriorate due to storms during which pollutants in the tributary are washed down with overland flow. These are discrete events and are not considered in this study.

The percentage of days when the daily flow of the Mahaweli River is below 180,000 m3/day is 11.3%, namely 41 days a year, and for the weekly flow 10.3% and 38 days a year, respectively. It should be noted that those days arise concentratedly in March and April as shown in Appendix 6.1, Vol. II-1, and make the situation more serious. Even in such a case, the river water is more or less diluted due to the location of the proposed Gohagoda Intake in the stagnant water body of the Polgolla Dam.

6.3.2 Guideline for Raw Water Quality for Water Supply

The guidelines for raw waterer quality for water supply in different countries are summarised in Table 6.2. They are the desirable standards defined in terms of the adaptability of water quality environmental standards and not in nature that, when the raw water quality exceeds the above standards, it requires the stoppage of intake.

In Japan, the normal treatment consisting of sedimentation, filtration and disinfection is applicable to BOD_5 of 1 to 2 mg/L (It is noted that the report, which was used for the establishment of standards, is based on the idea that BOD_5 of 2 mg/L can be treated by the slow sand filtration, and BOD_5 of 3 mg/L by the rapid sand filtration.). While EC standards, which is mostly applied to the international rivers, establishes BOD5 of 3 to 5 mg/L for the normal treatment and other countries such as India and Malaysia sets BOD_5 of 3 mg/L as well as Sri Lank, which sets BOD_5 of 3 mg/L in the draft stage.

BOD_5 of 3 mg/L is considered to be one criterion that the normal operation can be applied. As shown in the EC standards, it is possible to treat the water by the normal treatment even though BOD_5 exceeds 3 mg/L, however there is the possibility that the users complain the taste and odour when an extraordinary drought lasts.

6.3.3 Scenarios

When the river has the minimum flow of 180,000m^3/d, the water quality of the Mahaweli River is simulated under the different scenarios in the target year (2005 and 2015), the status of sewage works (no implementation, implementation of the Phase I project and implementation of the Phase II project) and water quality of the Mahaweli River itself (1 mg/L, 2 mg/L and 3 mg/L).

In this scenarios BOD5 of 1mg/L represents the present level and 2 and 3 mg/L present the deteriorated level

Asgiriya Stream and Dodamwela Stream drains areas which are not covered by the sewerage service and are with relatively high density of population compared to other unserved areas. Therefore, for Asgiriya Stream and Dodanwela Stream, pollution is assumed to reach BOD_5 of 8 mg/L with the provision of improved water supply. For Y. Udagama Stream and Dulwela Stream BOD_5 is assumed to reach 4 mg/L.

Approximate time of travel, from KMC Intake at Getambe to proposed Gohagoda Intake for different flows of Mahaweli River are estimated as follows:

180,000 m^3/d	-	6.3 hours
2,000,000 m^3/d	-	2.5 hours

TABLE 6.2 STANDARDS FOR DRINKING WATER SOURCE

Country	Class	pH	BOD (mg/L)	SS (mg/L)	DO (mg/L)	Total Coliform (MPN/100mL)	Adaptability
Japan	AA	6.5～8.5	≤1	≤25	≥7.5	≤50	water supply I - simple physical treatment, e.g. filtration
	A	6.5～8.5	≤2	≤25	≥7.5	≤1,000	water supply II - normal physical treatment, e.g. sedimentation and filtration
	B	6.5～8.5	≤3	≤25	≥5	≤5000	water supply III - extensive physical treatment with pre-treatment etc.
EC	A1	6.5～8.5	<3	25	>70 *	50	simple physical treatment and disinfection, e.g. rapid filtration and disinfection
	A2	5.5～9.0	<5		>50 *	5,000	normal physical treatment, chemical treatment and disinfection, e.g. pre-chlorination, coagulation, flocculation, filtration, disinfection (final chlorination)
	A3	5.5～9.0	<7		>30 *	50,000	intensive physical and chemical treatment, extended treatment and disinfection, e.g. chlorination to breakpoint, coagulation, flocculation, decantation, filtration, adsorption (activated carbon), disinfection (ozone, final chlorination)
India	A	6.5～8.5	2		6	50	drinking water source without conventional treatment but after disinfection.
	C	6.5～8.5	3		4	5,000	drinking water source with conventional treatment followed by disinfection
Thailand	1	n	n		n		conservation, not necessary pass through water treatment processes, require only ordinary process for pathogenic destruction
	2	5～9	1.5		6	5,000	consumption which require the ordinary water treatment process before uses
	3	5～9	2.0		4	20,000	consumption but have to pass through an ordinary treatment process before uses
	4	5～9	4.0		2		consumption but require special water treatment process before uses
Malaysia	I	6.5～8.5	1		7	100	water supply I - practically no treatment necessary (except by disinfection or boiling only)
	IIA	6～9	3		5～7	5,000	water supply II - conventinal treatment required
	III	5～9	6		3～5	50,000	water supply III - extensive treatment required
Philippines	AA	(a)					for public water supply
	A	6.5～8.5	10		5		for water supply requiring certain treatment
Sri Lanka	Drinking Water	6.5～8.5	2		6	50	simple treatment
	Drinking Water	5.0～8.5	3		4	5,000	conventional treatment

* dissolved oxygen saturation rate (%)
n naturally
(a) national standards for drinking water in the Philippines

Table 6.3 Etimated Water Quality of the Meda Ela

Scenario		現況	1-3	4-6	7-9	10-12	Remarks
Target Year		2001	2005	2015	2005	2015	
Sewerage Provision		No	No	Yes	Yes	Yes	
Sewage generated	(m^3/day)	8,961	9,960	14,297	9,960	14,297	(A), Table 4.6
Sewage treated	(m^3/day)	0	0	0	3,428	11,685	(B), Table 4.6
Sewage untreated	(m^3/day)	8,961	9,960	14,297	6,532	2,612	(C) = (A) – (B)
Flow of Meda Ela							
Own flow	(m^3/day)	16,000	16,000	16,000	16,000	16,000	Assumed based on measurement
Inflow of sewage	(m^3/day)	1,344	1,494	2,145	980	392	(C) x 0.15
Total	(m^3/day)	17,344	17,494	18,145	16,980	16,392	
BOD_5 loading							
Loading generated	(kg/day)	3,813	3,999	4,483	3,999	4,483	(D), Appendix 4.3
Loading treated	(kg/day)	0	0	0	1,319	3,406	(E), Appendix 4.3
Loading untreated	(kg/day)	3,813	3,999	4,483	2,680	1,077	(F) = ((D) – (E)
Loading to Meda Ela							
Natural loading	(kg/day)	0	0	0	0	0	Assumed to be zero
Inflow loading	(kg/day)	572	600	672	402	162	(E) x 0.15
Total	(kg/day)	572	600	672	402	162	
BOD_5 calculated	(mg/l)	33.0	34.3	37.0	23.7	9.9	
BOD_5 assumed	(mg/l)	33	34	37	24	10	

Note: According to the actual measurement, the rate of the sewage inflow to the Meda Ela to the sewage flow generated in the Meda Ela basin is 16.7 %, while the rate of the BOD_5 loading to the Meda Ela to the BOD_5 loading generated in the Meda Ela basin is 6.3 %. Although there is difference in inflow rates for quantity and quality, both are assumed at 15 % on the conservative side.

6.3.4 Results

Table 6.4 and Figures 6.4 and 6.5 shows the summary of BOD_5 variation in Mahaweli River for Scenarios 1 to 9. Scenario 5 represents the conditions in 2001 when quality of Mahaweli River is 4 mg/L at Getambe. Estimated concentration at Gohagoda varies between 3.93 mg/L for Scenario 9 and 5.11 mg/L for Scenario 7 when quality of Mahaweli River is 4 mg/L at Getambe. Former scenario is when sewerage service is provided for the master plan area with effluent quality of 20 mg/L and the latter is when there is no improvement in wastewater disposal.

Table 6.4 Results of the Simulation Analysis for Water Pollution in the Mahaweli

(unit: mg/L)

Target Year	Sewerage Provision	KMC Intake	Confluence with Meda Ela	Suspension Bridge	Proposed Gohagoda Intake	Scenario
2005	None	1.00	3.90	3.67	2.89	1
		2.00	4.79	4.50	3.54	2
		3.00	5.69	5.32	4.18	3
2015	None	1.00	4.27	4.01	3.18	4
		2.00	5.16	4.83	3.82	5
		3.00	6.05	5.65	4.47	6
2005	Phase I	1.00	3.25	3.07	2.45	7
		2.00	4.13	3.89	3.09	8
		3.00	5.01	4.69	3.72	9
2015	Phase II	1.00	2.76	2.62	2.10	10
		2.00	3.60	3.40	2.71	11
		3.00	4.45	4.18	3.31	12

The results of the Mahaweli River water quality simulation are summarized as follows:

Without sewerage

- When the water quality of the Mahaweli River is 1 mg/L in BOD_5, there is little problem in water quality at the proposed Gohagoda Intake. However, when it will be deteriorated by 2 mg/L, BOD_5 will increase by 3.54 mg/L in 2005 and 3.84 mg/L in 2015, respectively, at the proposed Gohagoda Intake.

With sewerage

- When the water quality of the Mahaweli River is within 2 mg/L in BOD_5, there is little problem in water quality at the proposed Gohagoda Intake. However, when it will be deteriorated by 3 mg/L, BOD_5 will increase by 3.72 mg/L in 2005 and 3.31 mg/L in 2015, respectively at the proposed Gohagoda Intake.

As described earlier, the past water quality data of the Mahaweli River is lack of reliability and cannot be used for reference in this Study. According to the new water quality data conducted on the improved analytical method, the averages of six samples taken every two hours a day were o.97, 2.57, 1.11, 0.90 and 0.83 mg/L in BOD5, respectively, and BOD5 of 2.57 mg/L was obtained that the river flow is about one-fifth the median flow. Therefore, it seems that the present water quality of the Mahaweli River is near to 1 mg/L . If this level of BOD5 will be kept, the presently adopted treatment process will be applicable, even though there will be some delay in sewerage provision. In case that water quality will be deteriorated by 2 mg/L in future, it is considered that presently adopted treatment process is still applicable, if being based on the EC standards, even though there will be some delay in sewerage provision. Although sewerage provision is important to keep the water quality of the Mahaweli River at the desirable level for normal water treatment, there is still lack of highly reliable water quality data throughout the year. The water quality for water supply at the proposed Gohagoda Intake is largely dependent on the development of the Greater Kandy itself, therefore it is strongly recommended that the water monitoring program will be continuously conducted for the Mahaweli River as well as the Meda Ela in future.

From the demographic viewpoint of the Mahaweli River (see Figure 6.6), it has a basin area of 10,327 km^2 equivalent to about one-sixth the national land with the longest length of 325km, and pours into the Bay of Bengal at Trincomalee. The river water is used for water supply, irrigation, power generation, industrial water supply, fishing, navigation, sand-mining, and people's bathing and washing, multi-purposely in the form of cascades, and is close to the people's living. In consideration of that the Greater Kandy is located in the most-upstream reach of the Mahaweli River and the largest city in its watershed, it is very significant to provide a sewerage system there.

As to the effect of wastewater from Asgiriya and Gohagoda Water Service Areas on the Mahaweli River, the existing and future wastewater generation from those areas does not affect the water quality at the proposed Gohagoda Intake significantly compared with the pollutant load in the Mahaweli River upstream of KMC Intake and that discharged through Meda River (or Gannoruwa STP effluent). The low population density, use of septic tanks at middle to high income housings and unlined drainage channels contribute to the relatively less pollutant load reaching the Mahaweli River.

Figure 6.4 Longitudinal Variation of BOD $_5$ Concentration in the Mahaweli River
(without Sewerage)

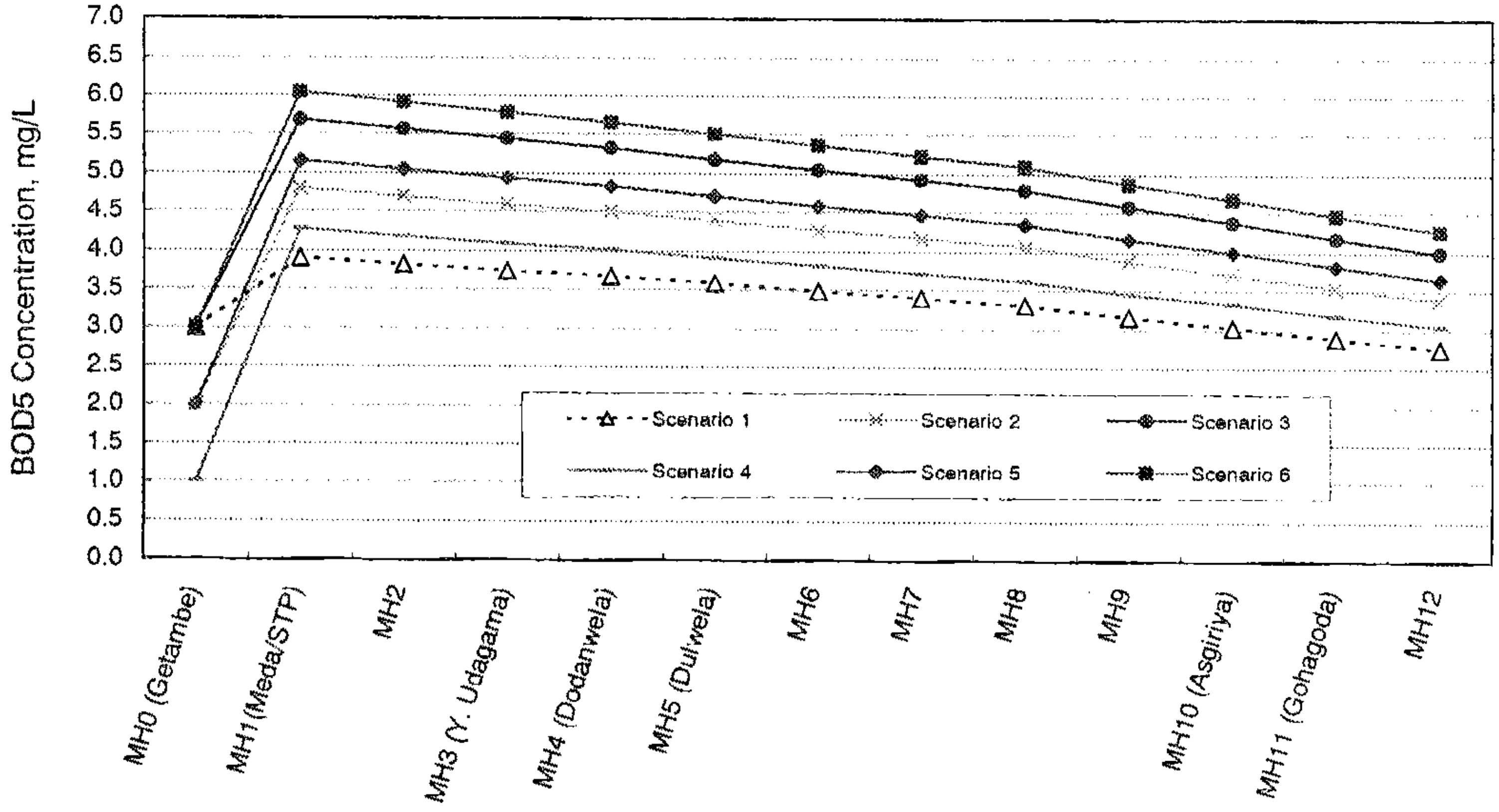
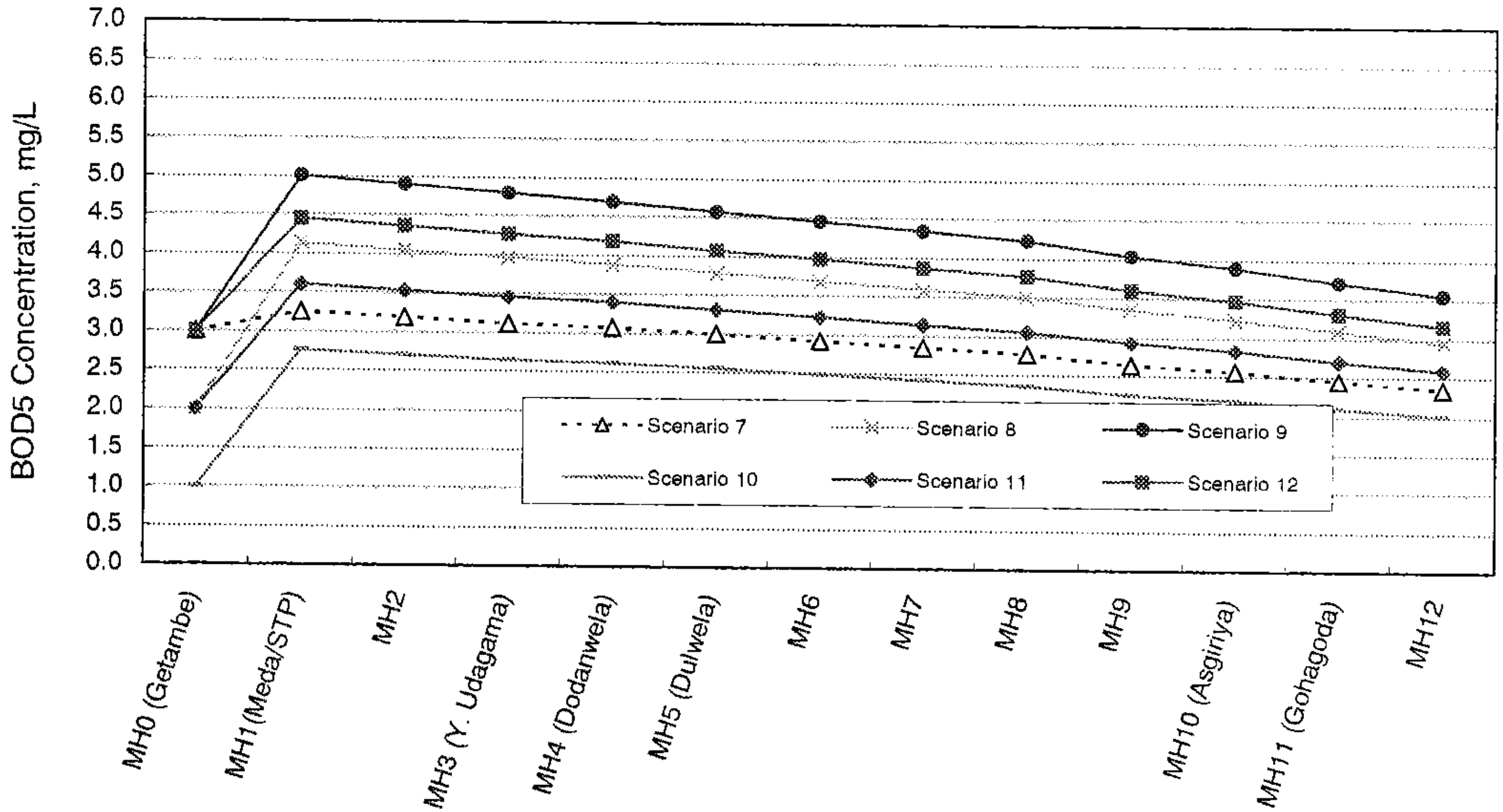


Figure 6.5 Longitudinal Variation of BOD_5 Concentration in the Mahaweli River (with Sewerage)



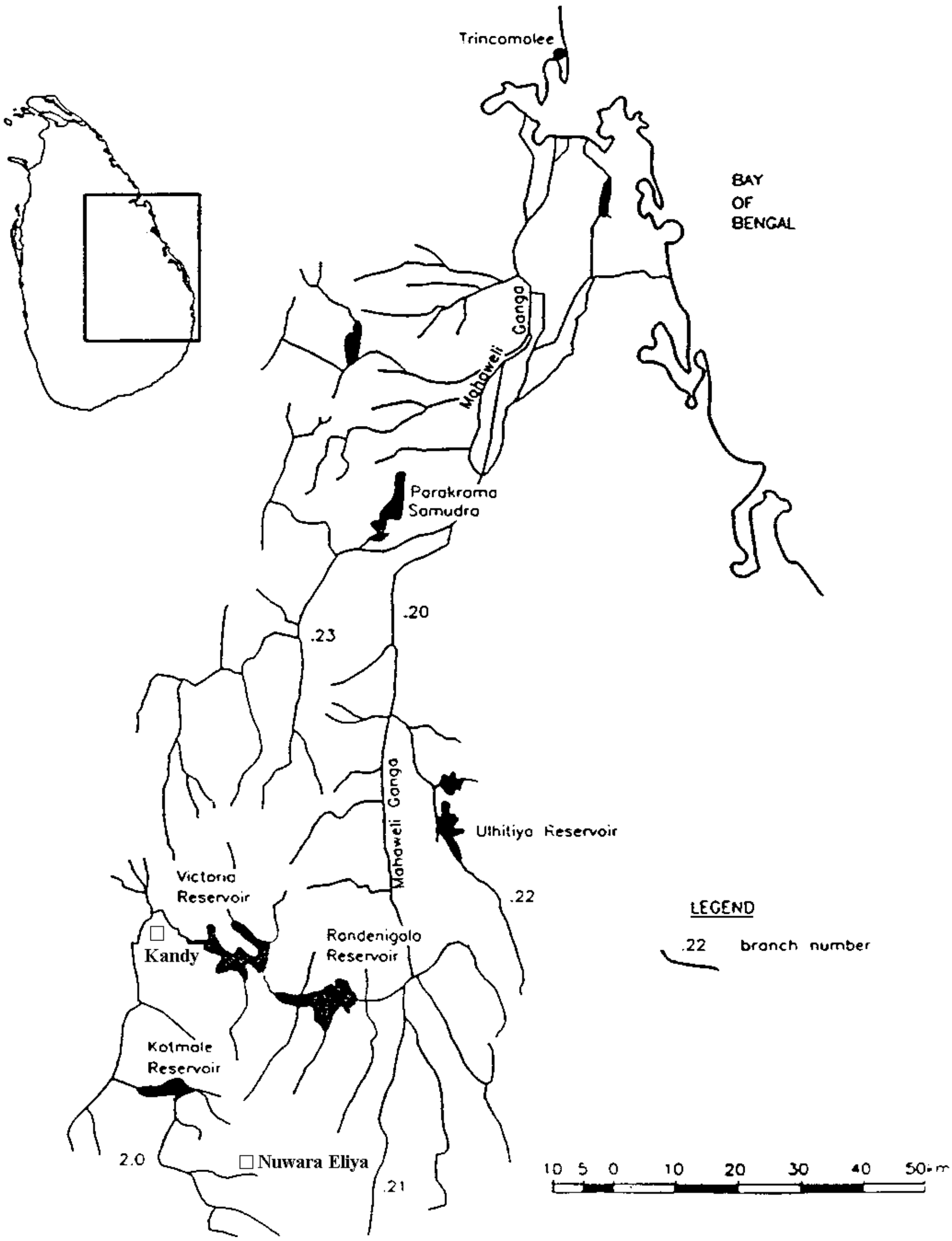


Figure 6.6 Mahaweli River Basin and Greater Kandy

CHAPTER 7 SEWERAGE MASTER PLAN REVIEW

7.1 General

A review of the sewerage system planning fundamentals regarding population, service area, design flows and proposed sites was carried out to evaluate the need for modifications to the preliminary sewerage system designs presented in the previous JICA Report.

7.2 Population and Wastewater Quantity

A review of the population data upon which the Sewerage Master Plan was based indicates that only minor changes in the available information have occurred since the previous JICA Report was completed. Therfore the population and wastewater quantity follows the figures as presented in the previous JICA Report.

7.3 Influent Quality

There is no basis for modification of the preliminary wastewater treatment designs presented in the previous JICA Report. The concentration is set at 240 mg/L in BOD5 and 250 mg/l in SS.

7.4 Effluent Standards

The preliminary wastewater treatment facility designs in the previous JICA Report were based on National Environmental Act (1980) standards which limit BOD and SS in treatment plant effluent to 30 mg/L and 50 mg/L, respectively. The standard for SS was subsequently reduced to 20 mg/L by NWSDB (letter from NWSDB Chairman dated 1 September 2000). However, it is recommendable to reduce the the standard for BOD to 20 mg/L for water source conservation based on the results in Chapter 6.

7.5 Wastewater Treatment Method

During preparation of the sewerage Master Plan, a site near Gannoruwa was identified as the location for the phase 1 wastewater treatment facility. At the time, it appeared that it might be possible to acquire additional land adjacent to that site, which opened up the possibility that the less expensive and easier to operate aerated lagoon process could be utilized instead of the oxidation ditch method. It has subsequently become apparent that additional land cannot be acquired and it has therefore become necessary to adopt the oxidation ditch process to conform to the limited land area available at the Gannoruwa site and to meet the more stringent effluent standard as mentioned above.

7.6 Pumping Stations

Due to the change in the location of a sewage treatment plant, a new in-manhole pump station is required to lift wastewater from the Bowala Area into the gravity sewer leading to the Getambe Pump Station. The Getambe Pump Station moved 1,080 m meters to the north east from the location as indicated in the previous JICA Report due to the availability of land.

To avoid the odour problem generated when carrying screenings and grit out, screenings and grit shall be removed at the sewage treatment plant. The Getambe Pumping Station therefore will not be provided with a grit chamber and screenings will be grinded to pump to the plant.

7.7 Disinfection Alternatives

Concern over the possible harmful effects on aquatic organisms or water supply intakes located downstream from the proposed wastewater treatment facility discharge point has resulted in the need for an evaluation of alternative disinfection methods. The most commonly used wastewater effluent disinfection methods worldwide are chlorination, ozonation or ultra violet irradiation. Of the three methods, only chlorination has been demonstrated to cause environmental problems downstream under certain conditions.

A detrimental effect on aquatic organisms as a result of the presence of residual chlorine has been demonstrated throughout the world. However, there is considerable evidence to indicate that the absence of mobile species, particularly fish, below effluent outfalls is a result of active avoidance rather than mortality. As such, the occurrence of lethal concentrations will differ considerably between rivers depending largely upon effluent volume and available dilution.

Due to the potential formation of trihalomethanes (THM) during effluent chlorination, the discharge of chlorinated effluents may adversely affect the quality of downstream water supplies. Chlorine reacts with naturally occurring organic compounds, such as humic and fulvic acid and algal products, to form THMs, including chloroform ($CHCL_3$), bromodichloromethane($CHCl_2Br$), dibromochloromethane($CHClBr_2$) and bromoform($CHBr_3$). THMs are considered potentially carcinogenic to man. In the case of wastewaters where a large array of organic compounds capable of being chlorinated exist, the range of chlorinated products may be very large. Factors affecting the formation of THMs include pH, chlorine dose, reaction time, temperature and the concentration of organic precursors. For conditions similar to those experienced in Sri-Lanka, total THM concentrations of 90. g/L - 70 . g/L have been reported. Recommended guidelines for THMs in drinking water range from 25. g/L (Germany), to 350 . g/L (Canada). A standard of 30. g/L maximum chloroform concentrations has been adopted by the WHO for “safe” drinking water. A guideline of 200. g/L has been approved by the National Health and Medical Research Council, Australia.

It is widely accepted that dilution is the predominant source of reduction in total residual chlorine level, with other phenomena (phototransformation, volatilization, physical or chemical reactivity) being responsible for the ultimate reduction in chlorine. The following dilution level standards for effluent are used in Queensland, Australia:

I The critical flow dilution equals zero:

In this case, obviously the worst possible situation, no effective dilution may occur, and chlorine residual levels in the receiving water body are likely to approach those in the sewage effluent. Free Chlorine residuals of between 0.3 and 0.7 mg/l could be expected immediately adjacent to an outfall. Conversion of free residual to the more persistent combined form would be highly likely. However, the potential exists for the maintenance of high total residual chlorine levels.

II The critical flow for dilution exceeds eight to ten times sewage flow:

Under these circumstances, dilution and diminution of chlorine residuals should occur at all times at a rate commensurate with the rate of lateral dispersion.

III The critical flow for dilution falls between zero and eight to ten times:

In this case, at worst, a certain reduction in chlorine level in the receiving water would occur, although not sufficient to produce levels of chlorine below those potentially toxic to aquatic organisms.

Since there is no information on required dilution factors under Sri-Lankan conditions, the standards used in Queensland, Australia have been used to examine the worst-case dilution condition. It is worthwhile to note that Sri-Lankan conditions are similar to conditions in Queensland during summer months.

If the minimum seven day average flow in the Mahaweli River at the water supply extraction point is assumed to be 180,000 m^3/day and effluent discharge is 15,800 m^3/day (phase 2 sewerage system development), then the dilution would be 11.4 times the wastewater discharge (180,000/15,800) which would fall within category II above, which is a sufficient level of dilution to avoid downstream water quality problems

The results of cost comparion as shown in Appendix 7.1 indicates that the initial investment is three times higher in ultra violet irradiation than in sodiu hypochlorite dosage, while the annual operation cost is cheaper in in ultra violet irradiation than in sodium hypochlorite dosage.

Although none of the three alternative disinfection methods would pose a threat to downstream aquatic life or water users, ozonation and ultra violet irradiation are significantly more expensive than chlorination. It is therefore recommended that chlorination be used to disinfect the Gannoruwa effluent.

7.8 Preliminary Design

The preliminary designs of the Master Plan and Priority plan sewerage systems have been revised to reflect the modifications discussed above (See Figures 7.1 to 7.3, Appendix 7.2 to 7.4).

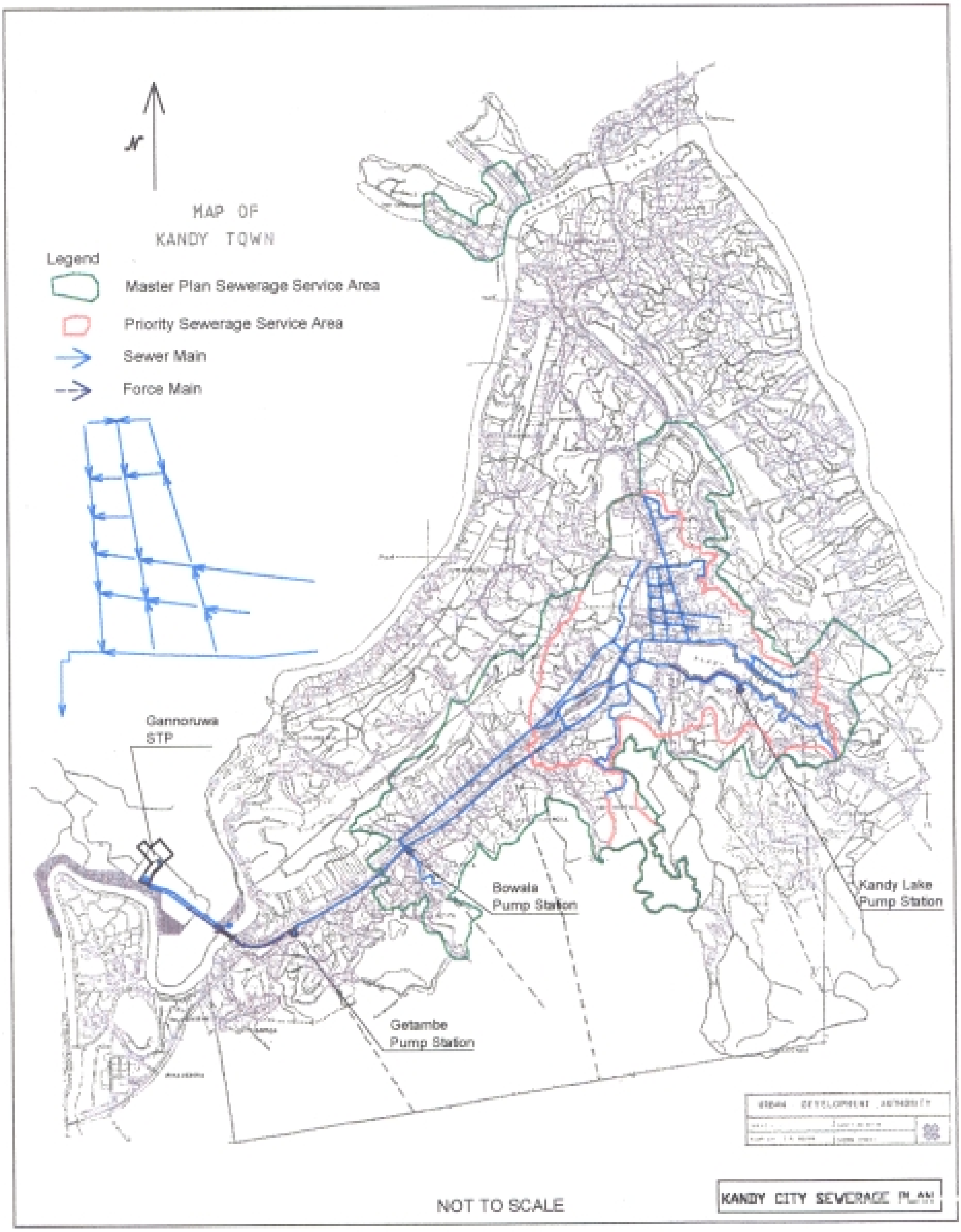


FIGURE 7.1 Kandy City Sewerage Plan

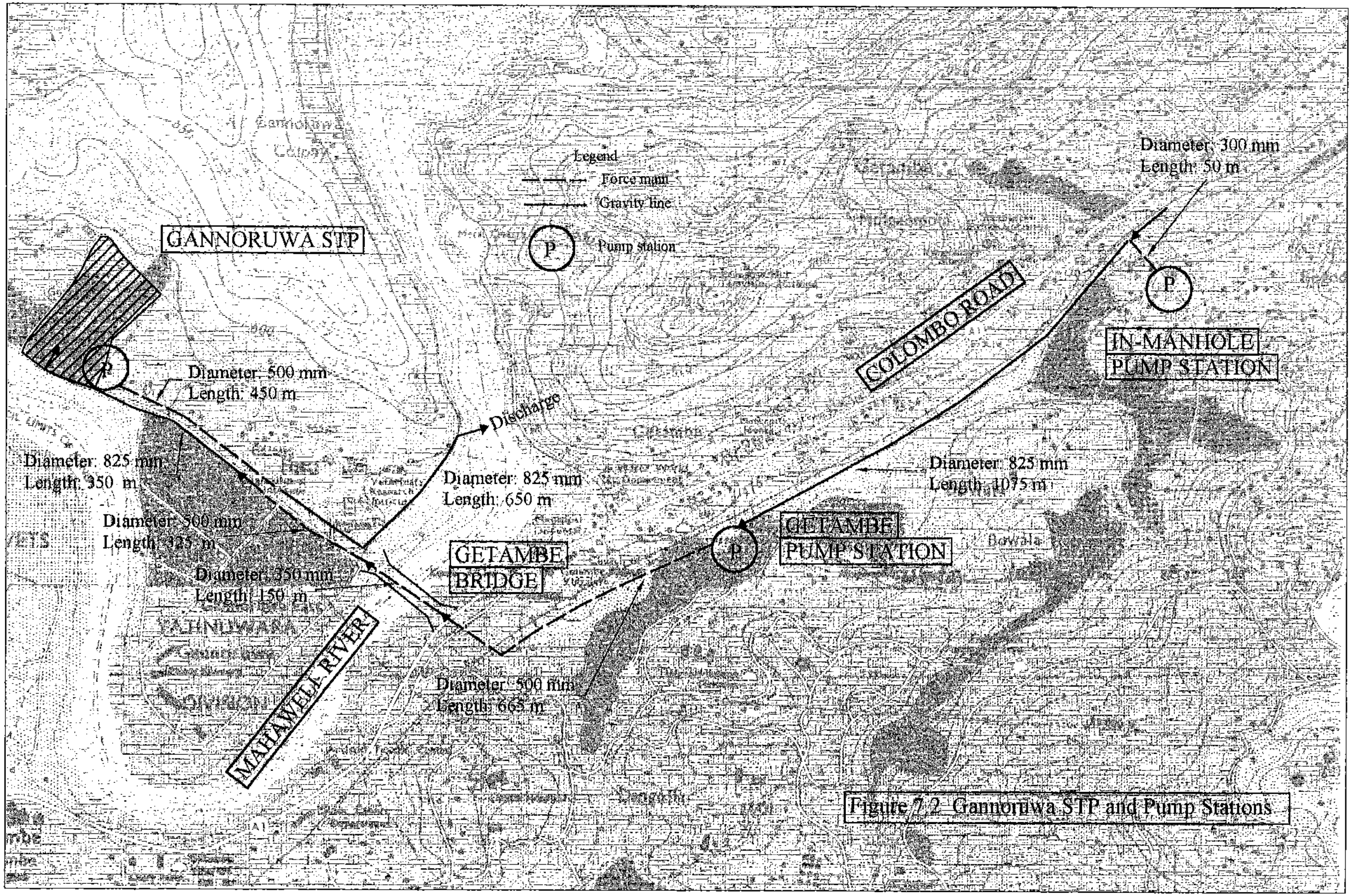


Figure 7.2 Gannoruwa STP and Pump Stations

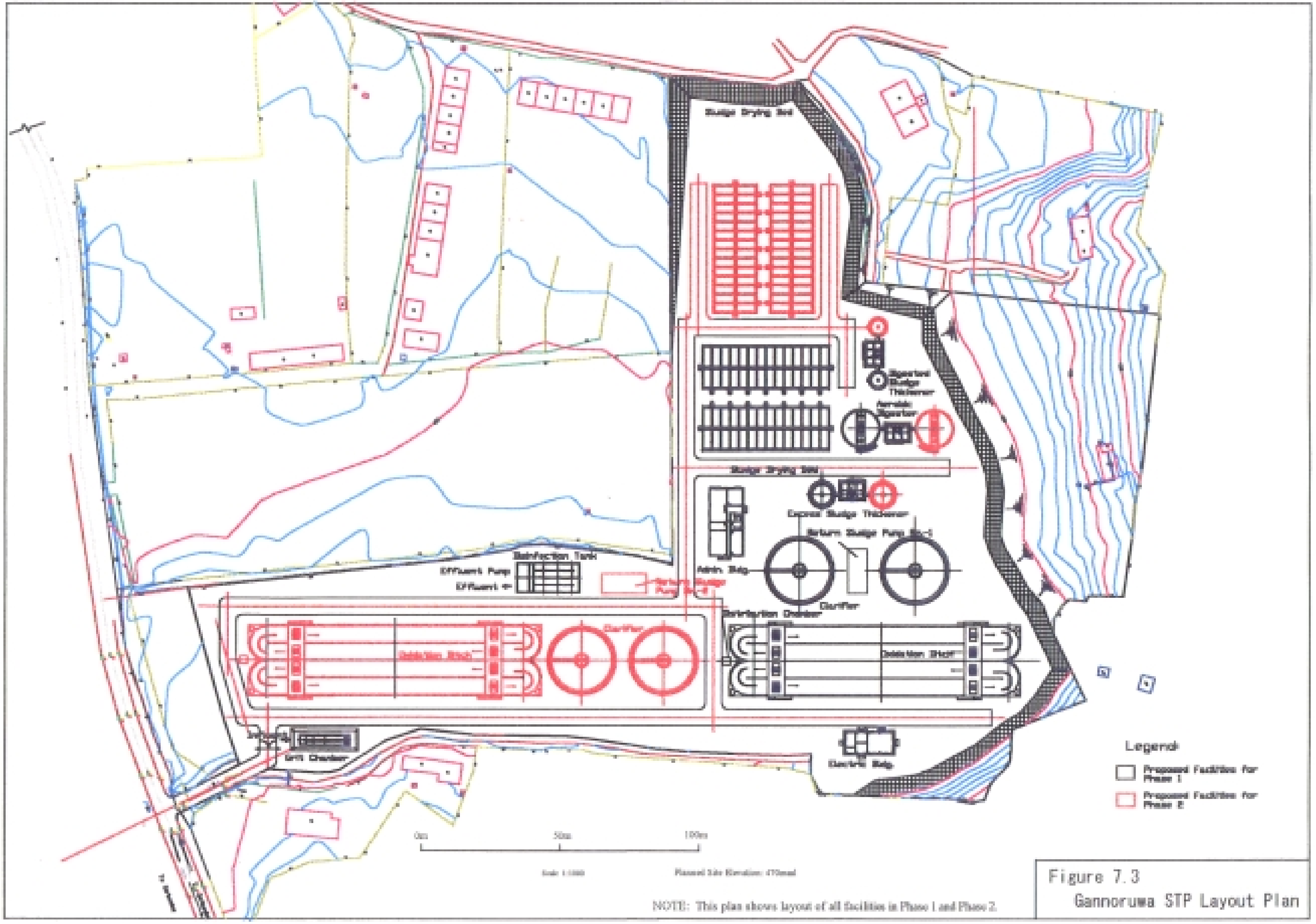


Figure 7.3
Gannoruwa STP Layout Plan

7.9 Project Cost

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

Total cost of the proposed project is estimated in Sri Lankan Rs. as follows:

Table 7.1 Project Cost of Kandy Sewerage Project

Unit: Thousand Sri Lankan s.

	M/P	Phase 1
(1) Construction cost		
1) Collection System	1,344,347	884,171
2) Pumping Station	72,963	62,573
Civil Work	14,658	13,170
Mechanical/Electrical Work	58,305	49,403
3) Sewage Treatment Plant	1,463,854	821,653
Civil Work	726,238	401,321
Mechanical/Electrical Work	737,616	420,332
4) Administration cost	93,872	52,966
Sub-Total	**2,975,036**	**1,821,363**
(2) Procurement of maintenance equipment	**32,000**	**32,000**
(3) Engineering cost		
1) Detailed design	104,000	60,000
2) Construction supervision	84,000	48,000
Sub-Total	**188,000**	**108,000**
(4) Common expenses		
1) General and administration expenses	20,000	10,000
2) Land acquisition	180,000	60,000
Sub-Total	**200,000**	**70,000**
(5) Contingency	**319,000**	**196,000**
(6) GST (12.5%)	**399,000**	**270,000**
Total	**4,113,036**	**2,497,363**

Note: Exchange rate: SL Rs. 1.00 = Japanese Yen 1.40 (as of December, 2001)

7.10 Reuse Plan of Treated Wastewater

7.10.1 Water Quality Standards for Treated Wastewater Reuse

The water quality standards of WHO and U.S. EPA for treated wastewater reuse are shown in Tables 7.2 and 7.3, respectively. The former provides the numbers of intestinal nematodes and faecal coliform as the microbiologicl quality guidelines for agricultural reuse, while the latter defines guidelines of pH, BOD_5, turbidity, SS and residul chlorine other than faecal coliform including those for groundwater recharge. The reuse of treated wastewater resultantly leads to the reduction in mass loading entering the Mahaweli River

Table 7.2 Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture (1989)

Category	Reuse Conditions	Exposed group	Intestinal nematodes (arithmetic mean no of eggs per litre [c])	Faecal coliform (geometric mean no per 100 ml [c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked sports fields, public parks	Workers, consumers,public	< or = 1	< or = 1,000 [d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, pasture and trees	Workers	< or = 1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminthes and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

a In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account, and guidelines modified accordingly.
b *Ascaris* and *Trichuris* species and hookworm
c During the irrigation period.
d A more stringent guideline (< or = 200 faecal coliform per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
e In case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprincler irrifgation should not be used.

Table 7.3 U.S. EPA Guidelines for Water Use (1992)

Type of Use	Treatment	Reclaimed Water Quality
Urban uses, irrigation of food crops eaten raw, recreational impoundments	Secondary, filtration, & disinfection	pH=6-9 ≤10 mg/L BOD ≤2 NTU [a] No detectable faecal coli./ 100 mL [b] ≥1 mg/L Cl_2 residual [c]
Irrigation of restricted access areas and processed food crops, aesthetic impoundments, construction uses, industrial cooling [d], environmental reuse	Secondary & disinfection	pH=6-9 ≤30 mg/L BOD ≤30 mg/L SS ≤200 faecal coli./ 100 mL [e] ≥1 mg/L Cl_2 residual [c]
Groundwater recharge of nonpotable aquifers by spreading	Site specific & use dependent, primary (minimum)	Site specific & use dependent
Groundwater recharge of nonpotable aquifers by injection	Site specific & use dependent, secondary (minimum)	Site specific & use dependent
Groundwater recharge of potable aquifers by spreading	Site specific, secondary & disinfection (minimum)	Site specific Meet drinking water standards after percolation through vadose zone
Groundwater recharge of potable aquifers by injection, augmentation of surface suppliers	Includes the following: secondary, filtration, disinfection, advanced wastewater treatment	Include the following: pH=6.5-8.5 ≤2 NTU [a] No detectable faecal coli./100 mL [b] ≥1 mg/L Cl_2 residual [c] Meet drinking water standards

a 24-hr average value. Should not exceed 5 NTU any time. Should be met prior to disinfection.
b Based on a 7-day median value. Should not exceed 14 faecal coli./100 mL in any sample.
c after a minimum contact time of 30 minutes.
d Recirculating cooling towers.
e Based on a 7-day median value. Should not exceed 800 faecal coli./100 mL in any sample.

7.10.2 Reuse Plan at Gannoruwa

The surrounding area of the proposed Gannoruwa Sewage Treatment Plant is owned by the Ministry of Agriculture and used as the pilot farms. For this purpose, there are a borehole in the river and wells for agricultural use as well as the irrigational distribution network.

Assuming that the required irrigation water volume is 3.0 m per annum for two irrigational seasons and each irrigational season lasts 90 days, the water volume is caluculated as follows:

3.0 m/year / (90 days/season x 2 seasons) = 16.7 mm/day

Add 25% water loss to the above, then,

16.7 mm/day x 1.25 = 20 mm/day

The crops as shown in Table 7.4 are cultivated in the pilot farms.

Table 7.4 Extent of Pilot Farms and Kinds of Cultivated Crops

Crop	Area	Growing season
Rice	2 ha (5 acres)	2 times
Brinjal	10 ha (1,000 m x 100 m)	2 times
Cabbage		
Capsicums		
Tomato		
Chili		
Pole beans		
Okra		
Snake Guard		
Bitter guard		
Lutta		
Wing bean		

The application rates to the land area are 100 % for rice and 30 % for other crops are assumed to estimate the required irrigation area.

2 ha x 1.00 + 10 ha x 0.30 = 5.0 ha

Accordingly, the irrigation water requirement is,

5.0 ha x 20 mm/day = 50,000 m^2 x 0.020 m/day = 1,000 m^3/day

The design capacity of a sewage treatment plant is 7,500 m^3/day for Phase I and has enough capavity to supply the irrigation water.

7.11 Environmental Impact Asssessment (EIA)

7.11.1 Legal background for EIA

As part of the study on the augmentation of water supply for Greater Kandy area and construction of a sewage treatment system, an IEE was completed in April 1998. This report was submitted for approval to JICA, the NWSDB, and the Central Environmental Authority (CEA) of Sri Lanka, which is the Government Agency responsible for issuing environmental licenses in the Country.

According to the order made by the Minister of Environment and Parliamentary Affairs by the powers vested in him under the Section 23Z of the National Environment Act No:47 of 1980 the proposed project is not a prescribed project requiring an EIA for approval. The Central Environmental Authority, after reviewing the IEE and considering the size and characteristics of different project components, had initially categorized this project as not prescribed and informed so by the letter dated August 21, 1998. Therefore, the NWSDB is not obliged to carry out an EIA study. Nevertheless, CEA recommended in-depth analysis on several aspects of the project components to minimize environmental impacts. Following this an EIA was submitted to the CEA for approval. Subsequently, the site of the STP has been changed. The presently proposed location is at Gannoruwa.

With this background JICA recommended that an EIA study be conducted for the STP at the proposed site in Gannoruwa following the Guidelines of JICA and JBIC in addition to conforming to the Sri Lanka Environmental Laws. The EIA will be very useful to obtain the environmental protection license that may be required under the existing laws and regulations.

The environmental protection license is required under the National Environmental (Amendment) Act No: 53 of 2000 and on the regulations published in Gazette Extraordinary 1159/22 of 22nd November 2000 prior to undertaking any prescribed activity. The regulations published in Gazette Extraordinary 1159/22 of November 2000 require that "Any common wastewater (sewage or industrial) treatment plant" is a "prescribed activity" which involve or result in discharging, deposition or emitting waste into the environment causing pollution.

In this sewage / wastewater treatment plant the effluent discharged in to Mahaweli Ganga can be considered non-polluting. In fact the quality of effluent from the STP is considered to be better than the wastewater carried in Meda Ela at present. However, to eliminate any controversy during construction and operation of Gannoruwa STP and discharging treated effluent to Mahaweli Ganga NWSDB must apply and obtain an Environmental Protection License from the Central Environmental Authority. The license is required one month prior to commencement of operation and shall be renewed every year.

7.11.2 Previous EIA studies

The only environmental Impact Assessment study carried out in the recent past is the study done in relation to the Greater Kandy and Nuwara Eliya Water Supply and Environmental Improvement Project of which the STP is a component. The particular EIA was cpmpleted in 1999. Based on this study the originally proposed site for the STP was abandoned and subsequently selected the new site at Gannoruwa.

7.11.3 Initial Environmental Examination

The Study Team has completed an IEE study for the STP at the proposed site at Gannoruwa in March 2001. In that study the direct impact areas identified are:

* Areas that will benefit from sewage service which are within Kandy Municipality
* Surrounding area of Gannoruwa STP
* Downstream of Mahaweli Ganga which will receive the treated effluent from Gannoruwa STP

The baseline information on the hydrology of Mahaweli Ganga and the water quality of Mahaweli Ganga at Peradeniya Intake, Getambe intake, downstream confluence of Meda Ela, proposed Gohagoda intake and Polgolla intake were studied. In addition the IEE address the aesthetic importance of Kandy Lake and the water quality of the lake and Meda Ela. Meda Ela is one of the potential threats to the water quality of Mahaweli Ganga.

The IEE study identified 23 environmental parameters and based on the JICA guidelines their impacts were evaluated. The IEE recommended further study on 8 of them. The present study has been designed to evaluate primarily these parameters.

- Loss of revenue from paddy cultivation
- Traffic Congestion
- Deterioration of Sanitation /Health
- Generation of excess excavated earth
- Land erosion / Soil erosion
- Change in flow of River
- Water pollution
- Odor

7.11.4 Environmental Impact Assessment (EIA)

The following is the Conclusions and Recommendations conducted by the local consultants.

(1) Conclusions

There are few environmental impacts that would persist during construction and operation of the facility unless extra measures are taken to minimize them. These residual impacts are presented here and corrective measures are recommended.

Loss of revenue from paddy cultivation is marginal, further paddy is not cultivated on a regular basis. These paddy lands are used mainly for training purposes. The selected site causes the complete loss of the paddy lands, therefore the training provided by the In-Service Training Centre would be adversely affected. However, acquisition of a tract of paddy lands from a suitable location close to the Horticultural Institute will be able to overcome the problem. During the construction period, the traffic congestion will remain in the peak periods, for which extra effort and better control of the traffic movements would be necessary. Deterioration of Sanitation /Health is not expected. Soil erosion at the site is not a problem if the excess earth excavated is disposed without allowing it to be washed in to the river. Proper planning of the cut and fill could reduce the earth excavated and whatever excavated earth could be used at the site for leveling and to upgrade the approach roads to the site. Soil erosion along the roads during the trenching will not be a serious problem to overcome if trenches are done during dry weather and if they are filled back and road repaired soon after trenching and laying the pipes. Currently 33,500 cubic meters of water is taken out at Getambe and the return flow to the river below the intake via Meda Ela is less than half of it. The return flow from the STP after treatment to the river at a point about 100 m below the intake is also about half the intake rate. Compared to the total base flow in Mahaweli River the return flow from the STP is very small, therefore drastic changes in the river flow due to the STP is not possible. Further, during dry weather base flow of the river is controlled by the operation of Kotmale, therefore the return flow from the STP will have very little impact on the flow regime of the Mahaweli River. According to the information presented, water pollution is not a serious problem compared to the conditions prevailing at present. However, Potential Eutrophication and algal growth in Polgolla Reservoir exist. In order to minimize nutrient enrichment, the retention time of water in the reservoir should be properly maintained. Emission of offensive ordour from the STP will be the main impact that will persist and this is the aspect that people of the area likely to object.

(2) Recommendations

On the basis of the EIA study it is recommend that the proposed site be adopted. The total extent of the paddy tract would be lost, an alternative tract of paddy lands should be provided to the Department of Agriculture to facilitate the training and research needs. It is important to adopt proper landscaping and establishment of a good vegetation to over come the aesthetic impacts most likely to prevail. The total facility could be well sheltered with the establishment of a good green belt between the STP facility and the main road. The facility should be operated at a very high level of efficiency and maintained well at times.

To reduce soil erosion cut and fill should be well planned on the basis of a close contour survey of the site to minimize the cut and fill in leveling process. The extra earth generated should be used to improve the approach roads to the facility.

In order to minimize the residual ordour it is recommended to establish well-organized green belt around the facility. Proper maintenance and operation of the facility must be according to the specification of the designers. The construction of oxidation ditches should be blended into the landscape of the site selected.

Regular removal of grit and sludge should be maintained.

Considering the possibility of having a large number of rainy days per year, attention must be paid to obtain proper and quick drying of sludge by protecting the beds from rains.

The improvement of surface water quality after the establishment of sewerage system would be the best indicator for such assessment. Therefore it is necessary to monitor the water quality of the Kandy Lake and Meda Ela on regular basis at least once a month following the implementation of sewerage system. The monitoring of Kandy Lake, Meda Ela and Mahaweli River as specified in chapter 6 is recommended.

It is very necessary to attend to proper maintenance of the STP system, regular monitoring of the Aquatic environment, particularly the water quality and assessment of the efficiency of the operational system in relation to stipulated objectives. Therefore it is recommended to establish an environmental management and monitoring unit at NWSDB with an especial emphasis on aquatic environmental issues and water quality monitoring.

If it is possible to undertake trenching along Peradeniya-Gannoruwa-Getambe road during non peak hours it would help to reduce traffic congestion on this road. Even otherwise extra traffic police officers would be necessary to regulate traffic on this part of the highway.

CHAPTER 8 TECNOLOGY TRANSFER

The technology transfer was one of major objectives in this Study, and both the Study Team and counterpart team were sincere as this is for the detailed design which directly links to the financial loan by the Japanese Government In the course of a series of activities such as joint confirmation of the site, topographical survey and soil investigation, establishment of design concept, designing and joint field inspection based on the designs, discussions resulted in mutual understanding and technology transfer. Besides those, the meetings with the NWS&DB project director contributed to settle the suspended matters and clarified each responsibility.

8.1 Presentation

At the end of the basic design stage when the basic concept of the new Greater Kandy water supply system has been almost fixed, the presentations were held two times on 1 and 6 August 2001, respectively, for the staff of NWS&DN RSC-CENTRAL who will undertake the actual operation and maintenance of the new water supply system after completion. The subjects were the mechanical and electrical system for the former and the water treatment process for the latter resulted in the active opinion exchange.

The presentation for the key staff of the NWS&DB head office in Colombo was also held upon every submission of the reports.

8.2 Group Training for Waterworks Engineering in Japan

In the course of the Study, Mr. M. Manoharan in charge of O&M of water supply facilities in the NWS&DN RSC-CENTRAL that had functioned as the counterpart for the Study Team, was dispatched to Japan in June 2001 to receive the training. The group training for waterworks engineering was done at JICA Sapporo International Centre for three months with the following curriculum.

Objectives

- To study the basic knowledge concerning the general waterworks such as the water source, intake facilities, water and wastewater treatment facilities, and water supply facilities,
- To master how to formulate the comprehensive plan as well as the technology necessary for operation and maintenance of facilities through lectures and practicals, and

- To assure sustainable supply of clean and safe drinking water in the developing countries

Target Level of Training

To understand the basic knowledge of water supply technology so as to be explainable thereon and to understand the function of water supply facilities resulting in strengthening the construction improvement plan and the institution for operation and maintenance in his own country.

Outline of the Course

1. Lectures

   Administration and management of waterworks in Japan
   Water supply planning
   Water treatment
   Water distribution control
   Design and construction supervision
   Water supply control
   Water quality control
   Groundwater
   Waterworks management
2. Practicals
   Construction supervision of water treatment facilities
   Designing of distribution pipes
   Operation of water treatment plants
   Maintenance of water treatment plants
   Maintenance of distribution facilities
   Leakage control
   Water quality control
   Water quality examination
   Groundwater sounding
3. Inspection
   Water source
   Water Treatment facilities
   Distribution facilities
   Other water supply facilities
   Other relevant facilities

Water supply facilities of other types of waterworks

After the completion of the group training, the short-term personal training was done at NJS Consultants Co., Ltd. In Tokyo and the Waterworks Bureau, the Osaka Municipal Government. The subjects were the introduction of new technology developed by the consultants in the former and the inspection of and discussion on the water treatment plant in the latter as well as subsequent discussions.

8.3 Technology transfer seminar

The technology transfer seminar was held in Kandy with the following agenda presided by Mr. W. Wicramage, Addl. G. M. of NWS&DB

Date: 28th February, 2002 (Thursday)
Place: The Tourmaline Banquet Hall

AGGENDA

10:00	*RECEPTION*	
	(Coffee Time)	
10:30 – 10:35	*AN OPENING ADRESS*	*Mr. S. GAMINI*
10:35 – 10.40	*SPECIAL ADRESS*	*Mr. W. Wicramage*
10:40 – 10:50	*Introduction*	*I. MIWA*
10:50 – 11:20	*Water Purification*	*S. SATO*
11:20 – 11:50	*Mechanical System*	*S. OSAKA*
11:50 – 12:20	*Electrical System*	*A. MIURA*
	(Lunch)	
14:20 – 14:50	*Water Transmission, Storage and Distribution Systems*	*S. SASAKI*
14:50 – 15:20	*Sewage Treatment*	*I. MIWA*
15:20 – 15:35	*Q&A*	
15:35 – 15:40	*A CLOSING ADRESS*	*I. MIWA*

The 67 attendees included the professor of Peradeniya University and the staff of Central Province and Kandy Municipal Council. The questions presented covers not only those on the new Greater Kandy water supply system but also those on the sewage treatment process and the study of the NWS&DB RSC-CENTRAL laboratory, showing deep concern of the participants.

CHAPTER 9 CONCLUSION AND RECOMMENDATION

9.1 Conclusion

(1) Locations of Water Supply and sewerage Facilities

The locations of the intake, water treatment plant and sewage treatment plant proposed in the previous JICA Report were selected based on their technical, economical, financial and environmental viability. Attention was paid especially for the realization of land acquisition. Such selection are considered to be reasonable at present

(2) Construction of Asgiriya and Gohagoda Reservoirs in Phase I

The wastewater to be generated from the Asgiriya and Gohagoda Reservoir service areas, which will be unserved by a sewerage system in future, will have little affect on the proposed water source at Gohagoda. The construction of both reservoirs, therefore, should be implemented in Phase 1 including the laying of transmission pipes from the Katugastota Water Treatment Plant thereto and connection pipes to the existing distribution network therefrom.

(3) Exclusion of Primrose Reservoir

The construction of the Primrose Reservoir (volume: 315 m3) and its related pump replacement at the KMC Water Treatment Plant are overlapped between the ADB and JICA projects. The existing Primrose Reservoir made of steel panels has a serious leakage and requires for its reconstruction as soon as possible. For this reason, its reconstruction is scheduled in Phase 1 under the ADB project that will start the construction from June 2001. From the viewpoint of efficient available land use and emergency, it is proposed that the Primrose Reservoir will be constructed with a combined capacity of existing and new reservoirs under the ADB project and be excluded from JICA project. However, as to the pump replacement at the KMC Water Treatment Plant, the replacement of impellers are supposed under the ADB project and it is necessary for a mechanical engineer to check whether such a replacement will meet the capacity requirement.

(4) Exclusion of Transmission Pipes to Dangola Reservoir

The existing pipe to the Dangola Reservoir is used for both purpose of water transmission and distribution resulting in insufficient water transmission to the existing Dangola Reservoir. The ADB project has a plan to separate the water transmission from the water distribution through the installation of new transmission pipes to the Dangola Reservoir in Phase 1. Therefore, it is suggested to exclude the installation of transmission pipes to the Dangola Reservoir from the JICA project and to undertake the construction of the new Dangola Reservoir (volume: 254 m^3) and its related connection work under the JICA project.

(5) Implementation of Sewage Works

The past records on the Mahaweli River water quality were doubtful in consideration of the situation that the Mahaweli River had been placed on. However, the dada based on the improved analytical methods showed that the water quality of the Mahaweli River were almost equal to 1mg/L. As long as those values will be kept, it will be practically possible to apply the currently-selected treatment process to the existing water source. The water quality of the Mahaweli River will be rather dependent on the development of the Greater Kandy itself, not but the upstream area. Therefore, It is necessary to continuously monitor the water quality of the Mahaweli River and the Meda Ela as well as the Kandy Lake.

From the demographic viewpoint of the Mahaweli River and the Greater Kandy, which is located in the most-upstream reach of the Mahaweli River, it is very significant to implement the sewage works in this area.

(6) Applicable Sewage Treatment Process

In the previous JICA report, the oxidation ditch process or the aerated lagoon process was proposed for the Gannoruwa Sewage Treatment Plant based on the Sri Lankan effluent standard of 30 mg/L in BOD and 50 mg/L in SS for inland water bodies. For the above more stringent requirement, the oxidation ditch process is still one of applicable options.

9.2 Recommendation

(1) Water Quality Surveillance

For the purpose of water source conservation, it is very important to monitor the water quality at the Mahaweli River and Meda Ela. Although the NWSDB Central Laboratory, which is a key organization for this purpose, started the monitoring program of the Mahaweli River since March 2000, its laboratory provisions are aged and poor including sampling kits and analytical instruments, which require their renewal/replacement for exact determination of the water quality.

For the BOD_5 analysis of the sample taken from the Mahaweli River, five times dilution to the sample volume has been applied at the NWS&DB RSC-Central Laboratory. However, in case of the sample BOD_5 of less than 4 mg/L, no dilution to the sample volume is recommended, because the ammonium chloride contained in the dilution solution will be nitrified by the nitrobacteria in the sample and such oxygen consumption for nitrification is counted among the BOD_5 concentration. The oxygen demand for nitrification is 5 mg/L at the maximum. Therefore, it is possible that the BOD_5 concentration becomes double or triple the actual one. It may be difficult to conduct the BOD_5 analysis in the completely right way at the Laboratory due to the limitation of available equipment, but even though using the ion-exchanged water for the distilled water and DO bottles for BOD bottles, approximate values to the actual one is obtainable as long as no dilution is applied to the sample with a BOD concentration of less than 4 mg/L.

The present sampling point under the monitoring program should be relocated to Peradeniya, Suspension Bridge (at the center) and Gohagoda (on the left bank) on the Mahaweli River and at the Meda Ela before the confluence with the Mahaweli River. In the Mahaweli River, the people use the river for washing and bathing with soap commonly. The river flows slowly in the almost straight watercourse in the storage zone starting from the Suspension Bridge and such polluted water by washing and bathing also flows along the riverbank without mixing to reach to the proposed Gohagoda Intake. As the sampling is usually done within a reach from the riverbank, the samples are directly affected by washing and bathing. It should be, therefore, taken from the not affected area by washing and bathing. The Suspension Bridge is located 3.4 km upstream of the proposed Gohagoda Intake and immediately after the 1.7 km long rapids where the Meda Ela water is considered to be completely mixed with the Mahaweli River water.

Those change of the dilution rate and sampling point of samples must be practiced immediately to identify the actual BOD_5 concentration of the Mahaweli River.

(2) Water Quality Conservation Measures for Upper Reach of Mahaweli River

The water pollution in the Meda Ela will be coped with the implementation of sewage works to a substantial extent. It should be noted, however, that the water quality of the Mahaweli River itself is vital and it should be protected from further deterioration. Various kinds of effective measures for water quality conservation should be taken for the upper reach of the Mahaweli River and, in particular, the following possible sources of contamination must be attended to:

b) Discharge of domestic sewage from towns or communities upstream of the intake.

c) Toxic or harmful wastewater discharge from industries in upstream of the intake.

d) Leachate from garbage dumping sites upstream of the intake.

e) Wastewater from water purification plants upstream of the intake.

f) Detergent and soap originating from washing and bathing at the main river.

As mentioned above, the water polluted by washing and bathing of the people near the river flows along the riverbank and reach to the proposed Gohagoda Intake without mixing. To protect the water source from this kind of pollution, it is suggested to ban the washing and bathing in the river between the Suspension Bridge and the proposed Gohagoda Intake. For this purpose, the measures be taken to include the area, where such people live in, into the water service area in the earliest time as well as to introduce the subsidiary water tariff.

CHAPTER 10 WATER DEMAND AND WATER RESOURCES

10.1 General

This section is concerned with the establishment of the water demands for the three Phases in the years 2005,2010 and 2015 on the basis of per capita demand, safe yield of available ground and surface water sources, and to ascertain the potentiality of the proposed Mahaweli River source at Gohagoda to meet the anticipated water demand of Greater Kandy.

10.2 Served Population

For the proposed long-term development of Greater Kandy area, the entire KMC area and parts of 10 adjacent P.S. areas were included. Of these, 100 percent water supply coverage for KMC area, Kandy Four Gravets and Akurana P.S. areas in the year 2015 is planned, and for the rest of the areas only part coverage is allowed. For the whole of Greater Kandy, Table 10.1 adopted in the 1999 JICA F/S population projections will be considered as the basis for Project.

Table 10.1 Water Supply Service Population in Greater Kandy

Area	Projected Population			
	2000	2005	2010	2015
KMC	144,000	153,000	162,000	171,000
Kandy Four Gravets (part)	58,000	62,000	67,000	71,000
Harispattuwa, Akurana, & Pujapitiya (part)	138,000	150,000	161,000	173,000
Kundasale (part)	87,300	93,800	99,500	106,000
Patha Dumbara (part)	42,900	46,000	48,400	51,600
Patha Hewaheta (part)	8,600	9,400	10,600	12,000
Udunuwara, Yatinuwara, & Uda- Palatha (part)	95,400	101,600	110,900	119,000
Sub-total outside KMC	430,200	462,800	497,400	532,600
Total	**574,200**	**615,800**	**659,400**	**703,600**

Different population growth rates for different areas had been used for this evaluation depending on the present circumstances.

Previous records of KMC area from 1981 to 1990 reflected the highest growth rate of 1.9 percent and next was Kandy Four Gravets. Of the suburban areas Harispattuwa, Akurana, Pujapitiya and Kundasale recorded the highest population growth rate of 1.6 percent. However, the long-term future trend will be a gradual reduction of the growth rate down to about 1.1 to 1.2 percent within the period 2010/2020.

10.3 Water Demand

The three factors governing the water demand of a particular water supply system are the water use pattern identified by per capita consumption, water loss by Non Revenue Water (NRW) and peak ratio, which is the ratio of maximum day demand to the average day demand. The accurate assessment of these factors require extensive studies and previous production and consumption records over several years, which are not available with any of Greater Kandy existing systems.

In view of this lack of data, the results of certain studies carried out before by FINNIDA for Greater Kandy, and ADB for KMC area were further developed, and compared with the corresponding data obtained from other major systems in the country and overseas and evaluated some reasonable values. Accordingly, the current NRW was estimated at 42 percent and proposed this to be reduced to 25 percent in year 2015. On the above basis the unit water consumption has been identified as given in the following Table 10.2.

Table 10.2 Per Capita Water Demand Rates and NRW Ratio for Greater Kandy

Description	Unit Rates (lpcd)			
	2000	2005	2010	2015
KMC Area				
Domestic	101	108	115	121
Non- domestic	58	61	65	69
NRW	115	95	81	63
Total	274	264	261	253
Outside KMC				
Domestic	78	82	90	98
Non- domestic	30	32	36	41
NRW	78	64	57	46
Total	186	178	183	185
Greater Kandy				
Domestic	85	89	96	104
Non- domestic	37	39	43	48
NRW	88	72	62	50
Total	210	200	201	202
NRW (%)	42	36	31	25

Incidentally, the reduction of NRW from 42 to 25 percent has resulted in a drop in the per capita consumption, despite the increase in the unit consumption rate over the years.

On this basis the projected water demand for Greater Kandy has been determined as per the following Table 10.3.

Figure 10.1shows water balance between demand and supply for various stages.

From the foregoing, it is clear that the full satisfaction in water supply can be achieved only in 2015 with the completion of Phase 3, whereas in 2005 there will be a deficit of production in terms of both the average and maximum day demand, and in 2010 in maximum day demand. Therefore, it is recommended to look for funding of Phase 2 activities, while Phase 1 works are in hand to prevent a water shortage continue to prevail beyond 2005

Table 10.3 Projected Water Demand in Greater Kandy

Description	Water Demand (m^3/d)			
	2000	2005	2010	2015
KMC Area				
Domestic	14,570	16,500	18,610	20,730
Non Domestic	8,352	9,333	10,530	11,799
NRW	16,560	14,535	13,1222	10,773
Total	39,482	40,392	42,282	43,263
Outside KMC Area				
Domestic	33,556	38,156	44,766	52,253
Non Domestic	12,906	14,689	17,965	21,631
NRW	33,556	29,619	28,352	24,500
Total	80,018	82,464	91,083	98.384
Total Greater Kandy				
Domestic	48,100	54,680	63,396	72,944
Non Domestic	21,258	24,022	28,495	33,430
NRW	50,116	44,154	41,474	35,273
Total	119,474	122,900	133,400	141,600

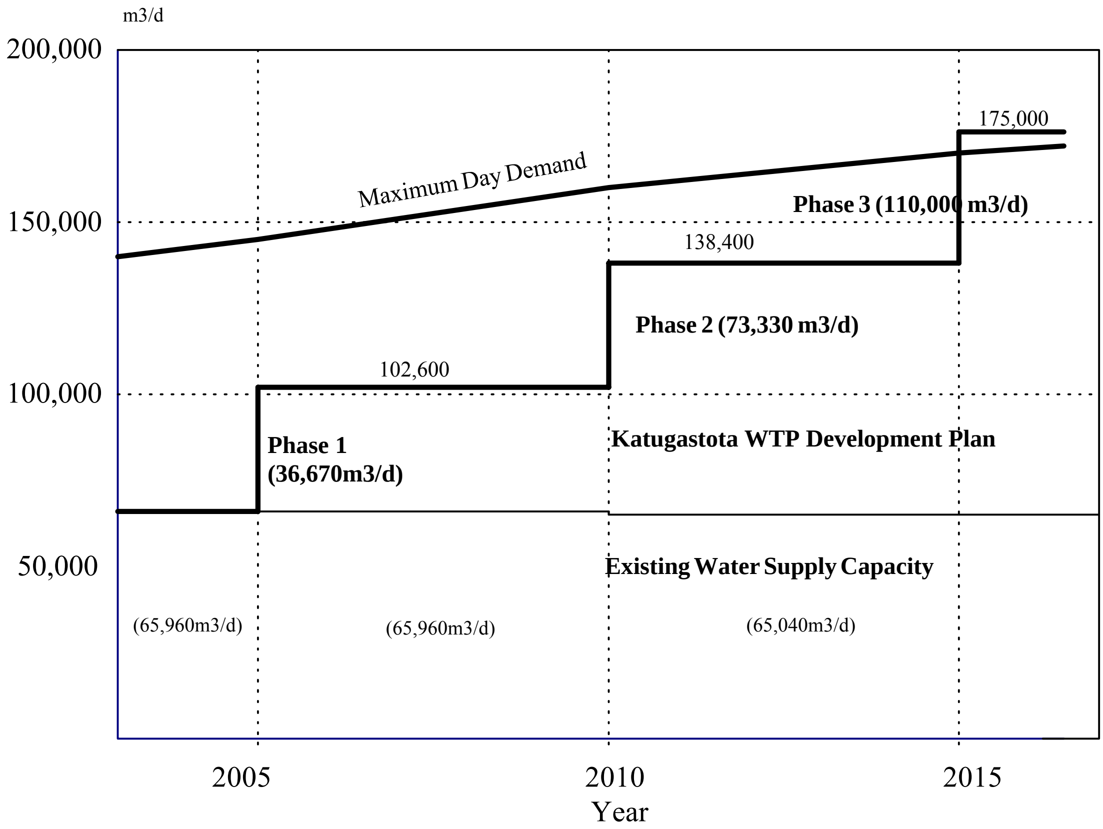


Figure 10.1 Water Demand and Supply

10.4 Water Resources

The major water supply source is Mahaweli River with a total draw off of 52,945 m^3/d, which feeds KMC system (33,400 m^3/d), Peradeniya University System (9,000 m^3/d), Penideniya TTC System (545 m^3/d), Department of Agriculture System at Kundasale (1,900 m^3/d), Udu/Yatinuwara (4,600 m^3/d)*, Pallekele (2,000 m^3/d) and Polgolla (1,500 m^3/d).

The other prominent perennial water sources in Greater Kandy include Kothmale Oya (catchment area 554 km^2), Atabage Oya (74 km^2), Nilambe Oya (66 km^2), and Hulu Ganga (160 km^2). Out of these Nilambe Oya and Hulu Ganga are being employed as the source of water for Udu- Yatinuwara and Kundasale water supply schemes. Kothmale and Nilambe Oya are being used for hydropower generation with reservoirs. Atabage Oya is not yet tapped though the water quality is acceptable. In addition to these there are several other small tributaries, which are not suitable as potential water sources due to quantitative, qualitative and economical considerations.

Hydrogeological studies in Greater Kandy have established the existence of potential ground water resources, but to date such locations have not been explored in a systematic manner. Hence, at present no definite decision can be taken of the exploitation of ground water sources in a major project.

Seventeen water supply systems in Greater Kandy are fed by ground water from boreholes with two systems combined with surface water sources. These were originally built to serve small isolated local communities, after discovering ground water in adequate quantities. However, most of these systems are currently malfunctioning due to the deterioration of the yield below 1000 m^3/d, and still worse to several hundred m3/d at places. Some are yielding hard water and some wells contain a high iron content rendering the water unsuitable for drinking and washing. Some are lowering the ground water table affecting the nearby paddy fields and shallow wells. Furthermore, the situation is further aggravated during dry season with a sharp drop in the yield qualitatively and quantitatively. This affects the pump performance as well. All these factors contribute to a low service level.

The boreholes are not recommendable as the source for large water supply systems, because of the high cost of production and the need to have a multitude of boreholes at scattered locations.

The topography of Greater Kandy also limits the potential areas for groundwater development. Notwithstanding, this is the most viable alternative for remote areas to provide limited supplies in view of the complicated and expensive centralized surface water systems, and the favourable prospects of finding potential ground water sources, as reckoned before.

10.5 Mahaweli River

This is the largest River in Greater Kandy with a total catchment area of 3,118 km^2 (1,292 km^2 at Polgolla and 1,109 km^2 at Nanu Oya mouth), and a daily average flow rate of 5.5 million m^3/d, and annual average rate of flow of 2 BCM per year, which has a host of major tributaries namely Kotmale Oya, Atabage Oya, Nillambe Oya, Pinga Oya, Hulu Ganga, Maha Oya, Hasalaka Oya and Heen Ganga and a few other minor ones within the catchment.

The flow of Mahaweli at Polgolla is regulated by the operation of Kothmale reservoir at upstream end, and Polgolla Dam at downstream end. River flow is monitored daily at Peradeniya Gauging Station by the Irrigation Department, and inflows to Polgolla dam is estimated by the downstream release and flow for power generation.

According to Irrigation Department, Mahaweli River flow from October 1989 to September 1999 measured at Peradeniya Gauging Station (tributary area 1,168 km^2), the median value of flow at Peradeniya was determined to be 23.68 m^3/d or 2,046,000 m^3/d, and for 7-day average median flow was 24.57 m^3/s or 2,122,900 m^3/d.

Storage volume of Polgolla Reservoir is 4.1 MCM at normal operating level (at 440.74 m AMSL, surface area 1.2 km^2) and the minimum storage volume is 2.0 MCM at 438.90 m AMSL (surface area 0.7 km^2). Average retention time in Polgolla Reservoir is around two days based on the median flow at Peradeniya. However, due to periodic siltation the actual retention time may become much lower than two days, from time to time.

The Normal Operating Level at Polgolla reservoir has been set at 440.74 m AMSL. However, at times the water level would rise up to about 441m AMSL during daytime, as the gates are not normally opened during day time due to dangers to the downstream users, unless under emergency conditions with advance notice.

The Low Water Level is set at 438.30m AMSL, below which the power generation at Ukuwela Power Station would stop. The lowest water level recorded during desilting was 434.34m AMSL.

Historical data firmly establish that flood water level will not rise above 441m AMSL even under the worst possible flood conditions. Table 10.4 summarises a historical record of the 39 worst floods of the river in the past 58 years from 1943, and the high flood levels reached on each occasion.

Polgolla Dam was commissioned in 1976 and the highest flood level recorded since then was 440.2m AMSL in 1978. In August 1985, Kothmale Reservoir was also commissioned upstream of Polgolla Dam facilitating the control of floodwaters from upstream end as well. Thus, there is absolutely no risk of rising the flood water level above 440.70 m AMSL, with the proper regulation of Kothmale Reservoir, Polgolla Dam and the downstream Victoria Reservoir, also commissioned in April 1985.

Table 10.4 The High Flood Levels of Worst Floods of Mahaweli River at Polgolla in the Past 58-Years

Rank	Year	Maximum Discharge (m^3/s)	High Flood Level (m AMSL)
01	1978	3054	440.2
02	1947	2550	439.6
03	1957	1875	438.3
04	1956	1758	438.1
05	1968	1758	438.1

Mahaweli Authority has also evaluated worst likely flood discharges up to a return period of 500 years as shown in the following Table 10.5.

Generally, water supply structures are designed for a serviceable period of 100 - 200 years, and the assumption of a flood level of 441m AMSL for design of Intake structure is quite safe and justifiable, in view of the above forecasted high flood level of 440.7m AMSL in 200 years.

Table 10.5 Forecast of Worst Flood Conditions

Return Period (Years)	Anticipated Maximum. Flood Discharges (m^3/s)	High Flood Level (m AMSL)
500	4000	441.80
300	3725	441.19
200	3425	440.70
100	3200	440.43
50	2850	439.83

The Mahaweli River Authority has set the minimum flow of the river at 180,000 m^3/d. However, in 1992 a serious drought took place causing the rainfall in January to fall to about 40 percent of its normal average monthly rainfall level with February and March having no rainfall, reducing the flow to 166,600 m^3/d for 8 days. Similar reductions were experienced in 1993 (2 days) and 1993 (3 days). The maximum daily demand of Greater Kandy in year 2015 is assessed to be 169,980 m^3/d of which the existing major systems will continue to supply up to 65,040 m^3/d. Hence, the required exploitation from Mahaweli River is 104,940 m^3/d (say 110,000 m^3/d), which according to past flow records is realistic. Nevertheless, abnormally high drought periods in future should be expected, and hence the existing groundwater sources should be preserved for possible standby utilization at such times.

There is no other water source, which can provide a bulk volume of 110,000 m^3/d of acceptable raw water quality. NWSDB has already secured the water rights from the Mahaweli Authority for the utilization of 180,000 m^3/d from the river, which includes the existing systems utilizing Mahaweli River, and there is still a certain surplus remaining for further extraction, if the need arises.

CHAPTER 11 INTAKE AND WATER TREATMENT PLANT

11.1 General

Consequent to the analysis of water quality of the raw water sources conducted during the review stage, the recommended treatment process is the rapid sand filtration system, as proposed by the 1999 JICA F/S. The process comprises of pre-treatment (pH adjustment, pre-chlorination, and coagulation), flocculation, sedimentation, filtration, and disinfection. This treatment is widely used in Sri Lanka with river sources.

The following technical principles are recommended in the detailed design of water treatment equipment and facilities for the Greater Kandy Water Supply Augmentation Project.

- To the maximum extent possible, the use of mechanical equipment should be limited which easy operation and low maintenance can be achieved,
- Hydraulically based devices that use gravity for works such as rapid mixing, flocculation, and filter rate control are preferred to mechanised and/or automated equipment in consideration of the available favourable topography of the plant site,
- Mechanisation and automation are appropriate only where operations are not readily accomplished manually, or where they greatly improve the reliability assuring safe and stable water supply, and
- Indigenous materials and products that are easy and safe for use in construction should be used to reduce costs, and to bolster the local economy and expand industrial development.

For the detailed design, the same design horizon recommended by the 1999 JICA F/S is adopted. The project will be implemented in three phases. Phase 1 project is designed to produce 36,670 m^3/day, based on the daily maximum supply quantity, which is 1/3 of the total overall capacity of 110,000 m^3/day.

Common facilities including intake, balancing tank, part of raw water conveyance pipes, structure for receiving well/distribution chamber, chemical building, administration building, and maintenance building is to be constructed in Phase 1, for the overall capacity.

Five percent of the production loss including in-plant water consumption and three percent of recirculation is considered for the design of equipment and facilities for the intake structure, balancing tank, receiving well/distribution chamber, flocculation basins, sedimentation basins, filter units, and chemical, and chlorination facilities.

These are summarised in the following Table 11.1.

Table 11.1 Design Horizon

Facilities	Design Capacity for Phase 1
1) Intake structure	115,500 m^3/day (3/3+5%)
2) Intake facilities	38,500 m^3/day (1/3+5%)
3) Balancing tank	115,500 m^3/day (3/3+5%)
4) Raw water conveyance pipe	*115,500 m^3/day (3/3+5%)
5) Receiving well/distribution chamber	115,500 m^3/day (3/3+5%)
6) Flocculation basins	39,700 m^3/day (1/3+5%+3%)
7) Sedimentation basins	39,700 m^3/day (ditto)
8) Filter units	39,700 m^3/day (ditto)
9) Clear water reservoirs	36,670 m^3/day (1/3)
10) Transmission facilities	36,670 m^3/day (1/3)
11) Chemical and Chlorination Facilities	39,700 m^3/day (1/3+5%+3%)

Notes: * Pressured pipe to the balancing tank will be 1/3+5% only.

11.2 Hydraulic Design

The water level at the head end of the process or the distribution chamber is set at 451.68 m AMSL, approximately 6 m above 445.82 m AMSL, the high water level of the clear water reservoir. The majority of the unit processes is above the grand line.

The lowest water level is set at 442 m AMSL, or one metre above the designed highest water level of the Mahaweli River, so that the drainage work for the sludge lagoons would be uninterrupted even during high water level at the Mahaweli River. Therefore, the bottom level of the sedimentation basins is determined at 443.0 m AMSL according to the required head loss of sludge discharge pipeline from the sedimentation basins to the sludge lagoons. The designed hydraulic profile is shown in the Drawings, Tender Documents.

11.3 Raw Water Intake and Balancing Tank

11.3.1 Raw Water Intake Facilities

The raw water is taken from the Mahaweli River to grit chamber through the intake mouth with the bottom elevation at 436.0 m AMSL, which is the present riverbed level and 2.3 m below the low operating water level of the Polgolla Dam. The lowest low water level is set at 437.6 m AMSL, 1.6 m above the riverbed based on the past record. The low water level is set at 438.3 m AMSL, same as low operating water level of the Polgolla Dam. The flood water level is estimated at 441 m AMSL based on available data given by the Mahaweli Authority of Sri Lanka. The ground level and motor floor level of the intake facilities is planned at 442.5 m AMSL (1.5 m above the high flood level) and 443 m AMSL (2 m above the high flood level), respectively.

It is proposed to install two sets each of coarse and fine screens at two trains of inflow conduits. The coarse screen is cleaned manually as accumulated debris to be removed should be minimal except during floods. The fine screens are mechanically operated on a timing device. Thereafter, the raw water is introduced to two trains of grit chambers with a detention time of approximately 15 minutes for Phase 3 capacity where grit with a diameter larger than 0.1 mm can be removed. Incidentally, the designed particle size to be removed at grit chambers of the existing KMC water treatment plant is 0.15 mm, and hence the grit removal will be more effective than the KMC system. The effective depth for grit accumulation of grit chamber is set at 1.0 m. In the event of maintenance, two grit chambers can be isolated each others and emptied by operating inflow and effluent sluice gate valves or stop logs, without interrupting the performance. Then, mobile pumps will be installed in one of the grit chamber to discharge the settled grit on the bottom regularly. The designed surface load is held at the low level of 200 mm/min to cope with unexpected overloading during rainy season.

To meet the designed water demands in 2005, two units of raw water intake pumps are installed in Phase 1 to supply the treatment plant with a variable flow, with one unit as standby. With each unit pumping at 38,500 m^3/d (0.446 m^3/sec), three units will meet the 2015 flow with a fourth, as standby, and space is provided for two more pumps to meet the 2015 demand. Detailed type and specification of pumps are referred to Chapter 9, Mechanical Facilities.

The pumping head required is the total of static head and friction head loss resulting from pumping a total of 115,500 m^3/d by three units of raw water intake pumps, through the raw water conveyance main with capacity for the design year 2015. The designed static head is from low water level at the suction sump to the top level of balancing tank to be installed along the route of the raw water pumping main as shown hereunder.

The motor room is provided with a gantry crane with a lifting capacity of 3.5 tons over the motors and discharge piping to remove items for repair. The roof is designed to have enough height to lift the vertical double suction volute pumps and install additional units in the future to meet 2010 and 2015 flows. The motor room would also include the motor control panel, alarms, flow indication equipment, and telemetry panels.

1) Number	:	2 inflow conduits, 2 grit chambers, 1 pump room, 1 motor room, and 1 electrical room to cater for Phase 3
2) Dimensions	:	6.0 m width x 33.5 m length x 3.1 m depth x 2 basins
3) Effective depth	:	1 m to allow for grit accumulation
4) Detention time	:	15.3 min. for Phase 3 capacity (10 to 20 min.)
5) Surface load	:	200 mm/min (200 to 500 mm/min.)
6) Average velocity	:	3.65 cm/sec (2 to 7 cm/sec)

11.3.2 Balancing Tank

A balancing tank has a function that avoids negative pressure along the raw water conveyance pipe caused by the up and down gradient of the ground level. The set high water level at the balancing tank is required to be 476.0 m AMSL. An overflow chamber is provided to discharge all of the raw water assuming that all outlets are blocked.

The raw water conveyance pipeline is of 800 and 1,000 mm DI pipe with a total length of 1.7 km, consisting of 0.5 km of 800 mm pressure pipe up to the proposed balancing tank, which will only cater for 2005 demand, and 1.2 km of 1,000 and 800 mm gravity flow from the balancing tank to the receiving well in the treatment plant, which will cater for 2015 demand. Along the gravity flow pipe, two sets of pressure regulating system by means of orifices with control valves are to be installed to control excess pressure.

1) Number	:	1 inflow chambers, 1 effluent chamber, 1 overflow chamber
2) Dimensions	:	9.0 m width x 7.0 m length x 4.1 m depth x 1 basin
3) Detention time	:	Approx. 3 min. for Phase 3 capacity

11.4 Pretreatment

The coagulation process is achieved by a rapid mixing system which disperses 10 percent alum solution, $Al_2\,(SO_4)_3$ $18H_2O$ as a coagulant uniformly throughout the entire mass of water, with maximum possible rapidity. Distinctive products or many types of rapid mixing equipment are available with every manufacturer. In line with the design concepts proposed in the previous section, the intensity of turbulence is preferably generated hydraulically through the hydraulic jump caused by weirs or flumes to be installed at the distribution chamber.

In case the alkalinity of the raw water is less than 20 mg/l, pre-lime is to be employed at the distribution chamber using 10 percent lime solution as an agent for pH adjustment, prior to the coagulation to ensure the effective coagulation process. In addition, pre-chlorination should be applied using gas chlorinators from time to time, for removal of iron and/or manganese and the algal control, if those parameters exceed the Sri Lankan Drinking Water Standards.

The detention time and effective depth of mixing chamber are designed to be 2.5 minutes and 3.9 m, respectively. Adequate baffles, surface area as well as weirs is provided with the distribution chamber to secure proper coagulation and flow measurement.

The applied design parameters of the pre-treatment process are summarised in the following;

1) Type	:	Distribution chamber with hydraulic rapid mixing by weir
2) Number	:	1 unit with a capacity of 115,500 m^3/day to cater for till Phase 3 extension
3) G value for rapid mixing	:	330 s^{-1} (> 300s^{-1})
4) Applied chemicals	:	Chlorination-------Liquid chlorine (99.9 percent) pH control--------- Lime (10 percent solution) Coagulant--------- Alum (10 percent solution)

11.5 Flocculation

Vertical-flow baffled channel flocculators with a detention time of approximately 30 min are designed, as recommended in the 1999 JICA F/S. Two trains is provided so that in the event of lower flows than the designed capacity, or maintenance works, one train may be shut down accordingly to attain a suitable flocculation intensity, G-value range from 70 to 10 s^{-1}. The width of the flocculation channels is sized in thirds to adjust the hydraulically required flocculation intensity from 70 to 10 s^{-1}, i.e. higher intensity to gentle mixing towards sedimentation process.

The provision of the Katugastota WTP is essential in order to enhance supplies to meet the anticipated increasing demands in the Greater Kandy area. Before commencement of the Phase 2 Project, with a production capacity limited to 36,670 m^3/day in Phase 1, there is a potential risk of a supply deficit being experienced. Hence, the proposed Water Treatment Plant would be operated at full designed capacity immediately from the time of commissioning. This means, that fluctuations of flow for treatment capacity are expected to be minimal, and would be manageable by the provision of a number of treatment trains, and the designed flow rates can easily maintain sufficient head losses in the channel for mixing.

The applied design parameters for the flocculation process are:

1) Type	:	Vertical-flow baffled channels
2) Number	:	2 trains with 3 staged tapered flocculation
3) Detention time	:	Approx. 30 min (from 20 to 40 min)
4) G value	:	Approx. 10 to 70 s^{-1}
5) Dimensions	:	1.1 m width x 11 m length x 3.50 m depth x 2 channels 1.5 m width x 11 m length x 3.50 m depth x 2 channels 2.3 m width x 11 m length x 3.50 m depth x 2 channels

11.6 Sedimentation

The sedimentation or clarification process in water treatment provides for the settlement and removal of a majority of the settleable solids of heavier and larger suspended particles from water, prior to the subsequent filtration process. To maximize filtration process, the settled water turbidity preferably should be between 2 to 5 NTU as observed during normal operations. However, the sedimentation is greatly dependent upon the adequate pretreatment processes, including coagulation and flocculation. The efficiency of the sedimentation basin is determined by the surface loading ratio *(Q/A)*, where *Q* is the rate treatment capacity, and *A* is the surface area of the sedimentation basin. The subsequent loading on the filters accordingly has a marked influence on their capacity; the length of filter runs in relation to the washing schedules, and the quality of the filtered water.

The proposed horizontal flow sedimentation is commonly used in municipal water supply systems. It is based on gravity flow separation process, in which a settling basin provides a quiescent environment that enables particles of specific gravity heavier than water to settle to the bottom of the tank. The outstanding feature of horizontal flow tanks is the flexibility to tolerate shock loads in terms of both quantity and quality of raw water. In fact, rectangular sedimentation unit can handle 50 to 100 percent higher flow rates than the original design capacity for short periods without significant deterioration of settled water quality. Consequently, the flexibility and predictable performance under most conditions brings about easy and stable operation and low cost maintenance, even though the capital cost may be higher than the other systems.

The applied design parameters for the sedimentation process are:

1) Type	:	Rectangular plug flow
2) Number	:	2 trains with hydraulic sludge removal pipes
3) Surface loading	:	25 mm/min (< 30 mm/min)
4) Passing velocity	:	0.31 m/min (< 0.4 m/min)
5) Collecting trough loading	:	370 m^3/m/day (< 500 m^3/m/day)
6) Dimensions	:	11 m width x 41 m length x 4 m depth x 2 trains
7) Intermediate chlorination	:	Effluent chamber to filter units

11.7 Rapid Sand Filtration

11.7.1 Type of Filter Media and Filtration Rate

Dual-media filter beds consisting of anthracite and sand provided in the original filter bed of filter Nos. 1 to 12 at Ambatale Water Treatment Plant made possible (i) higher filtration rates than of conventional filters, resulting in a reduction in the total filter area and cost for the given design capacity and (ii) longer filter runs at any given loading. However, an unexpected loss of anthracite took place because of an inconsistent washing schedule using the combined air scouring and water backwash, without wash troughs. The filters eventually did not function properly with a deterioration of the filtered water, which resulted in exceeding the water quality beyond the Sri Lankan Drinking Water Standards.

During the Ambatale Rehabilitation Project, the JICA Study Team provided with a single media of sand, 900 mm thick and 0.9 mm effective size, with a filtration rate of 202 m^3/day based on a pilot filtration study in 1996. The subsequent operation results of the Ambatale Water Treatment Plant reflected a satisfactory production record to date. The data indicated that only on six days in the period from April 1999 through April 2000 the filtered water quality exceeded the acceptable level of 1.0 NTU. Undesirable operation of the filters seldom happens, except when the clarifiers fail to remove turbidity to less than 5 NTU. This is mostly caused by sharp fluctuations of inflow turbidity.

For Kandy Project, water demand is expected to rise sharply, and therefore a filtration rate of 150 m^3/day plus a 30 percent allowance to make 200 m^3/day is recommendable during the transition period, between Phase 1 through Phase 3. This rate is justified in view of the designed filtration rate of 154 to 173 m^3/d at KMC treatment plant within almost the same range, and operating successfully.

The applied design parameters for the filter media and filtration rate are:

1) Filtration rate	:	150 m^3/day (< 200 m^3/day during backwashing)
2) Filter media	:	Silica sand, 1,200 mm thickness, E.S. = 1.0 to 1.2 mm, U.C. <1.5
3) Nos. of filters	:	4 units
4) Dimensions per unit	:	7.2 m x 9.6 m (= 69.1 m^2/unit < 150 m^2)

11.7.2 Filter Wash Arrangements

The applied deep bed filter is not compatible with surface wash system, even with fixed grid or rotating arm types, because the mixing energy provided by the surface wash may not reach towards the deeper portion of the bed where the retained material is clogged. A rotating arm type with dual-arm agitators is available for deep or dual media filters. However, this is not recommended due to the more complex structure and the inevitable maintenance of the rotating parts.

Therefore, the air scoring system is applicable in this case, which is widely employed in existing water treatment plants in Sri Lanka.

The rates of backwash need to be high enough to wash out the clogged substances in the filter media, but no higher. The percentage of expansion that accompanies any backwash rate is a function of the sand size, specific gravity and temperature of the water. Considering the relatively high temperatures and the existing conditions, a combination of 0.25 to 0.30

m^3/m^2/min of backwash and 1.0 m^3/m^2/min of air scoring is recommended. Backwash water will be tapped from the filtered water effluent chamber at the filter units into which the filtered water flows more than the required amount of the backwash, and pumped to each filter as necessary.

The applied design parameters for the filter wash arrangement are:

1) Backwash rate	:	0.25 to 0.30 m^3/m^2/min
2) Auxiliary wash	:	Air-scoring, 1.0 m^3/m^2/min
3) Backwash water	:	Tap the filtered water chamber at the filter units

11.7.3 Type of Filter Rate Control

An integral requirement for the sustainable operation of filters is to distribute the settled water evenly into each filter, and to backwash them regularly, if the loss of head reaches the designed level or after 24 to 48 hours of filter run, dependent on the settled water quality. Unscheduled backwashing will be inevitable in situations where the turbidity of the settled water is beyond the desirable level of 5 NTU. Inflow weirs, without filter controllers are recommended to hydraulically distribute the settled water evenly to each filter unit. Effluent weirs to be installed at the tale end of each filter unit is recommended to achieve a constant rate filtration system, which secures stable operation of filtration. The water level in each filter unit rises as necessary to accept an equal portion of influent and indicates head loss.

The applied filter control system is:

1) Filtration system	:	Constant-rate filter with influent splitting and varying water level
2) Inflow/effluent control	:	Weirs

11.7.4 Auxiliary Arrangements

The filter underdrain system is selected based on the combination of filter media and washing system, from strainers, dual lateral blocks, and precast concrete perforated underdrains, as commonly adopted. The selection criteria are reliability, simplicity of design/construction, durability, and low head loss during washing.

For this project, a nozzle type is preferably the most appropriate strainer, to provide easy installation and most stable underdrain system in combination with the proposed air scouring and washing systems. Supporting gravel is not necessarily required for the strainer underdrain system.

The applied underdrain system is:

1) Underdrain system	:	Strainer type

2) Supporting gravels : Minimal or not applicable

3) Valves : Electrically operated

11.8 Chemical Applications and Chlorination

Alum as a coagulant, lime for pH control, and liquid chlorine as a disinfectant are employed on the proposed Katugastota WTP, similar to the existing Ambatale and KMC Water Treatment Plants. The dosages (in mg/l) and applied points of each chemical is shown in Table 11.2 in reference to operation conditions of the existing KMC WTP facilities as discussed in the Main Report.

All of the equipment and facilities for chemical applications and chlorination are provided in the Chemical Building, which will be constructed near by the Administration Building for easy administration.

Table 11.2 Chemical Dosage

	Max.	Ave.	Min.	Dosing Points
Alum	60	30	10	Distribution chamber
Pre lime	30	10	5	Ditto
Post lime	20	5	5	Effluent chamber of filter units
Pre chlorine				Distribution chamber
Intermediate chlorine	5	2	1	Alternative for pre-chlorine at the effluent channel of sedimentation basins
Post chlorine	2	1	1	Effluent chamber of filter units

11.8.1 Alum

Alum will be delivered in bags containing 50 kg of aluminum sulphate $Al_2(SO_4)_3 \cdot 18H_2O$. According to the water quality records at the KMC WTP, the maximum dosage is not likely to exceed 30 mg/l, but provisions will be made to enable the operators to satisfy dosage demands up to 60 mg/l with a 10 percent solution. The flow of alum solution is manually controlled according to the alum demand and to the actual raw water flow. It is noted that KMC system is using Alum at an average rate of 30 mg/l, and hence the design is safe and satisfactory.

The alum feeding facilities is consist of two dissolving tanks, having a total net capacity equivalent to at least one or two days retention time at the maximum dosing rate. Two tanks, one for duty and another for standby with dimensions of 2.0 m x 2.0 m x 2.5 m (deep) is built in reinforced concrete or mild steel with suitable acid resistant lining. Each dissolving tank is provided with a screen, dissolving tray, electrically driven mixer, overflow pipe, drain pipe, solution suction pipe, each complete with manual valve, and level gauge.

11.8.2 Lime

Lime will be delivered in bags, containing 25 or 50 kg of imported hydrated lime. The maximum lime dosage is not likely to exceed 20 mg/l in accordance with the operating record of KMC Water Treatment Plant, but provisions will be made to enable the operator to satisfy dosage demands up to 30 mg/l with a 10 percent solution. The flow of lime slurry will be manually controlled according to the lime demand and the actual water flow.

Two slurry tanks are provided, having a total net capacity equivalent to at least one or two days retention time at the maximum dosing rate. Two tanks, one for duty and another for stand by with dimensions of 2.0 m x 2.0 m x 2.5 m (deep) are built in reinforced concrete or mild steel. Each slurry tank is provided with a loading hatch with dust removal unit, a screen, an electrically driven mixer, overflow pipe, drain pipe and slurry outlet valve, each with manual diaphragm or ball valve, level gauge (float and counterpoise along a graduated scale).

11.8.3 Storage of Alum and Lime

Alum and lime storage at the treatment plant will be sufficient for at least 30 days of operation, at an average dosage of 30 mg/l of alum and 10 mg/l of lime, respectively. Bag stacking does not exceed 3 m high. The chemical storage for each facility is provided with suitable loading equipment to accommodate the specified maximum daily consumption of alum and lime.

11.8.4 Chlorine

Chlorine will be supplied in tonne containers of liquid chlorine. The facilities include all equipment for storage, handling, dosing and injection of chlorine, together with safety equipment. The operation of the chlorinators will be controlled on a “START-STOP” basis according to the level in the distribution chamber, and/or clear water reservoir, similar to that detailed for the existing facilities of both the Ambatale and KMC Water Treatment Plants.

One chlorine drum of each row is supported on a weighing machine, which is provided with an adjustable tare lever and with supports for the drums. A row of chlorinators is equipped with one immersion pit, to reduce the damage in case of chlorine leakage. Evaporators is not necessary as a tonne container can feed evaporated chlorine about 10 kg/hr with no additional heat input or evaporator in premises at 20 to 25°C. The necessary number of chlorine cylinders is provided without evaporators based on the said conditions.

The dosing points for pre and intermediate chlorine shall be selected accordingly to the raw water chlorine and operation and maintenance purpose such as shock dosing for algae control in the flocculation, sedimentation, and filtration tanks. Subsequently, post chlorine shall be adjusted to retain necessary chlorine residual in the distribution network.

11.9 Clearwater Reservoir

The clearwater reservoir is to be constructed complete with two compartments on the plant site. The facility has a total volume corresponding to at least one hour of operation plus in-plant water. The amount needed for washing filter units will be stored in the effluent chamber at filter units.

Downstream and upstream isolation of each compartment is provided. Each compartment is designed to accept the nominal design flow without change of the normal operating levels. A sufficient number of baffles are installed in order to prevent dead zones in the clear water reservoir. Emergency overflows also are provided.

A post chlorine contact chamber is designed at the effluent chamber of filter units to accomplish proper mixing of chlorine and filtered water.

11.9.1 Filter Washwater Tank

A filter washwater tank may be advantageous in case of small-scale water treatment plants with several filter units, which possibly reduces the required capacity of backwash water transmission pumps. However, the number of filter units at the proposed Katugastota WTP in Phase 3 will be 12 units provided that number of filter units in Phase 1 is four. In this situation, the backwashing will be necessarily conducted at least once in every two hours or less, in the event of an emergency. The filter washwater tank should be then filled up in 30 minutes or so, which means that the backwash water transmission pumps will be operated continuously in the proposed washing method.

The proposed direct washing method by pumping is therefore desirable as backwashing will be able to be conducted anytime, if necessary.

11.10 Sludge Treatment

The sludge withdrawn hydraulically from the sedimentation basins is conveyed to sludge lagoons, which is considered the most appropriate sludge treatment process in tropical countries, as recommended in the JICA F/S. The dried sludge will be disposed of outside the treatment plant periodically by trucks. The expected amount of sludge generated in the sedimentation basins is estimated at 98 percent water content, and the estimated total volume is 35,380 m^3/year. The designed water content of dried sludge in the lagoon is 70 percent. The dried sludge volume is then computed to be 2,360 m^3/year. Two lagoons with a volume of 2,450 m^3 (>2,360 m^3/year) each are provided, including one lagoon for standby, taking unexpected weather conditions into account.

The applied design parameter for the sludge lagoons are:

1) Nos. of lagoons	:	2 (one for standby) to cater for Phase 1
2) Dimensions	:	70 m x 35 m x 1 m (effective depth)

11.11 Sampling of Process Water and Laboratory Equipment

For a permanent sampling of raw, settled, and treated water are drawn to the laboratory, to enable the control of the main parameters of the process water quality. The raw water is taken from the raw water main without sampling pump. The settled water is taken from the settled water effluent channel to filter units by sampling pumps. The finished or treated water is tapped from the service water pipeline.

At each treatment facility, the various treatment units (rapid mixing, flocculator, sedimentation basins, filters, chemical tanks, etc.) are provided with sampling taps in order to enable manual sampling of the various stages of water along the treatment processes.

A laboratory will be provided complete with necessary equipment, glassware and chemicals to enable the determination of the main physical and chemical parameters of the water with particular reference to the tests listed below and the analytical methods given in "Standard Methods for the Examination of Water and Wastewater" latest edition published by APHA, AWWA, WEF or the UK Standing Committee of Analysts, "Methods for the Examination of Waters and Associated Materials", HMSO, London.

Since this plant will be the first major treatment facility in the Central Region, provision will also be made for investigative studies to be undertaken on optimisation of chemical dosing rates etc., so as to identify the best operating regime for the plant and to develop essential operating data to assist in improvement of the existing water supply systems, and in the future design of water supply systems in the area.

11.12 Pipework

Site pipework for the water treatment plant is consist of piping underground between structures or process units carrying liquids to various destinations of the plant. Those are shown in the Drawings.

11.13 Administration Facilities

A two-storey building is to be constructed in the plant site. The ground floor includes an entrance with receptionist alcove, general office area, OIC room, stairs to the second floor, the laboratory and laboratory chemical storage room, chemist's room, a store, and toilets. Upstairs includes offices for the manager, engineers, conference room, a small library for drawings and engineering manuals in monitoring room, toilets and stairs to the lower floor are also be provided.

11.14 Maintenance Building

The maintenance building includes two offices, a garage, workshop, pipe yard, lockers for operators, showers, toilets, mechanical storage, and electrical storage. The building is single storey with roll-up doors for vehicle access to the garage, and large equipment to be repaired in the workshop. Pipes for transmission or distribution will be stacked in the pipe yard. Tools necessary for vehicle and minor repair work also will be provided. A crane is provided for use in the garage and workshop.

11.15 Site Infrastructure

11.15.1 Service Water Distribution

The service water distribution system in the plant to be provided in the clear water transmission pump room will supply the staff facilities, chemical solution water, and other high-pressure requirements, tapping clearwater from the clearwater reservoir.

11.15.2 Standby Power Generation

The present electricity supply is not reliable, and the CEB's records indicate frequent power failures. Provision of standby power generators for the intake and treatment plant to ensure continuity of water supply and for security concerns is considered to be must. One building each for the Gohagoda Intake and Katugastota WTP is provided for the standby generators and this is located as near as possible to the main electrical load centre, at the entrance of the Gohagoda Intake and the clearwater transmission pump station in the Katugastota WTP, respectively.

CHAPTER 12 TRANSMISSION, STORAGE, AND DISTRIBUTION SYSTEMS

12.1 General

The proposed Phase 1 transmission and distribution system comprise of 20 Nos. existing, augmented and new service reservoirs, 7 Nos. new booster pumping stations linked with Katugastota Treatment Plant by transmission pipelines. This has been designed to get the optimum use of the system with provisions made to satisfy Phase 2 and 3 requirements. To facilitate efficient performance of the system the entire service has been divided into 11 different zones namely, i) Gohagoda/ Yatihelagala, ii) Katugastota/ Uduwawala, iii) Katugastota/ Kahawatte, iv) Katugastota/ Madawala, v) KMC/Kandy Four Gravets (1), vi) KMC/Kandy Four Gravets (2), vii) Katugastota/Kundasale, viii) Talatuoya, ix) KMC/Eriyagama, x) KMC/R2, and xi) KMC/Uda Peradeniya. This covers the entire service area from the northern to the southern boundary.

12.2 Improvement Plan

The improvement plan for each service area intends to incorporate the existing facilities to the maximum in order to accommodate the future demands with minimum reinforcement pipelines. These improvements are summarized as follows.

i) Katugastota/Uduwawala Zone

By pass the booster sump at Kondadeniya, and directly pump water from Katugastota Treatment Plant to Kondadeniya SR to conserve energy and make maintenance simpler and easier.

ii) Katugastota/Kahawatte Zone

Lay a 350mm DI transmission main in Phase 1 from Kahawatte SR to Kurugoda SR to accommodate Phase 3 demand in one operation, in lieu of laying 250 mm uPVC main in Phase 1 followed by laying of 250 mm DI main in Phase 3. This is in order to avoid way leave limitations arising in the A9 road in this particular section, which is already occupied by a telecom cable and a water main.

iii) Katugastota/Madawala Zone

a) Convert the existing transmission pipeline originating from the borehole field at Pinga Oya to a future transmission main in the section from Madawala Road to Balanagala SR as the borehole is to be abandoned after implementation of Phase 1, which will result in a significant saving in cost.

b) convert the existing transmission main from Polgolla WTP to Bangalawatte and Pihilladeniya SRs to a distribution main, as new transmission mains are planned to be laid to link these two SRs with Katugastota Treatment Plant.

iv) Polgolla/Yatihelagala Zone

Duplicate the transmission main from main road to Gohagoda SR by a 225 mm dia uPVC main, 150 m long as the capacity of the existing 150 mm uPVC main is inadequate to carry the full future capacity.

v) KMC/ Kandy Four Gravets Zone

a) Transmission pipelines are planned for Uplands, Asgiriya and Bahirawakande SRs from Katugastota WTP. In line boosting is provided to Bahirawakande from Asgiriya.

b) The capacity required at Bahirawakande is 1,600 m^3, but the available only land is very steep and cannot accommodate a reservoir more than 600 m^3. Therefore, it is planned to provide this additional storage at Asgiriya SR, which commends an extensive service area in KMC.

vi) KMC/ R2 Zone

The existing Primrose SR constructed in 1985 is a steel tank (Braithwaite Type), which is profusely leaking over the past several years. ADB has planned to construct a new concrete SR in its place and the other improvement works on the existing transmission and pumping system, and therefore this work has been excluded in the scope of work under this Project.

vii) In KMC/ Uda Peradeniya Zone

The existing pumping main to Dangolla SR is being used as the distribution main on its way and hence the flow to the reservoir is very limited rendering the SR ineffective. The rectification of this situation is an urgent matter and hence JICA has undertaken to construct a new reservoir and ADB has agree to lay a new transmission main and installation of new pumps at the KMC treatment plant.

The total number of reservoirs including the existing ones outside of KMC area is 21 and within KMC system is 8. The selection of the reservoir sites has been done by NWSDB and the feasibility to supply water by gravity to the proposed service areas was determined by topographic surveys.

Table 12.1 tabulates the water demand allocations for each service area.

Table 12.1 Water Demand Allocation for Each Service Zone

Service Reservoir		Day Maximum Water Demand (m^3/d)		
No.	Name	2005	2010	2015
1. Katugastota – Uduwawala Zone				
1.1	Kulugammana	1,285	1,447	1,910
1.2	Kondadeniya	1,591	1,804	2,000
2. Katugastota – Kahawatte Zone				
2.1	Kahawatta	1,828	2,180	2,773
2.2	Kurugoda	1,894	2,226	2,773
2.3	Telambugahawatta	1,513	1,821	2,310
3. Katugastota – Madawala Zone				
3.1	Kahalla	2,092	2,331	2,773
3.2	Pihilladeniya	928	1,066	1,200
3.3	Bangalawatta	1,276	1,450	1,848
4. Polgolla – Gohagoda Zone				
4.1	Gohagoda (New)	816	1,069	1,400
5. KMC- Kandy Four Gravets Zone				
5.1	Asgiriya	10,465	14,740	15,609
5.2	Upland	7,612	10,830	11,170
5.3	Hantana Place (NWSDB)	320	366	398
5.4	Mullepihilla Low	395	449	500
5.5	Heeressagala Middle (NWSDB)	322	396	500
5.6	Heeressagala Upper	401	550	694
5.7	Elhena	826	990	1,200
5.8	Mullepihilla Low	395	449	500
6. KMC- R2 Zone				
6.1	Bahirawakanda	1,950	2,040	2,180
6.2	Primrose	1,770	1,860	1,980
6.3	Heeressagala Low	577	678	800
6.4	Heeressagala Middle (KMC)	322	396	500
6.5	Hantana Place (KMC)	190	230	260
7. KMC – Uda Peradeniya Zone				
7.1	Dangola	1,330	1,390	1,490

To identify the service areas 1:10,000 scale maps were prepared indicating locations of existing and proposed SRs, distribution systems and Grama Niladhari Division (GND) boundaries and thereafter pressure contours were drawn to demarcate potential areas which could be served with a residual head of 6m at the consumer's tap (hydraulic factor). Simultaneously, the population in each GND were obtained from the Divisional Secretaries, and the percentage of population which could be served were obtained from the respective OICs of the existing systems (geographic factor). By making use of these 3 factors i.e. total population, hydraulic factor and the geographic factor the potentially feasible population in year 2000 was evaluated. This population was further projected to 2005, 2010 and 2015 by assuming growth rate factors of 2.5 percent (high), 2.0 percent (medium) and 1.6 percent (low) for different areas decided by the OIC's considering the trends towards population increases in the future. However, such an exercise was not required for the KMC area as 100 percent coverage was envisaged.

12.3 Features of the Service Reservoir Areas

Kahalla SR Area

The service area to be commanded by this 600 m^3 elevated reservoir (HWL: 491.25 m AMSL, LWL: 485 m AMSL) is 2.55 km^2. The existing distribution system does not cover a significant portion of the proposed service area and hence an extensive new pipeline system and reinforcement of the existing system are planned. The existing area is presently served by Balanagala SR and with the commissioning of the new SR this area will be isolated from Balanagala SR through an isolating valve, but interconnection is possible whenever needed.

Bangalawatte SR Area

This 300 m^3 SR (HWL: 521.28 m AMSL, LWL: 518.35 m AMSL) is to be constructed by the exiting SR (100 m^3) and will command a service area of 4.6 km^2. The existing distribution system mostly covers the service area, but some reinforcements are needed. This system is to be interconnected with Pihilladeniya and Napana SR service areas via isolating valves to provide an integrated service.

Pihilladeniya SR Area

This 200 m^3 SR (HWL: 524.14 AMSL, LWL: 522.14 m AMSL) is to be constructed at the existing SR (100 m^3) site to enhance the storage capacity similar to Bangalawatte. The command area will be 3.18 km^2, which is currently served by Polgolla WSS. Adequate distribution system is available to cover the service area, but some reinforcements are planned. This area will be linked with the Bangalawatte SR area as mentioned above.

Kahawatte SR Area

This 600 m^3 capacity elevated SR (HWL: 522.25 m AMSL, LWL: 516.0 m AMSL) will have a command area of 7.04 km^2, which is presently served by Akurana WSS. The existing distribution system is adequate, but some limited reinforcements and extensions are planned. This system is to be linked with Akurana system via. three isolating valves.

Kurugoda SR Area

This 600 m^3 SR (HWL: 573.0 m AMSL, LWL: 569.0 m AMSL) will command a service area of 4.0 km^2. Which is currently served by Alawategoda WSS. An extensive distribution system is available but certain reinforcements and further extensions will be carried out under this Project. This SR will be linked with Vilana and Owissa SRs to the north and Akurana SR to the south by isolating valves to use in an emergency.

Thelambugahawatte SR Area

The service area of this elevated type 500 m^3 SR (HWL: 566.75 m AMSL, LWL: 561.5 m AMSL) is 2.90 km^2. The existing distribution system is highly inadequate and hence new supplementary pipelines will be laid. Originally this area was served by Alawatugoda and Akurana WSSs. This SR will be linked with Akurana SR via isolating valves.

Kulugammana SR Area

This 100 m^3 SR (HWL: 583.25 m AMSL, LWL: 579.25 m AMSL) will be constructed by the side of the existing SR (300 m^3) to enhance the existing storage capacity. Adequate distribution lines are available to cover the area and boosting is planned to serve northern parts until a new SR is constructed at Nugawela in Phase 2.

Kondadeniya SR Area

The new 200 m^3 SR (HWL: 535.25 m AMSL, LWL: 531.25 m AMSL) is planned at the site of the existing 300 m^3 SR to enhance storage capacity and will command a service area of 2.78 km^2. No more reinforcements or reinforcement of distribution system is not planned currently as the system is adequate.

Gohagoda SR Area

The new 200 m^3 SR (HWL: 531.2 m AMSL, LWL: 527.2 m AMSL) is to be constructed at the site of the existing 150 m^3 SR to augment the storage capacity and to serve high elevated areas not served by the existing SR by raising the HWL. The command area will be 2.14 km^2. There is an adequate distribution system and only some short extensions are planned. The service area is to be linked with Gohagoda old, Yatihelagala, Kulugammana and Wegiriya SRs via isolating valves.

Heerassagala (Middle) SR Area

This 250 m^3 SR (HWL: 617.0 m AMSL, LWL: 613.0 m AMSL) is designed to command a service area of 0.58 km^2. A substantial segment of a new residential area is integrated into the new service area. The existing distribution system is insignificant and hence an extensive system is planned to be laid. A booster pump house is also planned nearby the SR to pump water to Heerassagala Upper SR.

Heerassagala Upper SR Area

The service area of this 200 m^3 SR (HWL: 678.0 m AMSL, LWL: 674.0 m AMSL) is designed to be 0.48 km^2. The existing distribution system is insignificant and highly inadequate and hence an extensive distribution system will be laid. This SR will be linked with Elagolla and Hantana Middle SRs via isolating valves.

Hantana Place SR Area

The service area of this 200 m^3 SR (HWL: 641.0 m AMSL, LWL: 637.0 m AMSL) is 0.85 km^2 and proposed to serve the southwestern part of existing Hantana Upper and Hantana Lower WSSs to ease the burden of the latter two in the high elevated areas. However, on a request made by the KMC provision has been made to supply water to Kandy hospital quarters and Nagastenna lying within KMC area. Neither extensions nor reinforcements are planned in this systems other than the above mentioned.

Elhena SR Area

This 300 m^3 SR (HWL: 615.0 m AMSL, LWL: 611.0 m AMSL) is primarily planned to serve high elevated areas in the northern and eastern parts of Ampitiya service area covering 4.46 km^2. Some new distribution mains are also planned to be laid. This SR will be linked with Ampitiya SR by via isolating valves for a more integrated service.

Mullepihilla Low SR Area

This 100 m^3 SR (HWL: 713.0 m AMSL, LWL: 709.0 m AMSL) commands a service area of 0.55 km^2. The existing SR has a capacity of 25 m^3. There is an adequate distribution system to serve the area.

Service Reservoirs within KMC Area

Five SRs are planned to be constructed within KMC area, i.e. 4100 m^3 Asgiriya (HWL: 567.0 m AMSL, LWL: 561.5 m AMSL), 2960 m^3 Uplands (HWL: 566.0 m AMSL, LWL: 560.0 m AMSL), 600 m^3 Bahirawakande (HWL: 629.0 m AMSL, LWL: 625.0 m AMSL), 500 m^3 Dangolla (HWL: 531.6 m AMSL, LWL: 527.6 m AMSL) and 200 m^3 Heerassagala Low (HWL: 570.0 m AMSL, LWL: 566.0 m AMSL). There are existing small capacity reservoirs at Asgiriya, Uplands (57 m^3), Dangolla (180 m^3) and Bahirawakande (91 m^3). The Asgiriya, Uplands and Bahirawakande SRs will serve northern parts of KMC area and down town. Bahirawakande SR will also serve high elevated areas in western parts of KMC. Dangolla and Heerassagala low will serve the southern parts of KMC. The construction of Primrose SR is deleted from the scope of work and will be undertaken by the ADB Project.

12.4 Transmission Pipeline

The water demands in each zone has been evaluated in Table 12.2 for the 3 Phases. The summary of the transmission lines so designed to be laid under Phase 1 is illustrated in the following Table 12.2.

Table 12.2 Transmission Pipelines for Phase 1

Pipe Material	Pipe Dia. (mm)	Length to be laid (m)		Total Length (m)
		KMC System	Katugastota System	
DI	800	0	415	415
	700	0	1,850	1,850
	600	0	3,272	3,272
	500	0	4,390	4,390
	400	0	2,020	2,020
	350	1,002	4,309	5,311
	300	1,782	4,605	6,387
	250	0	4,624	4,624
	200	4,539	3,940	8,479
	150	1,972	0	1,972
uPVC	225	1,457	492	1,949
	160	767	0	767
	90	149	0	149
Total		**11,668**	**29,917**	**41,585**

12.5 Distribution Pipelines

Based on the identified each service zone, the existing distribution pipelines are isolated by valves for making the reformed distribution network for each service zone. The feeder main from service reservoir to the existing network, additional pipelines to the existing network, and new pipelines for unserved area were studied by the hydraulic analysis based on the supply condition as shown Table 12.3.

Table 12.3 Phase 1 Service Zone and Type of Supply

Service Zone		Service Reservoir	
No.	Name of Reservoir	Supply Type	Remarks
1	Kahalla	Single supply	
2	Bangalawatta and Pihilladeniya	Double supply	With existing SRs
3	Kahawatta	Single supply	
4	Kurugoda	Single supply	
5	Telambugahawatta	Single supply	
6	Kulugammana	Single supply	
7	Kondadeniya	Single supply	
8	Gohagoda (New)	Double supply	With existing SRs
9	Heeressagala Middle (NWSDB)	Single supply	Also supply to KMC
10	Heeressagala Upper	Single supply	
11	Hantana Place (NWSDB)	Single supply	Also supply to KMC
12	Elhena	Single supply	
13	Mullepihilla Low	Single supply	

Distribution feeder pipe from the new SR to the connection point of the existing distribution network will be of the most economical size with some allowance provided for unforeseen future water demand. Additional distribution pipes will be provided to reinforce the existing distribution network and to expand the service area to the unserved areas as suggested by the OIC of the existing WSS, such as potential developable areas, area where ground water yields are poor, intermittent supply area, etc. Among such pipelines, high priority and hydraulically feasible areas were selected and included in the detailed design.

Distribution pipelines with a total length of 27.7 km to be expanded under Phase 1 is summarised in Table 12.4.

Table 12.4 Distribution Pipelines for Phase 1

Pipe Material	Pipe Dia. (mm)	Length to be laid (m)		Pipe length (m)
		KMC System	Katugastota System	
DI	500	682	0	682
	450	1,206	0	1,206
	400	329	0	329
	300	0	873	873
	250	586	2,054	2,640
	200	0	41	41
	100	0	237	237
uPVC	225	0	7,412	7,412
	160	0	6,981	6,981
	110	0	3,454	3,454
	90	0	3,832	3,832
Total		**2,803**	**24,884**	**27,687**

12.6 Pipeline Design

12.6.1 Hydraulic Design

Pipelines will be sized using the exponential formula developed by Hazen and Williams shown below in metric units.

$$H = 10.666 \quad x \quad C^{-1.85} \quad x\, D^{-4.87}\, x \quad Q^{1.85}\, x \quad L$$

Where, H: friction loss (m)
C: friction coefficient
D: diameter of pipe (m)
Q: rate of flow (m^3/sec)
L: Pipe length (m)
"C" value equals to 130 for the new cement lined DI and uPVC pipes.

Applied friction coefficient (C) will be as indicated in Table 12.5.

The maximum flow velocity shall be the most economical and reasonable velocity. Peak factor for daily maximum demand was taken as 1.2 x daily average demand. Residual pressure of hydraulic grade line at inlet to the Service Reservoir will be more than 5 m.

A minimum service pressure of 6 bars (0.6 kgf/cm2) above ground level will be adopted for design under the peak hour demand condition for areas outside KMC.

Table 12.5 Pipe Friction Coefficients

Pipe Material	Existing (old) or New	Friction Coefficient (C)
Cast Iron	Existing (old)	90
uPVC, ACP	Existing (old)	120
Ductile Iron (DI)	New	140
uPVC	New	140

12.6.2 Pipe Materials

At present, DI pipe is used extensively for most of the medium and large diameters of 250 mm or larger pipelines. The DI pipe is an excellent pipeline material with good durability, ease of installation both in laying and jointing, and flexibility in jointing. However, the pipe should be protected from interior corrosion using a cement mortar lining and from exterior corrosion by a bituminous coating.

For smaller diameter pipes less than 250mm uPVC pipes are recommended in terms of cost and characteristics. These pipes are locally manufactured.

12.6.3 Structures for Pipelines

An aqueduct bridge is planned to cross the Mahaweli River near Katugastota WTP, and two pipes will be placed on that bridge, namely 800 mm pipes in Phase 1 by the year 2005 and 400 mm pipes in Phase 3 by the year 2015, to transmit clear water to the northern area of Kandy city through Bahirawakanda, Asgiriya, and Uplands service reservoirs. This transmission line will later be extended to Hantana Place reservoir and Talwatte Reservoir in Phase 2, and up to Gurudeniya, Talatu-Oya and Haragama in Phase 3.

For small size pipes, direct attachment to road bridge superstructure or piers may be possible, and the final installation method in each case was decided through discussions with road administrators (RDA, P.S.) and of the other relevant authorities.

In case of railway crossings, it has been the practice that after obtaining approval from the Railway Authority (CGR) for a particular railway crossing, and on payment of the estimated cost, the CGR will lay a concrete pipe ducting of agreed size under the railway track in advance, to enable the water pipe to be laid through the duct by the Project at the relevant time.

1 m of clear cover over the pipeline will be applied to protect the pipelines from traffic load and to keep them from “floating” when empty. In poor ground conditions suitable beddings or geotextiles will have to be placed to provide a stable ground support for the pipes to prevent subsequent settlements and damage to the pipe lines.

At low points along the profile, washouts are provided to drain the pipeline between isolation valves for repairs or for future connections. High points are provided with air and vacuum valves to remove air from the pipe during filling and to supply air into the pipe, if a sudden release of water or a water hammer effect will produce a vacuum. Where required washout and /or air valves are placed on either side of an isolation valve to facilitate draining of the pipeline between isolation valves for repairs or future connections.

12.7 Service Reservoir

12.7.1 Design of Service Reservoir

The service reservoirs are both ground level and elevated type. They are generally designed to retain about 6-hour demand of each particular service area for absorbing demand fluctuations and any stoppage of supply from the source due to a breakdown of CEB supply, repair or maintenance.

The ground reservoir is adapted if the elevation of proposed service reservoir has enough elevation to distribute by gravity and to keep 0.6 bar minimum residual pressure at the furthest consumer’s tap as set in the design criteria.

The elevated tank is applied where reservoir site elevation is lower than the surrounding area, thus water level is required to be raised to an additional height depending on the elevation in the service area. Maximum height contemplated is about 25 m from ground elevation to low water level.

The incoming flow to the reservoir will be discontinued when the high water level is reached by immediately shutting off the pumps. A float valve or an electrode will be installed to the inlet line to stop the flow. . A local level indicator is installed for operators to be aware about the prevailing water level of the reservoir, and the pumping is in hand, and there is no reason for caution due to a failure of the pumps or the transmission main.

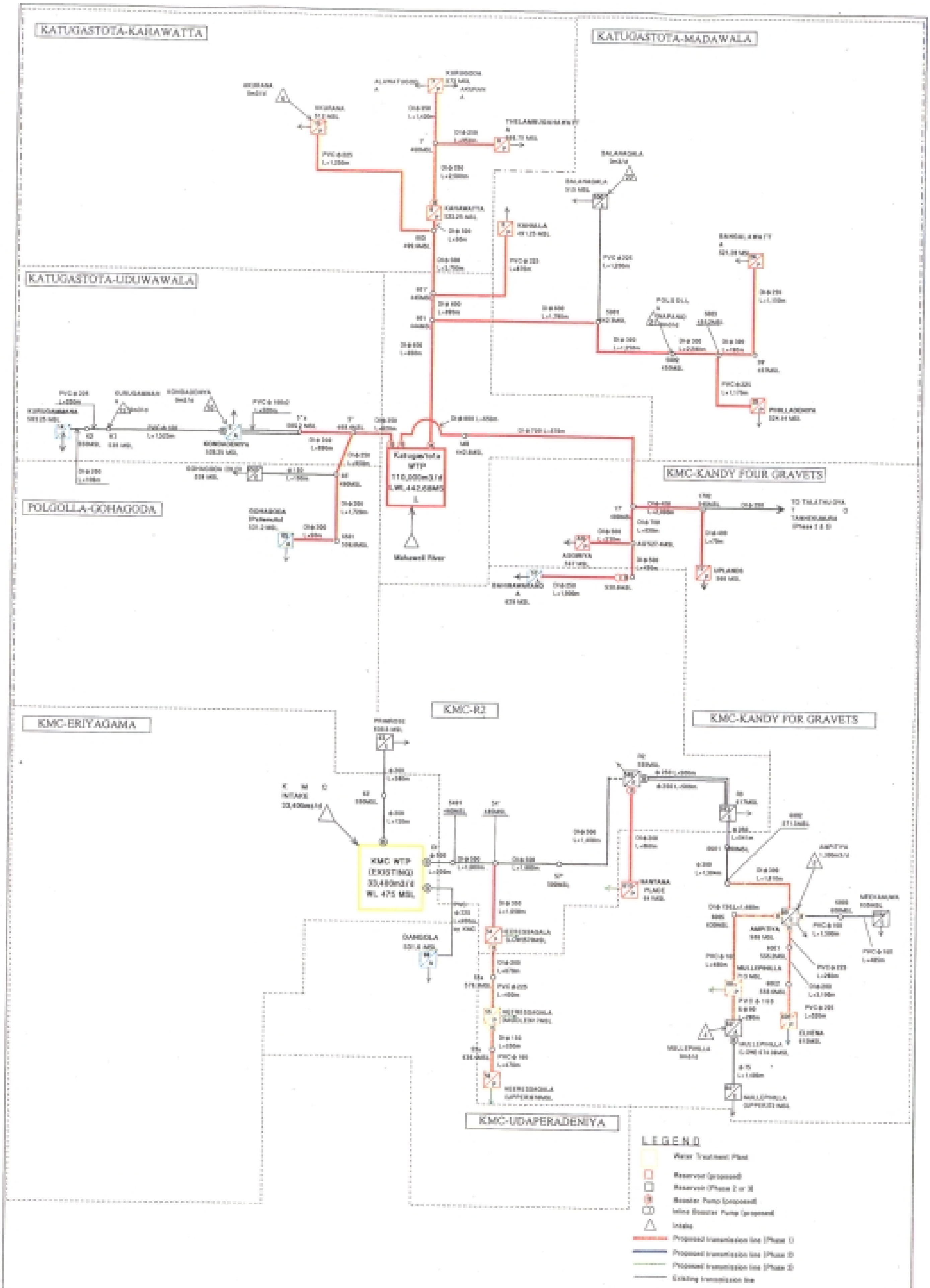
12.7.2 Proposed Service Reservoirs

A total of 19 service reservoirs with a total capacity of 12, 710 m^3 will be constructed in Phase 1. 13 SRs will be located outside of KMC and remaining six SRs will be located in

KMC area. The capacities of proposed service reservoirs and their respective elevations are listed in Table 12.6

Table 12.6 Proposed Service Reservoirs in Phase 1

Node No.	Name of Reservoir	Low Water Level	High Water Level	New Capacity (m^3)	Type	Existing Capacity (m^3)
Katugastota System						
PG	Clear Water Reservoir	442.68	445.68			
6	Kahawatte SR	516.00	522.25	600	Elevated	
7	Kurugoda SR	569.00	573.00	600	Ground	
10	Akurana SR	508.00	512.00		Ground	600
8	Thelambugahawatte SR	561.50	566.75	500	Elevated	
3	Kahalla SR	485.00	491.25	600	Elevated	
500	Balanagala SR	513.00	515.00			450
26	Bangalawatte SR	518.28	521.28	300	Ground	100
25	Pihilladeniya SR	522.140	524.14	200	Ground	100
5	Kondadeniya SR	531.25	535.25	200	Ground	300
14	Kulugammana SR	579.25	583.25	100	Ground	300
65	Gohagoda SR (new)	527.00	531.20	200	Ground	
65	Gohagoda SR (low)	524.00	528.00			150
65G	Gohagoda SR (old)	524.00	528.00			300
AG	Asgiriya SR	561.50	567.00	4,100	Elevated	
AG'	Asgiriya Pump Station		-	-		-
57	Bahirawakanda SR	625.00	629.00	600	Elevated	204
17	Uplands SR	560.09	566.00	2,960	Ground	27
KMC System						
KMC	KMC Treatment Plant	471.00	475.00			
63	Primrose	631.50	635.50	(by ADB)		501*)
582	R2	549.49	555.00			3,636
583	R3	613.00	617.00			1,136
66	Dangolla SR	527.60	531.60	500	Ground	118
54	Heerassagala (low) SR	566.00	570.00	200	Ground	
55	Heerassagala (middle) SR	613.00	617.00	250	Elevated	
56	Heerassagaa (upper) SR	674.00	678.00	200	Ground	
61S	Hantana Place SR	637.00	641.00	200	Ground	
60	Ampitiya SR	582.50	586.00			900
60M	Meekanuwa	633.00	635.00			225
60+	Mullepihilla (new) SR	709.00	713.00	100	Ground	
60'	Mullepihilla (old) SR	672.50	674.36			25
60"	Mullepihilla (high) SR	728.00	731.00			45
60E	Elhena SR	611.00	615.00	300	Ground	
Note: under the KMC (ADB) project.			**Total =**	**12,710 m^3**		



Fugure- 12.1 Transmission System in Phase 1

CHAPTER 13 CIVIL AND STRUCTURAL WORKS

13.1 Codes and Standards

The structures are designed according to the limit state design philosophy. The following British Standards, namely

BS 8110: 1985 - For framed building structures and
BS 8007: 1987 - For water retaining structures

are used mainly in the design and calculation of civil works for the component of the Project.

Other references from British Standards or other nationally recognises standards are used for specific areas of design such as concrete mix, concrete quality, chemical attack on concrete and reinforcement. Following is a list of other standards used in general.

BS 5950 – Structural steel
BS 5400 – Bridges and related structures
BS 8004 – Foundations
BS 6399 Part 1 – Design loading for buildings-Live Loads
BS CP3 chapter V part 2 - Basic data for the design of buildings – Wind loads
BS 6312 – Guide to selection of constructional sealants
BS 4449 – Hot rolled steel bars for the reinforced concrete
BS 4461 – Cold worked steel bars for the reinforced concrete
BS 5328 – Specification for concrete including ready-mixed concrete

Depending on the type of structure a suitable computer software package was used for the analysis and where necessary for the design of structures.

13.2 Design Criteria for Water Retaining Structures

13.2.1 Concrete

Concrete for reinforced non-prestressed, cast in place concrete construction is complied with the requirement of grade 35 of BS 12, having a characteristic strength of 35 N/mm^2 with a maximum water/cement ratio of 0.45.

Blinding concrete under footings, slabs of water retaining structure is grade 15 (15 N/mm^2) of BS 12.

The final choice of cement depended upon the results of the soil investigation, which indicates the chemical characteristic of the ground water. In general, the cement to be used is “Ordinary Portland Cement (OPC)”, complying with the requirements of BS12.

13.2.2 Reinforcement

Non-prestressed reinforcement will be high strength deformed bars with a specified characteristic strength of 460 N/mm^2 or mild steel bars with a characteristic strength of 250 N/mm^2.

13.2.3 Design Procedure

The analysis and design was carried out in accordance with the limit state design philosophy of BS 8110 and BS 8007.

(1) Structural design:

a) The structural designs of water retaining structures are designed to satisfy Limit State of Serviceability and Ultimate limit state.

b) The partial safety factor for retained water is designed to be 1.4 for most situations at ultimate limit state (ULS) and 1.0 at serviceability limit state (SLS).

c) The structures are designed with a minimum factor of safety of at least 1.1 against flotation.

d) The maximum crack widths for reinforced concrete – All faces of liquid containing are 0.2 mm max and where aesthetic appearance is critical are 0.1 mm max.

e) Deflection – All members are checked to ensure that the deflection limitations of BS 8110 are not exceeded.

f) Early age thermal and moisture shrinkage – Reinforcement is provided to ensure the early age thermal and moisture shrinkage cracking is properly controlled in accordance with the requirements of BS 8007.

(2) Structural analysis:

a) All structures required to retain liquids are designed for both the full and empty conditions and the assumptions regarding the arrangement of loading is to cause the most critical effects. Particular attention is paid to possible sliding and overturning.

b) At any given limit state the liquid level is taken to the top of the walls for design purposes assuming all outlets blocked.

c) No relief is allowed for beneficial soil pressures in designing walls subjected to internal water loading.

d) Thermal movement in roofs is minimized by appropriate means. It is noted that where a roof is rigidly fixed to a wall, forces will be generated in the wall should the roof expand or contract.

e) Earth covering roof is treated as a dead load and construction load of 5.0 kN/m^2 will be considered in the design.

13.3 Design Criteria for Reinforced Concrete Framed Structures

13.3.1 Concrete

Concrete for reinforced non-prestressed, cast in place concrete construction is complied with the requirement of grade 25 of BS 12, having a characteristic strength of 25 N/mm^2.

Blinding concrete under footings, slabs of water retaining structure is grade 15 of BS 12, having a characteristic strength of 15 N/mm^2.

The final choice of cement depended upon the results of the soil-testing programme, which indicates the chemical characteristic of the ground water. In general, the cement to be used is Ordinary Portland Cement, complying with the requirements of BS 12.

13.3.2 Reinforcement

Non-prestressed reinforcement is high strength deformed bars with a specified characteristic strength of 460 N/mm^2 or mild steel bars with a characteristic strength of 250 N/mm^2.

13.3.3 Design Procedure

The analysis and design of building and frame structures are carried out in accordance with the provisions of BS 8110:1985 “Structural use of concrete”.

13.4 Steel Structures

BS 5950:1985 “The structural use of steel work in building” or other internationally recognised Standards are used for any structural steel element design.

13.5 Environmental and Loading Criteria

13.5.1 Wind Speed and Climate

The lateral loads considered in the design are due to wind forces and in the absence of a National Building Code for wind forces, the BS CP3 Chapter V in conjunction with the Report, “Design of buildings for high winds in Sri Lanka - Ministry of Local Government, Housing and Construction”, is followed in designing structures against forces due to wind.

According to this Report, the Project Area falls into Zone 3 where recommended basic wind speed is 75 mph. (34 m/s). This wind speed is therefore used to calculate characteristic wind speed, which is dependent on factors such as topology, height of structure and life of structure. The buildings and components of buildings are designed for pressures due to relevant characteristic wind speed.

Design wind speed Vs 34 m/s

An enhanced wind speed of 40 m/s is, however used in designing water towers.

13.5.2 Live Load Criteria

• Inaccessible roofs	:	1.5 kN/m^2
• Roof with mechanical equipment	:	According to actual weights and provisions of BS 6399
• Floor of mechanical rooms	:	Min.10.0 kN/m^2 or according to actual weight of machinery whichever is higher.
• Floors accessible to trucks	:	BS 5400 - HA type loading
• General public access	:	5.0 kN/m^2
• Offices	:	3.0 kN/m^2
• Electrical rooms	:	Min. 12 kN/m^2 or according to actual weights of electrical equipment whichever is higher.

13.5.3 Earth Pressure Criteria

• Compacted soil density	:	20.0 kN/m^3
• Active lateral soil pressure coeff.	:	0.33 (to be confirmed by Geotechnical Investigation)
• Passive earth pressure coeff.	:	3.0
• Surcharge on walls	:	0.9 m of earth or HA –uniformly distributed load where the walls can get subjected to lateral pressure due to vehicles.
• Water head at bottom of walls	:	groundwater level, if present
• Density of water	:	10 kN/m^3
• Allowable bearing pressure	:	As per recommendations in soils investigation reports.

The above criteria for soil density and earth pressure generally conforms with engineering properties of soil commonly occur in the Project Area. However, where the soils investigations reveal values that lead to structures with lesser factors of safety, than the designs for that particular site was reviewed accordingly.

CHAPTER 14 MECHANICAL FACILITIES

14.1 Raw Water Intake Pumps

In order to accommodate the wide range of operating heads due to fluctuation of Mahaweli River water level, variable speed pumping is recommended.

Speed control is justified for the following reasons;

- continuous setting - the pumps with speed control can be continuously operated against the varying heads within the pre-determined range. The pumps with pole change motors and valve control have the same performance, but the control system is more complicated and expensive.

- low operating cost - the pumps with speed control has a lower operating cost than pumps with pole change motor and valve control.

By providing speed control for the raw water intake pumps and monitoring flow, the flow adjustment of raw water can be accomplished automatically.

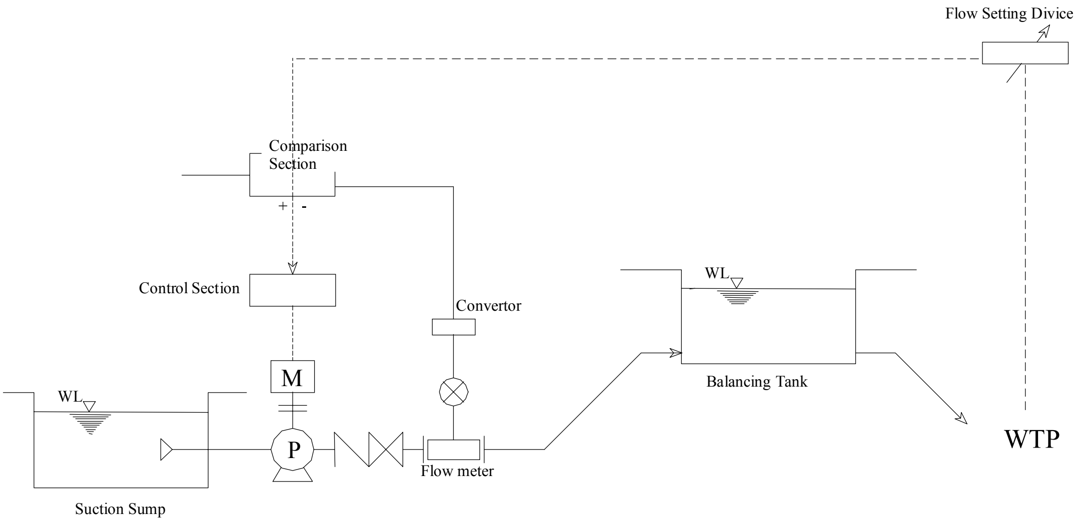


Figure 14.1 Intake Pump Control System

Surge analysis has been undertaken using the final pipeline configuration and design. No surge protection system is required for this pumping system.

The applied design parameters for the intake pumps are;

1) Number : 2 sets (including 1 set for standby) with additional spaces provided for 1 set each for Stages 2 and 3

2) Type : Vertical double suction volute pump with dry sump

3) Capacity: : 446 l/s each (26.74 m^3/min, 1,604 m^3/hour)

4) Head : 44.0 m (operation range: 38.0 to 44.0 m)

14.2 Sludge Collection for Sedimentation

Submersible travelling blade, reciprocating flight, and chain flight sludge collectors are compared for the employed horizontal sedimentation tanks with intermediate collection system. Reciprocating flight sludge collector has the following specific advantages;

- low cost – simple operation and structure for the collector will incur low cost;
- easy maintenance - simple operation and structure for the collector does not require special devices and materials for repair or maintenance. Local technicians could handle repairs using materials available in the local market.

14.3 Clear Water Pump Station

14.3.1 Pump Selection

A-1 (Upland/Asgiriya/Kondadeniya etc), A-2 (Gohagoda) and A-3 (Kahawatta etc) systems are designed for Phase 1 and A-4 (Uduwawala) system are designed for Phase 2, respectively as shown in Table 14.1.

Dry well horizontal double suction volute pumps are recommended for the clear water transmission. Wet well vertical mixed flow (turbine) pumps can also be applied, but more installation space is necessary at clear water pump station in the treatment plant. The proposed pump has the same superior advantages as listed for the intake pumps above. The number of pumps is determined by the availability of low voltage motors, which are available up to approx. 500 kW, and could be locally repaired.

Table 14.1 Clear Water Pumps

No.	Service Reservoir		Daily Maximum (m^3/day)	Pump No.		Flow (m^3/min)	Head (m)
				Duty	Standby		
A-1	Upland/Asgiriya	3	17,600	1	1	12.22	134
A-2	Gohagoda Kondadeniya	3	4,710	1	1	4.08	104
A-3	Kahawatta etc	6	14,390	1	1	9.99	93
A-4	Uduwawala	-	-	-	-	-	-

As for the anti-surge protection system, surge tanks with rubber bladders or pressure vessels, and flywheels are acceptable for this system. Taking into consideration of a compact area required and simple maintenance-free construction, flywheels are the preferred option for the surge protection system.

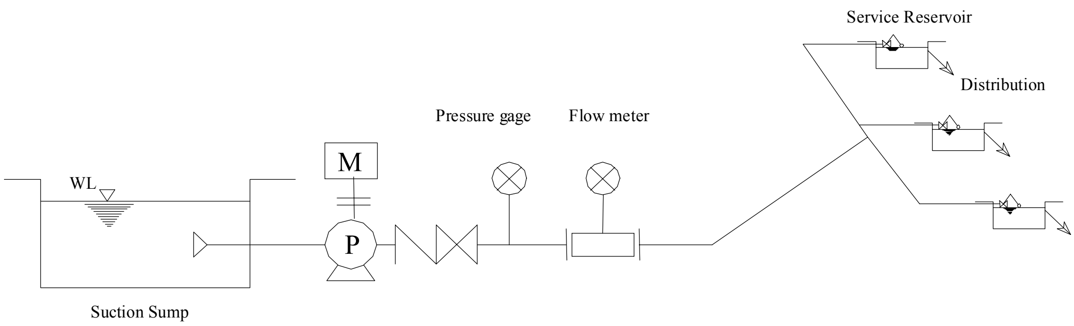
14.3.2 Pump Control System

Pumps should be operated to meet water demands of service reservoirs, whereas float valves installed at the service reservoirs are operated according to the variation of water level in the reservoirs. Each transmission system contains several reservoirs (ex. four reservoirs for A-1 system). Therefore, special control devices, such as variable speed pumping are needed.

In order to accommodate the operation of the float valve, automatic cut-off system will be provided for pump operation. For this purpose, a flow switch and a pressure switch will be provided on the delivery pipe of each pump station to monitor no flow or high head in the pipe. The pump will then be automatically stopped by sensing the no flow in the pipe, which takes place when the float valve in the service reservoir is closed. The pump will then be re-started by a timer or manually after the lapse of a certain period of time.

Figure 14.2 illustrates the proposed control system.

Figure 14.2 Clear Water Pump Control



14.4 Booster Pumping Station

14.4.1 Pump Selection

The booster pumping stations are designed for nine transmission systems at seven service reservoirs as shown in Table 14.2.

In the majority of these booster pumping stations, the designed flow for Phase 3 will increase by less than 200 percent from that for Phase 1. Therefore, pumping facilities will be provided for the designed flow in Phase 3, except for Systems E and G.

The following table summarises the flow and head of pumping facilities in each booster pumping station.

Table 14.2 Booster Pumps

System	Service Reservoir	Direction		Pump No.		Flow (m^3/min)	Head (m)
				Duty	Standby		
B	Heerassagala Low	Heerassagala Middle	1	1	1	1.90	68
C	Heerassagala Middle	Heerassagala Upper	1	1	1	0.49	77
D-1	Ampitiya	Elhena	1	1	1	0.83	45
D-2	Ampitiya	Mullepihilla	1	1	1	0.68	145
D-3		Meekanuwa	1	1	1	1.49	73
E	Kahawatta	Kurugoda etc	2	1	1	2.94	65
F	R-2	Hantana Place	1	1	1	1.36	102
G	Asgiriya (In-line)	Bahirawakand a	1	1	1	1.58	68
H	Kondadeniya	Kulugammana	1	1	1	1.11	64

14.4.2 Pump Control System

Pumps should be operated to accomplish water demands arising at the service reservoirs, whereas float valves installed at the inflow of service reservoirs are operated according to the variation of water level in the reservoirs. Transmission flows in these systems are relatively small and each system is connected to a reservoir, except the E system. Therefore, special control methods, such as variable speed pumping, will not be required.

Figure 14.3 illustrates the proposed control system for booster pump stations.

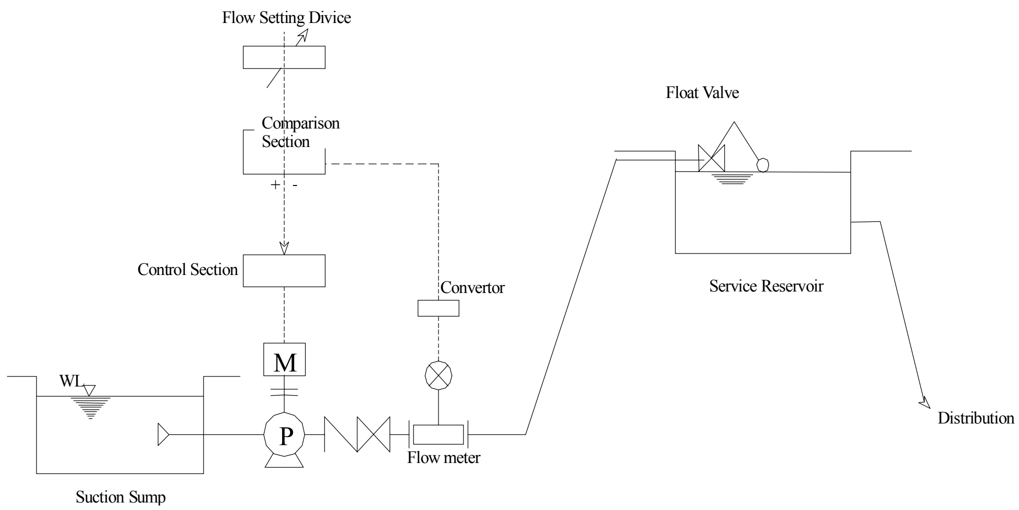


Figure 14.3 Booster Pump Control System

In order to accommodate the operation of the float valve, automatic cut-off system shall be provided for pump operation. For this purpose a flow meter will be provided on the delivery pipe of each pump station to monitor no flow in the pipe. The pump will then be automatically stopped by sensing the no flow in the pipe, which takes places when the float valve in the service reservoir is closed. The pump will then be re-started by a timer or manually after the lapse of a certain period of time.

CHAPTER 15 ELECTRICAL SYSTEMS

15.1 Power Supply

15.1.1 Main Power Supply

The power supply to the intake and the water treatment plant is by the single incoming system, 3-phase 3-wire, 33 kV, 50 Hz from the CEB. The reservoirs are 3-phase, 4-wire, 400 V, 50 Hz supply from the CEB. In Phase1, the intake is provided with a 3-phase, 4-wire, 400 V, 50 Hz supply.

15.1.2 Back-up Power Supply

The standby generator should be installed in view of supply interruptions caused by the CEB, in order to maintain continuous operation of the plant. The type of the generators is a diesel engine driven, radiator cooling, battery operated, and 3-phase 400 V output. The generator should have the capacity to take the maximum demand load to operate the plant uninterrupted. The fuel tank should have capacity for 28 hours continuous operation of the generator. 750 kVA generator is installed in the intake and 2000 kVA generator is installed in the water treatment plant. These capacities cover all of electrical loads in Phase1. In the reservoirs, the generators are not adopted.

15.2 HT System and Transformers

15.2.1 Circuit Breakers

Vacuum circuit breakers (VCB) are adopted for high-tension circuit breakers for ease of maintenance. The breaking capacity at receiving point is 1000 MVA at 33 kV. The breaking current rating of VCB's should be 20 kA at 33 kV.

15.2.2 Main Transformers

In the water treatment plant, the type of main transformers is the molded dry type transformer with metal enclosure for fire-proof, crack-proof, dust and moisture-proof, which is also smaller, lighter, stronger than the oil immersed transformer.

33 kV power supply from CEB should be stepped down to 415 V by 2 numbers of main transformers in Phase 2. In this case, the main transformers should run in parallel. In Phase1, one transformer is installed in water treatment plant. A necessary capacity of the main transformers is about 1500 kVA in Phase1. But it is installed 2000 kVA transformer, considering future expansion. In the intake, power receiving is low voltage from CEB in

Phase1 and Phase 2. But power receiving will need HT transformer in Phase 3. Therefore, only space for future expansion is prepared in Phase1.

15.2.3 Metering and Protection

The electricity-metering device, which comprises of VCT and kWh-meter, is installed on the 33 kV side by the CEB. An over-current relay is provided in the power-receiving panel to protect the electrical equipment from electrical faults such as over-currents.

The earthing system is the earthed neutral system, type TN-S system, in which neutral and protective functions are combined in a single conductor throughout the system. In this system, a grounding over-current relay is provided to protect the electrical equipment from electrical faults such as grounding fault.

15.3 LV System

1.1.1Low Voltage Distribution

The power from the transformers is distributed at 415 V, 3-phase, 4-wire to the low voltage distribution boards. Low voltage bus bars are provided to carry the full load current of the transformers and designed to endure the full short circuit load of the transformers. In principle, all outgoing feeders are installed with grounding over-current relays to protect the electrical equipment from faults such as grounding fault.

15.3.1 Power-factor Improvement

Power-factor improvement is achieved by static capacitor, and the compensated power-factor is 95 percent. The capacitors will be installed at the low voltage bus bars except above 55 kW loads. As for more than 55 kW load, the capacitors will be installed individually. The power-factor is adjusted automatically by APFC (Automatic Power Factor Controller), which is installed at the secondary feeder of transformer.

15.3.2 Motor Control Centre

Motor control centres should be installed to supply power for loads up to 55 kW. Motor control centres are composed of draw-out type units that are assembled in circuit breakers, magnetic contactors and similar control devices. Motors or equipment should be controlled by auxiliary hard relays and PLCs’ software. Auxiliary hard relays and PLCs have manual-mode operation, and auto-mode operation control circuits respectively.

15.3.3 Motor Starters and Voltage

All motors will be provided with starting as follows:

up to 7.5 kW	- DOL starting at 400 V
7.5 kW to 37 kW	- star delta starting at 400 V
above 37 kW	- auto transformer starting at 400 V
raw water pump motor of 280 kW	- soft starting or VVVF starting at 400 V
transmission pump motor	- soft starting at 400V

All motor starters are installed in separate cubicles, and provided with over current protection.

15.4 Instrumentation Equipment

1.1.2 Measuring Items and Types

Table 15.1 Measuring Items and Types

Measuring Items	Types
Raw water wet well level	Immersion water level (pressure) gauge
Raw water intake flow	Ultrasonic flow meter
Filter level	Ultrasonic level gauge
Back wash water flow	Ultrasonic flow meter
Air scouring flow	Orifice flow meter
Back wash return water flow	Ultrasonic flow meter
Back wash water reservoir level	Immersion water level (pressure) gauge
Clear water reservoir level	Immersion water level (pressure) gauge
Clear water transmission flow	Ultrasonic flow meter

15.5 Control and Supervisory System

15.5.1 Concept of System

In principle, the hierarchy system and distributed control system is adopted. The hierarchy system make it easy to monitor due to supervision of the whole set of equipment from one location. And the distributed control system improves the reliability of the control system. The supervisory system is classified into three levels. They are the field level, electrical room level, and central monitoring room level. The detail of each level is shown in the following.

15.5.2 Site Level

Operations such as single operations carry out unit test or, adjustment test for the load like a pump etc. accordingly, to carry out it without failure, it is necessary to be assembled with a hard relay for the single operation, even in the event that abnormal conditions happen to the

PLC of the upper class system. The loads without direct relation to the process operations like the sump pump, ventilation fan etc., should be considered as a site operation activity only. For loads other than site operations, it is necessary to install a “LOCAL-REMOTE “ switch.

The process values, such as electric current and water level etc., that are needed for single site operation should be indicated on the local operation panel. These process values are branched off from the instrumentation converter directly, without passing through the PLC. The failure display lamps, such as over load and/or mechanical failure, should be installed on the local operation panel along with the group failure indicating lamps. Also, the condition status indicating lamps, such as high and low water levels are installed on the local operation panel, at the same location.

15.5.3 Electrical Room Level

The electrical room level has a function of the main control and local supervisory. In the each electrical room, there are PLC panels, hard relays panels and instrumentation panels. The distributed control system is realized to install these panels dispersively in each electrical room. This system prevents the accident of one facility from spreading to other facilities. In principle, the PLC work for the automatic and the link operation, and the hard relays panel work for the single operation. In case of the PLC failure, it is at least possible to operate by manual by auxiliary hard relay. The instrumentation panel is composed of indicator, controller, setting device and so on. All measuring values of instrumentation can be watched on this panel.

15.5.4 Central Monitoring Room Level

All of important items such as an alarm or status can be monitor comprehensively from central monitoring room. In the central monitoring room, there are two master PLCs, two computers, one server, and two printers. Two master PLCs are connected with all local PLCs by optic fibre cable and communicate each other by Ethernet protocol. Master PLC transmits the information of local PLCs to the computers. The computers are a man-machine interface to monitor the whole plant through a graphical interface. Two sets of PLC and computer have same function. This means, it is possible to monitor two sites at the same time and also mutual back up. The data, which are transmitted to the computers, are accumulated to the server. The server plays a role of data processing so that it can generate reports to the printer, such as daily, monthly and yearly report, historical trend graph, historical process running and historical alarm.

15.5.5 Principal Automations

(1) Intake flow automation

Set the target value of raw water intake flow, which then will control automatically the number and speed of intake pumps to keep the constant intake flow and amount. It is possible to set the target value both at the intake site, and at the central monitoring room of administration building in the water treatment plant.

(2) Filter backwash automation

The sequential control of filter backwash consists of "open-close" of valves or gates and "start-stop" of pumps or blowers. This sequential control is started by pushing the button of the selected filter. Operation of the filter backwash is exclusively done on the local operation panel at site level. Please refer to FILTERING TIME SCHEDULE for details.

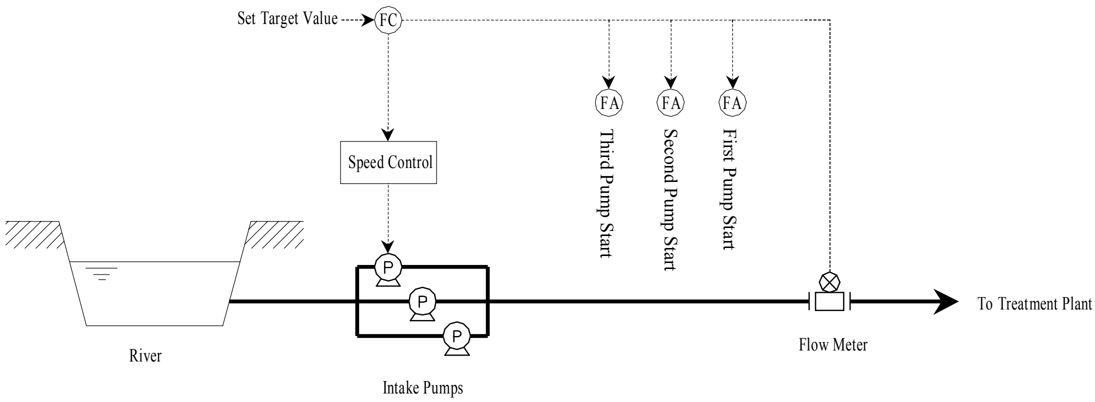


Figure 15.1 Intake Pump Operation

(3) Transmission pump automation

The operation of the transmission pumps is done at a fixed speed. Automatic control of stop and restart are done as following. The confirming timer starts to work when the transmission pressure exceeds the some settled value or the transmission flow rate below the some settled value. After the set up time passes, if pressure or flow rate is unusual continuously, the pump will stop automatically. The restart of pumps is done by the transmission pressure and timer.

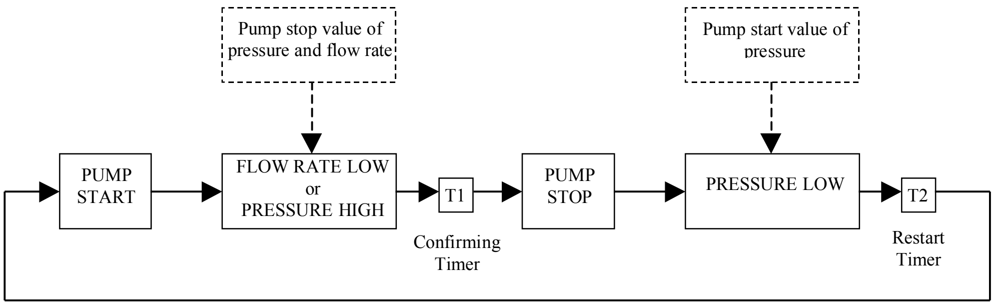


Figure 15.2 Transmission Pump Operation

15.6 Telecommunication System

The system should be geared for 24 hours extensive monitoring from the central monitoring room of the administration building in the water treatment plant. The communication between intake and water treatment plant is by a telecom dedicated line.

The contents of monitoring are operation conditions, alarms, flows, etc. It is possible to monitor all of intake facilities and to set the target value of the intake flow rate from the central monitoring room in the water treatment plant.

CHAPTER 16 OPERATION AND MAINTENANCE

16.1 General

It is vital that maintenance resources such as materials, spare parts, tools and equipment are always on hand and this can be achieved by maintaining close liaison among different offices/ departments handling operations, maintenance, material control and procurement activities.

Another critical issue is the budgetary constraints for proper operation and maintenance, resulting in the lack of maintenance resources, and thus the repairs and maintenance are neglected eventually leading to drastic consequences with the facility malfunctioning.

The maintenance of each facility/equipment is achieved through a regular patrol/inspection, operation and maintenance. By regular patrol/inspection the normal function, working condition of each facility/equipment could be checked and the feedback on faults can be relayed to the maintenance crew to restore normal functioning by way of cleaning, overhaul or other preventive measures. Patrol has a shorter duration than inspection.

The relation of operation and maintenance is shown in Figure 17.1. In order to obtain optimum results for an effective and efficient production of water fulfilling the required quantity and quality, the regular operation and maintenance should be standardized and systematized as described below.

16.2 Daily Patrol/Regular Inspection

This is necessary to explore the adequacy/shortfalls of the day to day water production and supply, current operating conditions of all facilities/equipment, identify defects (if any) and to take immediate countermeasures. As regards civil structures the inspections could be made at longer intervals than mechanical/electrical facilities. This process will maintain all equipment/facilities in a very sound and serviceable condition.

16.3 Maintenance Work:

Removal/disposal of grit/sludge, detailed examination and overhaul of mechanical/electrical facilities, flushing of chemical feed pipelines etc., have been identified under maintenance work. The proper maintenance will guarantee the facilities even beyond the expected life. On the other hand, after expiration of the useful lifetime the facilities/equipment may deteriorate despite effecting proper regular maintenance, and in such situations timely maintenance/repair should be considered on assessment of its relative economy. By daily and periodic checking the repair stage of the facility/equipment could be ascertained. It is to be noted that the large scale rehabilitation or renovation entails considerable expenses.

16.4 Water Quality Control:

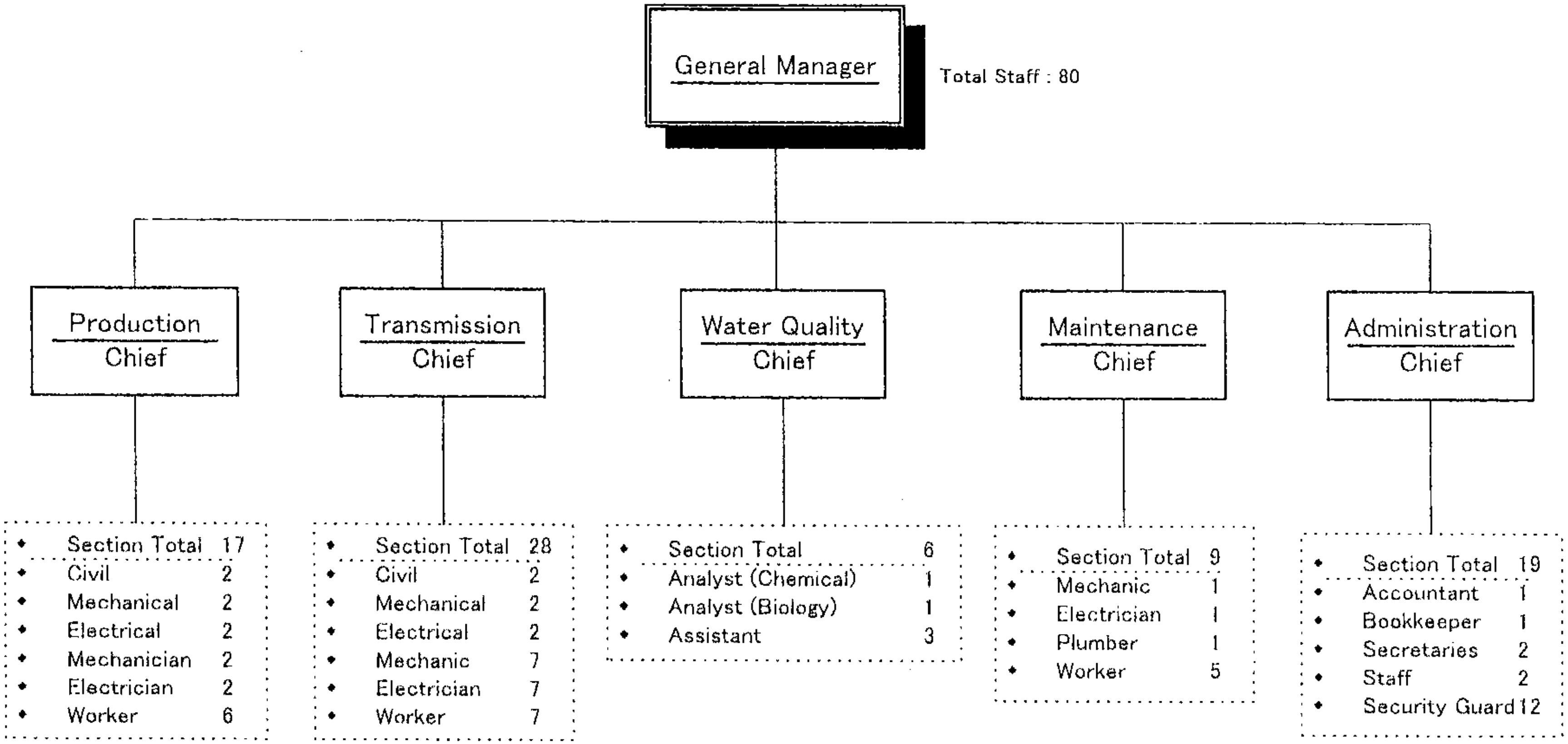
To guarantee hygienic, safe and clean water to the consumers the water quality control is essential. To facilitate this the source, different stages of treatment process, and the transmission and distribution system should be maintained in optimum and clean condition, which are described in the main report. The main report has also identified situations whereby the whole water supply should be suspended under certain extreme circumstances, until the reason for suspension is eradicated.

16.5 Organization of Operation and Maintenance

In order to attain an efficient operation and maintenance program, it is essential to formulate a suitable organization with the necessary authority and the appropriate number of personnel.

Figure 16.1 shows the recommended organization for the operation of the proposed water supply systems. A manager who is recommended to be in the rank of an AGM will head the overall operation and maintenance of Gohagoda Intake and Katugastota WTP systems. Under him there will be 5 sections/departments; namely production, transmission, water quality, maintenance and administration. A total numbers of staff is 80 including shift workers.

The production section will monitor the production process at Intake and Water Treatment facilities. The pumping system, transmission pipelines, service reservoirs and distribution networks will be the responsibility of the transmission section. Water quality section presently located at Sarasavi Uyana will be housed at the Katugastota WTP where water quality of raw water, process water and service water will be analysed and monitored. The maintenance section will oversee the overall maintenance work of the facilities in close liaison with other sections.



Note: Nr. for security guard is for 3 shifts.

Figure 16.1 Organisation for Operation and Maintenance

CHAPTER 17 STATEMENT OF CONSTRUCTION METHOD

17.1 General

In the detailed design of the construction activities, topographic surveys and level surveys were conducted to determine the location of reservoirs, design the pipe networks and pump specifications. Soil investigation conducted was vital to design the foundations of structures, roads, and to ascertain pipe-laying methodologies. Test excavations along designated pipelines facilitated the identification of existing underground utilities, soil conditions, presence of rock, water tables, which enables in design the most desirable pipe laying methods and routes.

17.2 Construction

During the construction period the contractor should cause the minimum inconvenience to the traffic flow, and to accomplish this he should always leave one lane open for traffic at all times over the full length of the construction area. If the inconvenience to the traffic is inevitable night time work should be planned. Similarly, access to the properties should also not be blocked and where unavoidable alternative access should be provided.

The contractor will require site offices located in the northern, central, and southern part of the Project area to facilitate proper organization and closer supervision of the works for the progress of work with dispatch, for which Kahawatte SR site, Katugastota WTP site, Gohagoda Intake site and Asgiriya SR site are proposed. The set up of these offices is illustrated in Figure 17.1.

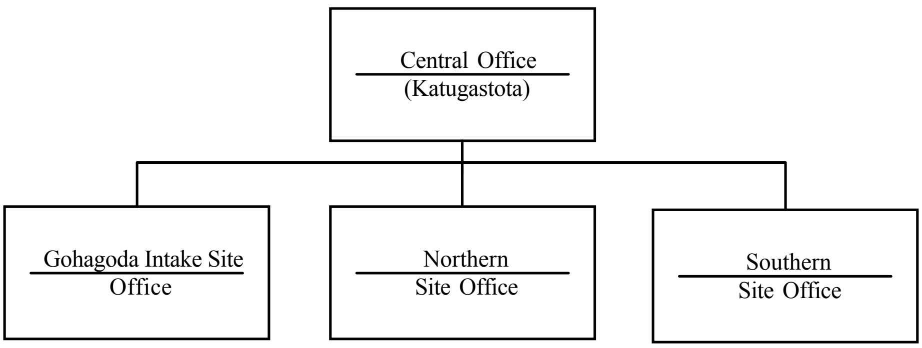


Figure 17.1 Set Up of Site Offices

The proposed Katugastota site office will be used as the main site office accommodating the main staff of the Engineer, Consultant and the Contractor, together with the treatment plant supervising staff. The other site offices will control the Gohagoda intake, transmission, distribution and service reservoir facilities in their respective areas.

At Gohagoda Intake site removal of garbage on the access route and construction of the temporary road and rock excavation will be the first task to handle by the contractor. The temporary road is necessary for the residents around the area to occupy in their day to day activities. At the Treatment Plant a peculiar work is large scale of site filling amounting about 50,000 m^3. The diversion of a stream flowing across the site and provision of an access road to the residents and the temple are priority works. The latter will lead to good rapport with the neighbours.

The detailed analysis for construction methods is described in Main Report (2).

CHAPTER 18 IMPLEMENTATION PLAN AND PROJECT COST

18.1 Conditions of Special Yen Loan

The conditions governing the procurement of material and equipment have been stipulated in the document under the title "Loan Agreement for Greater Kandy Water Supply Project – Loan Agreement No. SL-P71 dated March, 2001" prepared by GOSL. Particulars is summarised as shown hereunder.

The Prime Contractors shall be nationals of Japan, or juridical persons incorporated and registered in Japan, and which have their appropriate facilities for producing or providing the goods and services in Japan, and actually conduct their business there.

The Sub-contractors shall be (i) nationals of Japan, or juridical persons incorporated and registered in Japan, and which have their appropriate facilities for producing or providing the goods and services in Japan, and actually conduct their business there, or (ii) nationals of the Democratic Socialist Republic of Sri Lanka, or juridical persons incorporated and registered in the Democratic Socialist Republic of Sri Lanka, and which have their appropriate facilities for producing or providing the goods and services in the Democratic Socialist Republic of Sri Lanka, and actually conduct their business there.

Not less than 50 percent of the total costs of goods and services to be financed under this contract shall be procured in Japan. The goods and services procured from the eligible manufacturing company(ies) (hereinafter referred to as "the Eligible Local Manufacturing Company(ies)") invested by Japanese manufacturing companies can be regarded and counted as Japanese origin if such Eligible Local Manufacturing Company(ies) satisfy(ies) the following conditions:

- juridical persons incorporated and registered in the Democratic Socialist Republic of Sri Lanka, and which have their appropriate facilities for producing or providing the goods and services in the Democratic Socialist Republic of Sri Lanka, and actually conduct their business there;
- not less than 10 percent of shares are held by a single Japanese manufacturing company; and
- the proportion of shares held by any single company of the third country(ies), other than Japan or the Democratic Socialist Republic of Sri Lanka, is not more than that held by any Japanese manufacturing companies.

18.2 Contract Package

Since, none of the facilities can be put into service ahead of the other connected structures, it is prudent to engage a single contractor to complete works on schedule. Furthermore, the Intake, Water Treatment Plant and Service Reservoirs are identical in materials and construction methods and are located within Greater Kandy in close proximity, which favours treating the works as one package. As the Mechanical and Electrical equipment such as pumps would be procured from the same sources there will be a great saving in operation and maintenance costs and allocation of spare parts for repairs. In addition, overhead and work related problems would be reduced to a minimum. With several contractors coordination problems would increase, and could even lead to claims on the Employer, if one contractor's work is affected by the default of another contractor. These reasons amply justify treating the entire work as one package and engaging a single contractor.

A 6 km long, 300mm and 600mm DI clear water transmission main is planned to be laid on the Wattegama road, which is programmed to be renovated by the RDA under ADB funding during September 2001 and September 2004. RDA therefore stressed NWSDB to advance the laying of this main from the above timeframe to before they commence their renovation works. The procurement of piping materials will be financed under the Special Yen Loan, while the pipe laying work will be born by NWS&DB. Therefore, the construction works were split into two packages as follows.

Package 1: Construction Work for Greater Kandy Water Supply Augmentation Project
Package 2: Construction Work for Water Transmission Main Along Wattegama Road

Package 1 includes the entire portion of sophisticated civil and electrical/mechanical works, excepting for the portion of Package 2, for:

- the intake pump station structure, screens, pumps, inlet gates, piping, cranes, electrical equipment and instrumentation. Excavation in rock, water and soil are required as well as a temporary coffer-dam, reinforcement, concrete, backfill and slope protection. The structure will have a capacity of 115,500 m^3/d and equipment will be installed for the first phase capacity of 38,500 m^3/d;

- the treatment plant will have an initial production capacity of 36,670 m^3/d and will be designed to be extended to 110,000 m^3/d. The work includes the distribution chamber, flocculation basins, sedimentation basins, filtration units, pipe gallery, clear water reservoir, clear water transmission pump station, sludge lagoons, chemical building, standby power generation and on-site pipework;

- all ancillary works;

- testing, commissioning and training of NWSDB personnel for the works under the Contract.

18.3 Implementation Schedule

As shown in Figure 18.1, the construction period has been determined as a total of 33 months, including three month operation and maintenance assistance with allowance made for rainy seasons taking place, especially in October and November.

18.4 Project Cost

Unit prices and lump sum prices in the cost estimates were determined from "Rate 2001" prepared annually by NWSDB based on recent contracts awarded, and a host of other relevant information collected. Provisional Sums are applied when the particular work cannot be accurately quantified. Provisional quantities will indicate the best possible estimates and such works may or may not be required to be carried out under the Contract.

The Bill of Quantities and the schedule of rates consist of Sri Lankan Rupee (local) and Japanese Yen (foreign) components, where the earlier is meant to cover local inputs and all forms of taxes, and the latter for the inputs to be procured from outside the country.

The rates for construction materials are estimated from "Rate 2001" and relate to on site prices and placed mainly under local cost (foreign cost shows over head etc.). On the other hand the rate for materials such as DI pipes/Special valves are estimated based on the quotation from Japan as the Cost Insurance Freight Price. The works/laying include both local and foreign components. The rates of supply of equipment/plant are based on the recent manufacturers' quotations, and are the full overall costs and this is considered as foreign cost. The installation part will consist of both local and foreign components.

The reinstatement of the roads is provided under Provisional Sum item according to the costs agreed by the NWSDB with the road authority, and also A9 road which will be carried out by the Contractor.

The overhead factor for the construction works is taken as 31 percent. For procurement of plant and equipment the suppliers' overheads are added. 67 percent is included for installation works of the Equipment. General items include from 8.87 to 15 percent.

The taxes, duties and other levies to be paid by the contractor are calculated in the estimates as per the rates existed in February 2002. The categories not in "Rates 2001" have also been taken from the "Sri Lanka Customs Tariff Guide 1999".

The total Project cost except taxes is approximately 4,995 million Japanese Yen which completely covers all civil, mechanical and electrical works at intake, water treatment plant, transmission and distribution pipelines, service reservoirs and supply of maintenance equipment for Package 1 and 2 as defined in the contract. The exchange rate of Sri Lankan Rs.1.00 = Japanese Yen 1.3532 was applied in the cost estimates of local portion based on the average over the last 6 months' fluctuations.

Table 18.1 Project Cost in Japanese Yen (x 1,000 Yen)

	Descriptions	Local Portion	Foreign Portion	Sub total
1	General	287,198	105,348	392,546
2	Intake faculties	248,286	456,307	704,594
3	Water treatment plant	742,372	1,321,796	2,064168
4	Transmission pipelines	186,180	552,906	739086
5	Service reservoirs	307,661	285,400	593,061
6	Distribution pipelines	87,807	93,957	181,764
7	Maintenance equipment	3,431	49,009	52,440
	Total	**1,862,936**	**2,864,722**	**4,727,658**

The JBIC Loan Agreement stipulates that not less than 50 percent of the total cost of goods and services shall be procured from Japan, and this condition has been satisfied with an estimated 50.00 percent procurement from Japan as shown below.

i)	**Total Estimated Project Cost**	:	**4,727,658**
ii)	Estimated cost for foreign portion	:	2,864,722
iii)	Estimated cost for products imported from the third countries, estimated as foreign portion	:	500,887
iv)	**Total cost regarded as eligible goods and services for the Project** = ii) – iii)	:	**2,363,836**
	Percentage of eligible goods and services (iv/i x 100)	:	**50.00 %**

(Notes) Unit in x 1,000 Japanese Yen. The cost shown above includes Package 1 and 2, excludes taxes.

As shown below, the estimated cost is within the JBIC cost allocation in the Loan Agreement.

	(unit in mil. J.Yen)	JBIC Loan	Estimated Cost	Balance
i)	Civil works	4,302	4,728	4
ii)	Contingencies	430	N/A	
	Total	**4,732**	**4,728**	**4**

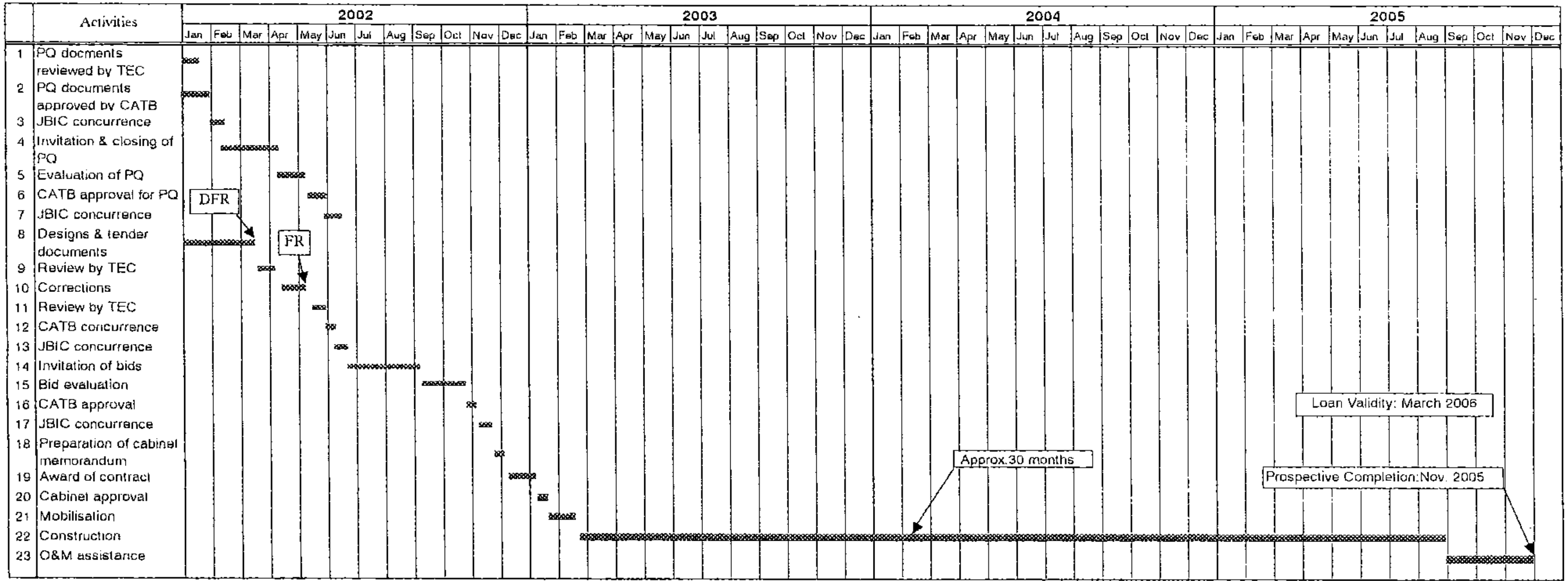
In other words, if the contractor will give careful consideration to the countries that the material/equipment will be procured, it is possible to keep the cost within the cost allocation in the Loan Agreement, meeting the condition that more than 50 % of goods and services be of Japanese origin.

The cost estimated has already included the price and physical contingency.

- The price escalation of construction materials such as concrete, reinforcing bar and fuel, and labour costs will be a major issue during the construction period because such changes are very common. The estimated costs includes with a provisional sum with an amount of approximately 50 million Japanese Yen covering the price escalations.
- Soil investigations had been carried out to identify the subsoil conditions as much as possible for the civil structures as well as test excavations for proposed pipelines. The designs were carried out on the basis of these results and the some additional quantities of works, equivalent to approximately 10 million Japanese Yen, had been addressed on a provisional basis as physical contingencies. Therefore, the estimates consider all the technical possibilities that may be happened.

The cost exceeding the above provisional sum will be born by the Sri Lankan side.

Although there is a sharp fluctuation of Sri Lankan Rupee and the Japanese Yen due to the present trend of devaluation of both currencies. Fortunately, the relationship between these two currencies has not been significantly changed unlike the other currencies, and it is assumed that this situation would prevail in future also without much detrimental effect.



Notes:

1) This schedule is prepared assuming that JICA DD will be finalised in May 2002 and during the DD study NWSDB proceeds to prepare prequalification ducments in close cooperation with the JICA Study Team.

2) DFR: Draft Final Report. FR: Final Report

Figure 18.1 Implementation Schedule for the Project

CHAPTER 19 RECOMMENDATION TOWARDS PROJECT IMPLEMENTATION

Pre-Construction activities for the Project involve basically coordination with the concerned agencies, including JBIC, RDA, etc. Necessary permits such as the excavation permits, permit to cut trees and Environmental Compliance Certificate (ECC) are secured by NWSDB.

The overall construction period is estimated to be approximately 30months after the award of contract. There are several factors causing for critical delays for the implementation programme such as land acquisition, approvals required from various authorities for buildings, structures and pipe laying, CEB power supply, securing of borrow areas. Hence, these issues need to be resolved expeditiously for the timely completion of the Project. Likewise, it is unpredictable in advance if the tendering will be successful or not, due to the cost overrun against the loaned amount, NWSDB may have to consider re-tender with adjustment of scope of works, unless otherwise NWSDB would secure the counterpart fund increased.

The activities that are vital for the timely implementation too have been identified for the three Phases. During the pre-construction phase it is mainly the liaison with the concerned authorities namely RDA, CEA, UDA, Police, KMC and PSs to procure particular building/structure and pipe laying approvals necessary. Liaison with JBIC is necessary both before and after prequalification and tendering with the necessary documentations to receive its concurrence.

NWSDB will have to secure its budget to meet the expenses, which are essential, but left out in the Loan Agreement. These include general administration costs, taxes and duties, land acquisition, compensation and other expenses. In addition, securing of borrow fill areas, sludge disposal sites, garbage removal from the Gohagoda site are as well priority requirements. It should also not be forgotten that although the water quality of the Mahaweli River is currently acceptable as the source of water with the type of treatment proposed, there is a potential risk that the quality of water deteriorating in the future due to enhancement of various activities causing pollution, which will further aggravate during the dry seasons when the flow drops very low.

During the Construction Phase NWSDB has to finalise its organisation set up for the operation and maintenance of the Project after completion. This includes procurement of well experienced and responsible O&M staff, and training them not only in operation of the plant but also in preventive maintenance to guarantee the smooth, efficient and trouble free operation over its full designed lifetime. Apart from it, NWSDB will have to secure the budget necessary to meet the O&M cost after commissioning.

During post construction phase preventive maintenance will play the major role to guarantee the full life span of the Project. The O&M manuals prepared by the consultants and the training given to the staff during pre-construction period will be of immense benefit to achieve the desired objectives. Nevertheless, despite enforcement of proper preventive maintenance procedures, after long years of operation of equipment, facilities and integrated systems may deteriorate, and may require large scale rehabilitation/improvement programmes n order to restore them to their original condition or to update their efficiency. Thus, NWSDB must secure the depreciation budget to meet such costs in future.