Small Towns and Rural Arid Areas Water Supply and Sanitation Project

ADB TA 4853-SRI

Final Report

Annex 1
Urban Water Supply and Sanitation – Technical Standards and Options

NIPPON KOEI

In association with

March 2008

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water

ANNEX 1 - URBAN WATER SUPPLY AND SANITATION – TECHNICAL STANDARDS AND OPTIONS

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GLOSSARY AND ACRONYMS

ADB	Asian Development Bank
AF	affected families
AP	affected people
CAD	computer-aided design
CAP	community action plan
COSTAB	ADB financial analysis program
CPFPG	Compensation Policy Framework and Procedural Guidelines (ADB)
CSD	Consulting Services Division (ADB)
DED	detailed engineering design
DFID	Department for International Development (UK)
EA	executing agency
EIA	environmental impact analysis
EIRR	economic internal rate of return
EMP	environmental management plan (ADB)
FIRR	financial internal rate of return
GAP	gender action plan
GC	Greater Colombo
GDI	general development index
GIS	geographic information system
GND	Grama Niladari Division
GPS	global positioning system
GTZ	German Development Corporation
HDI	human development index
HH	Household
HPI	human poverty index
IA	implementing agency
IBRD	International Bank for Reconstruction and Development (or World Bank)
ICT	information communication technology
IDD	international direct dialling
IEC	information-education-communication
IEE	initial environmental evaluation
IPDP	indigenous peoples' development plan (ADB)
ISA	initial social assessment
IT	information technology
JBIC	Japan Bank for International Cooperation
KAP	knowledge, attitudes and practices
KfW	Kreditstalt für Wiederaufbau
LAR	land and resettlement
LCB	local competitive bidding
M	Million
M&E	monitoring and evaluation
MIS	management information system
MOF	Ministry of Finance
MOH	Ministry of Health
MoHA	Ministry of Home Affairs
MOU	memorandum of understanding
MPA	Methodology for Participatory Assessments
MRM	management review meeting issues paper (ADB)
NGO	non-government organization
NK	Nippon Koei
NRW	Non Revenue Water
NWSDB	National Water Supply and Drainage Board

O&M	operation and maintenance
PCR	project completion report (ADB)
PFL	Pour Flush Latrine Toilet
PHAST	Participatory Hygiene and Sanitation Transformation
PLF	project logical framework
PMO	project management office
PMR	project management report (World Bank)
PPAR	project performance audit report (ADB)
PPE	Property plant and equipment
PPMS	Project Performance Management System (ADB)
PPR	project performance report (ADB)
PPTA	Project Preparation Technical Assistance
QARQ	quantity, accessibility, reliability and quality (water indicators)
QCBS	Quality and Cost-Based Selection
RAP	resettlement action plan
RFP	Request for Proposal (ADB invitation document)
RO	NWSDB Regional Office
ROW	right of way
RP	Resettlement Plan
R&R	resettlement and rehabilitation
RRP	Report and Recommendation to the President (of ADB)
RSC	NWSDB Regional Support Centre
RWSS	rural water supply and sanitation
SA	special account
SEIA	Summary Environmental Impact Analysis
SOP	standard operating procedure
TA	technical assistance
TOR	terms of reference
ToT	training of trainers
UK	United Kingdom
UNDP	United Nations Development Program
UNICEF	United Nations Children’s Fund
USA	United States of America
USD/$	United States dollar
VIP	Village Improvement Program (WB)
WB	World Bank
WHO	World Health Organization
WSES	water supply and environmental sanitation
WSS	water supply and sanitation
WTP	willingness to pay

1. Design Criteria (Urban Water Supplies)

Demand Projections

1. Water demand projections are based on the following key governing features. More details are discussed in Annex 3 "Urban WSS Sub-Projects", under the relevant urban sub-projects. A GND is the basic administrative boundary considered as the basic element for assessing water demands under the proposed augmentation of the four urban water supply schemes.

1.1.1 Design Horizon

2. Design horizon has been taken as year 2030, assuming that certain elements of the proposed project could be started in year 2010 with the design & tendering phases of the project. Some of the improvements planned under the overall augmentations would be given priority (e.g. replacement of existing BH pumps etc) in order to improve the production capacities up to a reasonable extent until the overall augmented facilities are in place. Hopefully such improved water facilities would be available for distribution at least by mid 2010. Hence the yearly demand projections have been based on the starting year of 2010. Since the official records of populations in most of the project areas are available up to year 2006 the population in year 2006 has been used for all population forecasts. Respective estimated growth rates for the population forecasts are also discussed in Annex 3.

3. In consideration of the history of population growth in the project areas, many abnormal variations can be observed, especially in the war affected areas. Hence it is not realistic to project the population throughout the design life, using a growth rate derived straight from such historical values. A detailed analysis of growth rates is needed in order to avoid the unreasonably high or low growth rates for projection of population in the project areas. Hence the strategic year of 2020 (mid of design life of the proposed project) has been assumed as the saturation point of population under the distorted growth rates resulting from the current civil unrest in most of the project areas and fairly reasonable growth rates have been assumed from that year onwards for the projection of population.

4. Apart from that, probable lower & upper bands of demand projections have been developed to overcome the prevailing uncertainties of the growth rate forecasts and these details are given in the Annex 3 for each of the Towns.

1.1.2 Population Density Criterion

5. Population density criterion is an important feature in planning water supplies, in order to avoid expensive or non-viable investments for construction needed to expand the water supply networks into areas having low population density, which will provide inadequate revenue and income levels. Also, if the pipe water distributions are provided in low density areas, then the O&M viability is also under threat due to the large expense of maintaining the large pipe networks with low levels of revenue.

6. The adopted density criterion and the recommended coverage under the proposed schemes are given in Table 1, below. The figures were derived in accordance with past experience of piped networks in the other similar urban areas of Sri Lanka. Also it is on a par with the application of NWSDB planning parameters for works of a similar nature (e.g. Feasibility study of Badulla- Bandarawela integrated urban water supply system in yr 2007)

Table 1: Density Criteria

Density (per Km 2)	Area Coverage (% from GND)
< 300	30%
300-500	40%
500-750	50%
750-1000	60%
1000-1250	70%
1250-1500	80%
1500-1750	90%
>1750	**100%**

7. However, certain deviations have been made to include even the GND's having low densities (less than 300 per Km2) in the planning process of proposed schemes under the following circumstances, where:

- Areas with existing water supply of the schemes
- GND's along the transmission routes
- GND's in and around the proposed water sources
- GND's where safe water sources are absolutely scarce
- Where possible developments are demarcated for the near future (e.g. Universities, Industrial zones etc)

1.1.3 Water Serving Population

8. Population served with water as a percentage of the total population in the area by each year is designated under this. It is obvious that 100% of the population for a particular area need not be covered under the proposed pipe networks, other than in very particular instances of high population density. In general, provision of piped water services to the households may depend upon their real need and social expectations. Hence, the water serving population by the provision of new facilities would have to be analyzed accordingly. Hence % factors have been derived zone-wise for the proposed project areas from the findings of the socio-economic surveys under following principle parameters.

- Status of residencey and the condition & status of houses
- Status of available water supply facilities and user perception (both reliability & acceptability of their available water sources or services)
- Development trends at the area and current level of other infrastructure facilities

1.1.4 Level of Service

9. A piped supply with individual metered house connections and a 24 hour water supply is the fundamental level of service planned to be achieved under the proposed project. However, in accordance with the NWSDB technical operational requirements, at least 12hrs of supply should be maintained as the minimum where there is a scarcity of water at the water sources in a particular period of a year. Hence such minimum requirement would hopefully be fulfilled in all cases. Even for severe drought periods , the issue of secure resources has been considered in the selection of water sources and their assessment of probable yields.

10. The residual pressure criterion is also on a par with the national technical guidelines. A minimum of 7m or maximum of 40m residual pressure at the service outlets has been considered as the basic pressure criterion for distribution network designs.

11. Stand posts/yard posts are not encouraged as a domestic water supply, the use of them is confined only to public places, ie markets. In accordance with the prevailing NWSDB policies, all stand post supplies need to be metered and the bill payment responsibility lie with the respective owners of such public places.

1.1.5 Per Capita Consumption (Domestic)

12. Per-capita consumption considered for domestic supplies in planning is based on the past history of the piped water supplies in the project areas and the evaluated data from the house hold surveys carried out. It is a matter of fact that the per-capita consumptions vary with the availability of secondary water sources at a close proximity. Hence it is quite obvious that the per-capita consumptions of high density areas would be comparatively higher than that of low density areas, where water sources are available, in general at least for secondary domestic purposes.

High population density areas (density > 1750 per sq. Km)	- **120 l.p.c.d**
Other areas	- **100 l.p.c.d**

13. Public yard post consumptions are considered as a percentage of normal domestic demands in the respective areas and the percentages are based on the historical supply style of those areas. Certain deviations were made where there are public yard/stand post supplies of a temporary nature available at such places as resettlement camps. More details on per-capita consumption at the project areas are given in Annex 3.

1.1.6 Non-Domestic Consumptions

14. Non domestic demands including Institutional and Commercial demands are computed as a percentage of the respective domestic demand based on the fact that Institutions and Commercial establishments serve the population in that area and their expansion or reduction is normally proportionate to the population growth.

15. Such demands as a percentage of domestic demand are based on the historical records of the respective schemes and overall behaviour of the respective NWSDB regions. However, certain deviations were made to accommodate uncertainties at the demand forecast and also to make realistic assumption to suit the design horizon.

16. Scheme wise non-domestic consumption patterns are elaborated more in the respective Town study in Annex 3.

1.1.7 Non-Revenue Water (NRW)

17. Despite the prevailing high values of NRW for the existing NWSDB water supplies in the project areas, these have been disregarded for demand forecasting, as the existing water supply systems are being refurbished and replaced under the planned sub projects. Hence the existing NRW should not be used in the development of the base demand. For the purpose of demand forecasting, future NRW has been assumed as **15%** of the total production available for distribution and thereafter till year 2020. From year 2020 onwards the overall future NRW has been taken as **20%** of the production, since the systems are getting older and there would be unavoidable natural losses from the system components even assuming proper rehabilitation, commissioning of the project components and the introduction of effective monitoring mechanism for leakage identification and control.

18. The above assumptions are in accordance with the NWSDB planning guide-lines, but further attempts are needed to lower the NRW values in the operation of the schemes, at least for the new elements under the proposed augmentations. Nevertheless, reduction of NRW further has great advantages both in respects of water conservation and reduction of O&M expenses. More discussion on management of NRW is made in Section 3 section “Technical Choices” below.

Network Characteristics

1.2.1 Transmission Networks

19. Transmission mains, either raw water or treated water have been modelled to transmit water from one operational point to the other. It could be either by gravity or pumping mains, depending upon the ground profile of the connecting points. A peak flow factor of 1.1 has been used to keep the operational flexibility of daily operation of the production units. In order to economise on the pipe sizes and at the same time to avoid silting up at the pipe lines, the velocity of flow was kept at 1.0 m/s where possible. “Water Cad “version 6.0 has been used for the hydraulic modelling of both transmission & distribution systems.

1.2.2 Reservoirs

20. Storage reservoirs feeding distribution networks have also been modelled using the computer software “Water CAD” version 6.0. Optimum capacities of the reservoirs were decided, based on the demand patterns of the day with storage included in the modelling.

21. Storage reservoirs would be placed at the ground level or would be elevated depending upon the ground morphology and the residual head at the distribution ends of the designated distribution zones. Wherever possible, storage reservoirs are planned for dedicated distribution zones for better control in the operation of the system. In general, bulk water meters are proposed to be installed at the outlet pipes of storage reservoirs for each zone for effective flow measurement and water management. Basic accessories such as overflow controls, washout facilities, access ladders, flow control valves, lightning arrestors etc are incorporated with the structures. The storage reservoirs should be constructed of waterroof concrete, following standard structural designs to BS practice for water retaining structures. The shape of the elevated water tanks would be circular with conical bottom which is considered economical for comparatively large capacities over 500 m3. However, ground tanks would have the option to be rectangular with a flat roof or circular with domed roof. The structural foundations will depend upon the conditions of the ground.

1.2.3 Distribution Network

A. Peak factors

22. A peak flow factor of 2.0 has been assumed in general, to accommodate the morning & evening demand peaks of the respective areas. However, hydraulic analysis was made for the water distribution around the clock to compare the variations at each 6 hrs intervals. As stated above, such demand patterns were the deciding factor for assessing the storage capacities needed.

B. Residual Pressures

23. Where geographical conditions permit, the distribution system has been divided into different supply zones. This would facilitate easy operation and maintenance and maintaining NRW at desired levels.

24. Residual pressure is an important feature to consider, in a water distribution network with respect to its maximum & minimum values. Maximum residual pressure value would govern the safety and durability of the appliances of the networks especially at the service connections. Minimum residual pressure is to maintain the continuity of supply at the service connection with a reasonable head and velocity.

25. Residual pressures within the supply zones have been limited as follows:

Minimum	0.7	bar (7m at ground level)
Maximum	4	bar (40m at ground level)

C. Network Modelling

26. As stated before, Water Distribution Network Modelling has been done with the aid of computer software “Water CAD- version 6.0” and the following factors were taken into consideration.

- Peak factor for the maximum hourly flow = 2.0 times peak daily demand flow
- Nodal demands are based on GND demands unless there is a need of special inbuilt allocations (i.e. special demands such as bulk demands)
- Roughness coefficient for friction loss calculations based on the Hazen William roughness coefficient factors. Appropriate different coefficients were used depending upon the types of pipes. For new pipes the following has been applied.

  HDPE -140;
  UPVC -130;
  DI -120

27. Minimum diameter for primary distribution network is UPVC 90mm but for the dead end mains 63mm diameter was applied. The individual service connections may have smaller diameters depending upon the water requirement, all the connections should be metered.

28. Rider mains where proposed to be laid at the main roads (opposite side of the distribution mains) have not been taken into consideration for hydraulic modelling and those are basically considered as the feed main from the distribution mains to the properties.

Pipe material

29. Different pipe types which can be used for the transmission & distribution networks are discussed in Section 3.4 Technical Choices. The following pipe materials have been used for the proposed water supply systems as the best and appropriate choice in respect of both capital investment and O&M reliability.

1.3.1 Transmission

30. Consistent with working pressure considerations & the topography of the pipe traces either HDPE (High Density Poly Ethylene) or DI (internally cement coated Ductile Iron) has been used for transmissions pipes and the PE pipe type would be SDR11, PE 100 , PN16 unless the operational pressures needs fairly low values. Flanges to DI pipelines shall also be DN16. The choice between PE and DI has been based on the ground suitability of the pipe traces. As an example corrosive environment at the coastal areas, pipes were mainly HDPE or uPVC (type 1000) depending upon the pressure requirement and the design diameter.

31. However, use of uPVC was limited to the application up to the diameter of 225 mm considering the availability with the local manufactures and the practicality of the past performance. In general, all the above-ground applications are planned with DI pipes and fittings, including special crossings such as bridge crossings with necessary concrete support columns.

1.3.2 Distribution

32. In general, it is proposed to use uPVC type 600/1000 pipes depending upon the pressures for all branch distribution networks. For distribution trunk mains, either HDPE (SDR 11, PE100, PN 10) or DI pipes are proposed where the required diameters exceed 225 mm. However, depending upon the ground conditions at those specific areas even lesser diameters of HDPE have been used. Ductile Iron pipes are only proposed at special crossings or at hard rock terrains. In some instances, Hume pipe casings have been proposed to protect the uPVC or HDPE pipes where susceptible for external damages.

33. Rider mains have been provided at the main roads where distribution mains are proposed to be laid. This is to avoid regular damage of the main roads, when giving service connections to the premises at the other side of the road to the distribution main. However, rider mains were confined to the areas absolutely necessary, in order to minimise the huge cost of placing rider mains at each and every road. In general, rider mains are of UPVC with diameter of either 90mm or 110mm depending upon the linear density of that particular road stretch. Special crossings were avoided for the rider mains where possible. As stated above, the flows at rider mains have not been taken into the hydraulic characteristic of the model.

To be consistent with pressure considerations, for gravity distribution mains, uPVC Type 600 pipe is proposed up to a maximum diameter of 225-mm. Type 1000 uPVC pipe is used only for pressures exceeding 6 bars.

34. Pipes for both transmission and distribution shall be laid with a minimum cover of 1.0 m from the ground surface. Where the pipelines are laid in a common trench the transmission pipe shall be laid deeper and staggered from the distribution line. All the above-ground pipes in areas that may flood, need to be restrained for uplift pressures and buoyancy.

Pumps and pumping stations

35. For raw water intakes from rivers and impounding reservoirs, submersible pumps have been used to overcome the operation & maintenance difficulties at the seasonal water level fluctuations at the water sources. In borehole intakes, submersible pumps are used to avoid the suction head constraints. Thereby the protection of such pumps from external surface flows and possible damages due to dry running at low water flows is ensured. For high lift pumping stations, split casing or vertical delivery centrifugal pumps with positive suction (whenever possible) has been used, depending upon the delivery application. Variable speed pumps have been promoted for local distribution, where they are not

integrated with other complex supply zones. This has an added advantage in saving on capital cost by avoiding service reservoirs and the energy saving during long term operations.
In addition, the following features have been considered when selecting the pumps and pumping stations.

- Pumping stations delivering to storage have been planned to operate between 21 and 22 hrs/d considering the operational flexibility at the production units.
- For each individual delivery mains, a minimum of one standby pump has been provided.
- Where multiple pumps are required identical pumps has been proposed. The basis of this was duplicate pumps to suit the ultimate design requirements and not to provide total capacity with a single pump at the initial stage. Thereby Pump installations have been designed for staged development or for a maximum useful lifetime of 15 years. However, impellers of the pumps need replacement about every five years.
- System automation has been introduced wherever possible for better control in operation & to reduce the O&M costs. System automation is proposed to be introduced at all operational points including the existing operational sites. In general, a pumping station and its corresponding storage point have been considered as one automation unit, but all are inter-connected (net working) through Programmable Logic Controller (PLC) to make possible control from a central operating point. Radio frequency transmitters or GSM could be introduced at the detailed design stage where appropriate for signal transmittal. Level sensors & the flow totalisers would be inbuilt elements of the system.

2. Unit Rates

Reasons for developing Unit rates

2.1.1 NWSDB Year 2007 Rates

36. The unit rates developed by NWSDB for year 2007, for water supply elements were based on rates prevailing in the last quarter of year 2006 and have been inflated to year 2007 by assuming a 10% price increase. Development of the NWSDB rates has been done by analysing supplier's quotations, contract prices and by making certain assumptions etc. as at year 2006 from NWSDB records. Further, these rates have been developed as generalised rates for the entire island and area specific variations have been addressed limitedly.

37. Actually, fuel prices have drastically gone up during the year 2007. From the records available, the overall price variation during the year was 27% in comparison to prices as at December 2006. It is a clear fact that the fuel price fluctuation has an impact on its by-products and associated items as well. As a result, prices of certain items have gone up by PVC [by 20%], Cement [by 17.4%], Steel [by 29%], Metal [by 40%] etc. within 2007. The price of sand also has gone up [by an average of 44%] due to the banning of sand mining in certain areas by the government authorities.

38. Hence, direct application of NWSDB rates for costing is not appropriate for certain items as stated above since the 10 % assumed price fluctuation within a year was far below the reality. Therefore rates for some of the major items needed to be developed to obtain realistic market rates.

2.1.2 Area Specific Deviations

39. Due to the prevailing poor security situation especially in Mannar & Vavuniya districts the prices of commodities had increased considerably during the past few years.

40. It has been recorded that the transport costs of materials to Vavuniya and Mannar districts are comparatively higher than the other project areas mainly due to the thorough security checks at several check-points and the resultant long idling charges of the transport. Further, unloading and reloading goods at the check-points cause big delays, damage to goods and extra costs in transporting of goods. This situation has created an additional burden to the contractors and suppliers working in those areas and has ultimately increased their overheads considerably on the supplies of construction materials.

41. In addition, scarcity of some construction materials such as metal, etc due to limitations of usage of blasting materials to obtain rock and excessive demand from neighbouring non-cleared areas has caused high prices. Also due to the ongoing resettlement housing programs funded by donor agencies there is a high demand for building materials. Thereby causing a rise in the prices of such building materials.

42. Nevertheless, according to recently obtained supply quotations from the contractors who are working in the areas cleared of war in Vauvniya & Mannar districts, labour rates do not differ much when compared with other project areas, unlike material prices. This has been proved from the rates approved by "District Secretariat rate committee" for the last three quarters of 2006.

43. Having considered all of the above area specific deviations among the project areas, it was decided to incorporate an adjustable factor in the estimates to compensate for the hardships encountered in those districts. Average factors applied for the estimates are as follows.

- **Extra over 5% of supply** rates has been provided as the transport difficulty factor for supply of pipes and M&E equipment.

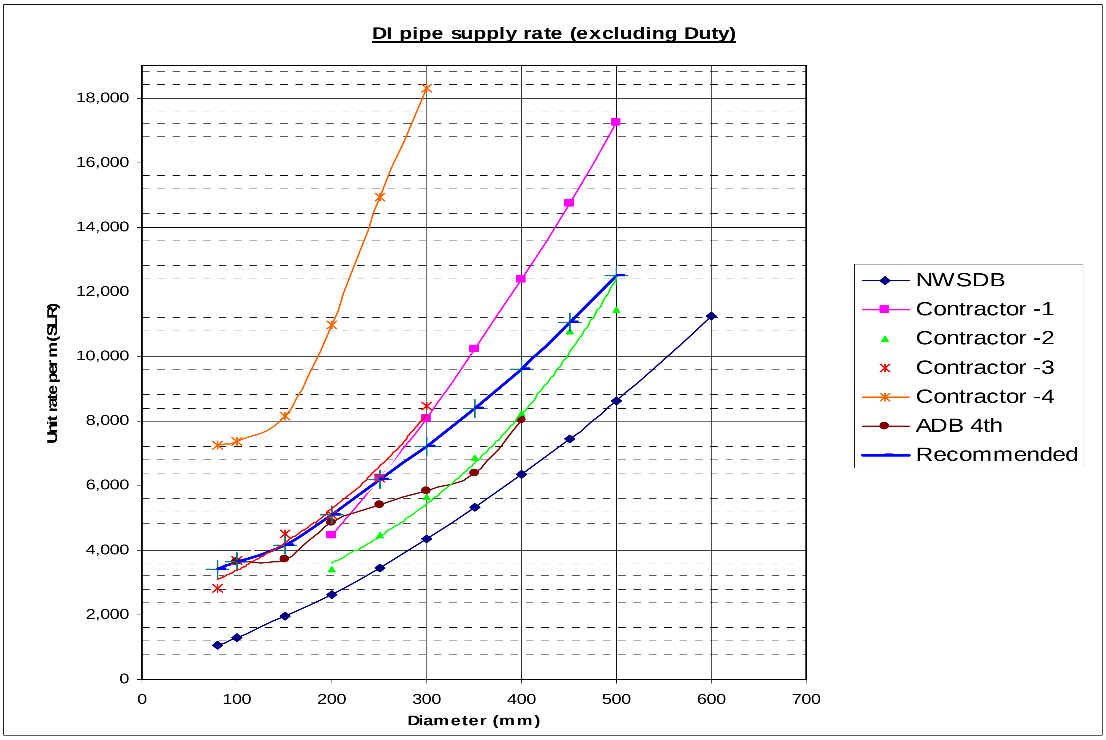
- For **civil works, extra over 10%** of the itemized rates has been provided to compensate for the transport difficulties.

44. The above percentages have also been decided on by the Rate Committee of the Divisional Secretariats of Vavuniya & Mannar, for compensating for transport delays and market prices of material in such disturbed areas. As an example, the Rate Committee of Vavuniya has recommended paying for two additional days in charges for the delays in transport of goods.

Basis for Unit rates

2.2.1 Pipe Works

45. The pipe-work rates have been developed based on comparison of some contractors quoted prices for 2007, NWSDB rates for 2007 and the rates developed by 4th ADB project in year 2007. Graphical representation below indicates the deviation across each other.



46. It has been noted that the NWSD unit rates of DI pipes are far below all others. With regard to the Contractor's rates, some have quoted unrealistic and exorbitant unit prices. Accordingly, taking an average value seems to be more realistic and appropriate for the application in the proposed project. On that basis the recommended unit rates for different types of pipes which are to be used in the proposed project areas are summarised below. A fixed standard percentage has been added to the estimates for the pipe fittings for the transmission & distribution systems separately. These percentages are 15% for transmission pipes and 20% for distribution pipes. The following table indicates the recommended unit rates for both supply and laying of pipes, to be used for the cost estimates.

DI Pipes (DN 16)

Dia. (mm)	Supply rate/m	Duty SLR	Laying rate/m SLR.	Testing & commissioning
80	3,400.00	592.54	1,850.00	127.00
100	3,630.00	632.61	2,180.00	130.00
150	4,150.00	723.28	2,800.00	136.00
200	5,080.00	885.27	3,200.00	143.00
250	6,200.00	1,080.42	3,420.00	150.00
300	7,190.00	1,252.95	3,650.00	155.00
350	8,400.00	1,463.82	3,930.00	165.00
400	9,610.00	1,674.69	4,220.00	170.00
450	11,050.00	1,925.63	4,480.00	180.00
500	12,300.00	2,143.59	4,840.00	188.00
600	15,000.00	2,614.02	5,450.00	205.00

uPVC Pipes (type 600)

Dia. (mm)	Supply rate/m SLR.	Laying rate/m SLR.	Testing & commissioning
63	110.00	790.00	69.00
90	285.00	1,050.00	69.00
110	490.00	1,105.00	69.00
160	1,050.00	1,320.00	81.00
225	2,060.00	1,450.00	101.00
280	2,990.00	1,545.00	111.00

HDPE pipes

	PN 10		PN 16		
Dia. (mm)	Supply rate/m SLR.	Duty SLR	Supply rate/m SLR.	Duty SLR	Laying rate/m SLR.
90	475.59	141.83	684.00	204.00	1,100.00
110	694.23	207.04	1,005.00	300.00	1,150.00
125	883.57	263.50	1,298.00	387.00	1,190.00
140	1,125.87	335.76	1,640.00	489.00	1,220.00
160	1,460.59	435.59	2,133.00	636.00	1,290.00
180	1,839.26	548.52	2,731.00	814.00	1,348.00
200	2,276.54	678.92	3,384.00	1,009.00	1,400.00
225	2,865.96	854.70	4,256.00	1,269.00	1,454.00
250	3,538.78	1,055.35	4,682.00	1,396.00	1,525.00
280	4,513.64	1,346.08	5,203.00	1,552.00	1,620.00
315	5,698.11	1,699.32	6,591.00	1,966.00	1,715.00
355	7,247.74	2,161.46	8,331.00	2,484.00	1,850.00
400	9,174.91	2,736.19	13,430.00	4,005.00	2,000.00
450	11,586.69	3,455.44	17,011.00	5,073.00	2,192.00
500	14,370.38	4,285.61	20,637.00	6,154.00	2,385.00

UPVC pipes

Dia. (mm)	Supply rate/m SLR.	Duty SLR	Laying Rate /m in SLR						
			upto 2m	upto 3m	upto 4m	upto 5m	upto 6m	upto 7m	upto 8m
150	1,537.00	330.00	8,251.00	10,932.00	14,538.00	18,918.00	41,769.00	48,937.00	56,122.00
200	1,944.00	417.00	9,260.00	11,974.00	15,723.00	20,256.00	43,268.00	50,608.00	57,978.00
250	2,305.00	495.00	10,047.00	12,852.00	16,689.00	21,320.00	44,439.00	51,898.00	59,397.00
300	3,073.00	660.00	10,405.00	13,259.00	17,139.00	21,815.00	44,985.00	52,499.00	60,060.00

2.2.2 Civil Work Unit Rates

47. Civil work unit rates were developed in accordance with the standard building work rates given in the BSR and adjusted with current market prices for materials. The overhead factor has been considered, 27% has been used for civil works, as recommended in the NWSDB 2007 rate book. A summary of unit rates for basic items for civil works are tabulated below.

Concreting & Masonry works

				Yr. 2007	
Item description	Resources	Unit	Qty	Rate	Amount
Mixing 1:1:4(20) concrete (3m3)	Labour (A)				
	Skilled	day	1.11	700.00	777.00
Grade 35 A	Unskilled	day	6.4	500.00	3,200.00
	Material (B)				
	Cement	Bags	24	685.00	6,440.00
	Sand	m3	1.8	2,120.14	3,816.25
	Metal	m3	2.9	1,590.11	4,611.31
	Water	Lt.	191	0.40	76.40
	Plant (C)				
	Concrete Mixer	day	0.34	3,500.00	1,190.00
	Tools (3% of A)				119.31
	Transport				
	Cement	bags	24	22.50	540.00
	Sand	m3	1.6	451.28	722.04
	Metal	m3	2.8	451.28	1,263.57
	Total mixing cost for 3m3				32,755.88
	Basic Cost per 1m3 of mixing				**10,918.63**
Placing - 225x225mm RCC column including curing (1.25m3)	Labour (A)				
	Skilled	day	3.2	700.00	2,240.00
	Unskilled	day	3.2	500.00	1,600.00
	Material (B)				
	Mixed concrete	m3	1.5	10,918.63	16,377.94
	Jute Hessian	m2	5.6	33.00	184.80
	Plant (C)				
	Vibrator	day	1	1,250.00	1,250.00
	Tools (3% of A)				115.20
	Total placing for 1.25m3				21,767.94
	Basic Cost per 1m3of placing in column				**17,414.35**
	Rate of 1m3 for Provision & Placing with 27% OH				**22,116.23**

General civil works

Item No.	Description	Unit	Rate Rs.
Earth work			
1	Removal of Top soil, 150mm deposit within site	m2	73
2	Excavate for trench/pit in **loose/soft** soil, deposit spread	m3	242
3	Excavate for trench/pit in **ordinary** soil, deposit spread level.	m3	528
4	Ditto - for every additional depth	m3	145
5	Excavate for trench/pit in **land/dense** soil, deposit spread	m3	826
6	Excavate for trench/pit in **mud/wet** soil, deposit spread	m3	704
7	Excavate for trench/pit in **soft, disintegrated rock (not requiring blasting)**, deposit spread level.	m3	623
8	Excavate for trench/pit **rock (requiring blasting)**, deposit spread level.	m3	1,092
9	Backfilling and compact in trench/pit **with selected excavated earth .**	m3	242
10	Dewater in trench depth up 3m	m	381
11	Dewater in trench depth up 4m	m	762
12	Dewater in trench depth up 5m	m	1,905
13	Dewater in trench depth up 6m	m	2,667
14	Dewater in trench depth up 7m	m	3,429
15	Dewater in trench depth up 8m	m	4,191
Provision and Placing of concrete			
	Concrete Grade 15		
16	50mm thick screeds	m2	561
17	75mm thick screeds	m2	855
	Concrete Grade 20		
18	150mm thick mass concrete in ground floor	m2	1,924
19	225 X 225 mm Column	m3	19,826
20	225 x 225 mm Beam	m3	20,376
21	125mm slab at 1st floor level	m3	18,097
	Concrete Grade 25		
22	225 X 225 mm Column	m2	21,395
23	225 x 225 mm Beam	m3	21,944
24	125mm slab at 1st floor level	m3	19,535
	Concrete Grade 35 A		
25	225 X 225 mm Column	m3	22,116
26	225 x 225 mm Beam	m3	22,666
27	125mm slab at 1st floor level	m3	20,196
Reinforcement			
28	Tor steel / Mild steel	kg	200
Brick and Block work			
29	Brickwork 225mm.thk.in 1:5 mix **in wall**.	m2	1,961
30	Brickwork 115mm.thk.in 1:5 mix **in wall**.	m2	1,001
31	100mm.thk **Hollow block** masonry in 1:5 mix	m2	758

2.2.3 M&E Works Unit Rates

48. M&E work rates are mostly in par with the NWSDB rate structure and an extra over percentage (about 5%) was included for the basic unit rates to accommodate overall cost of supplying & installation, spares, testing & commissioning and on the job training for

operators to run the system smoothly.

49. However the NWSDB rates for year 2007 were adjusted with the current market rates up to some extent for certain items such as electrical goods, laboratory items etc.

Specific Features of Unit Rates at Water Supply and Sanitation

50. Depth of the pipe trenches in sanitation pipe works is considerably higher than that of the depth of pipe trenches in water supply systems. In some project areas ground water table is fairly shallow or water logged. In those instances it would cause extra expense for protective shoring and consequently high pipe laying rates in sanitation pipe work could be expected more than pipe laying at water supply in shallow trenches. This matter has been taken into consideration at the estimation and the depth wise rating for excavation in trenches has been adopted.

51. Water retaining structures are the predominant feature in the water supply and sanitation sector. In this respect the grade of concrete used is high (eg: grade 35 A in BS standard) and additional precautions need to be made at curing and sealing joints. This matter has already been addressed at the NWSDB rating for storage elements and it has been similarly applied at the unit rates herein as well. In addition, testing and commissioning is a prime need for water retaining structures and pipe-lines and rates need an additional costs. Thereby on par with NWSDB rates, certain adjustments of rates has been applied for relevant elements.

52. The other specific feature is supplying filter media for filter units that comply with the stipulated specifications. In most filters the filter media is graded sand and gravel. Nowadays the supplying of filter media is a real hazard to the contractors because of the ban of sand mining at most of the rivers. Obtaining permits is also a difficult task especially for pebbles. Hence the unit market prices of filter media has drastically gone up and thereby the matter has seriously been taken into consideration at fixing unit rates for filter media associated with the different types of filters.

Unit Rates for Rural Water Supply

2.4.1 Rural Pipe Systems

53. In principle, low cost technologies have been adopted for rural water supply sub-projects at their designs to keep the sub-project cost at an affordable limit to the project and the user communities and make the operation and maintenance of the elements suit the village level technical “know-how”. Thereby the following specific features have been considered during the development and application of unit rates. However the basis for developing of unit rates are more or less similar to the above stated scenarios and the 2007 NWSDB rates were the basic foundation.

- Following the community action plan strategy, each component of the works has been divided into two components, one as “Project contribution” and the second the “Community contribution”. In the overall estimations of pipe systems more than 20% community contribution was maintained for selected rural pipe systems. However generalizing this factor for all project districts might give difficulties in later stages, especially in the war affected areas. Thereby certain deviations should be permitted during the implementation stage, depending upon the technology choice, ie complex water treatment, water resources availability and the associated transmission lengths and finally the capability of the user community to pay the cash contribution.

- Due consideration has been given to allocate un-skilled labour components under the community contribution and CBO managed contracts were promoted wherever possible in order to keep the overheads low and in addition to develop the technical capacity at the village level. However, it is a necessity to consider the hardships facing by the communities in the war affected areas and the prevailing difficulties to devote free labour as the contribution.

- Priority has been given for the use of locally available materials in the vicinity to minimize the burden of transportation, especially at the Vavuniya & Mannar rural sub-projects. Since the diameters of the pipe-lines both for transmissions and distributions are comparatively small, uPVC pipes are the main pipe type used for the pipe systems other than in special crossings. Similar rates stated above have been used for uPVC pipes, with an adjustable factor for transport. In this respect it is important to make it possible for the CBO's to purchase pipes with the same stipulated discounts from the manufactures as offered to NWSDB, when purchasing bulk stocks.

2.4.2 Community Dug-Wells

54. In general, construction costs of dug wells have significant variations with the depth of the water table and the type of soil in the overburden. As an example, construction of dug wells in collapsible soil with shallow water table would include additional costs of safety shoring, dewatering, etc than the deep wells with lateritic soils as their overburden. If the excavations are needed in hard or even in soft rock formations, the costs are extremely high. Hence developing average unit rates at least for a particular District is not an easy and practicable task. If we consider Mannar or Puttalam district, the overburden and the water table vary significantly from coastal belt to inland, irrespective of the safe water quality at those terrains.

55. Hence the costing has only been done at the selected 3 rural sub-projects for the technical studies, in order to obtain an idea of the variation of unit costs among each other. It is recommended that further sample costing needs to be undertaken at different localities of the project districts during the implementation stage prior to take the decision for a cost ceiling for dug wells.

56. Since there is a considerable number of wells that need rehabilitation especially in Vauvniya district, which is also a favourable option, a unit cost analysis has been done in that respect at the selected study area of Cheddikulam . Summary of sample costing for dug wells at Cheddikulam sub-project (Vauvniya district) is tabulated below.

Table: Unit rates for shallow dug wells (Vauvniya district)

Name of sub-project	Well Description	Average Project Contribution (Rs)	Av:Community Contribution (Rs)	Total unit cost Per well (Rs)
Cheddikulam ST - Vauvniya district	a) Shallow well new (depth 9.0 m and dia 2.4m)	133,179.00	67108.00	**200,287.00**
	b) Rehabilitation of wells	89658.00	21095.00	**110,753.00**

Unit Rates for Rural Sanitation

Pour Flush Latrines

57. Pour Flush Pit Latrine (PFL) are the common type of latrines proposed under the sub-projects for construction (more details on other available types are discussed in Section 4 "Technical Choices for sanitation". This is the accepted model by the department of health with the consent of the user communities.

58. Bills of quantities were prepared as per the standard drawings for the type selected. However, there could be further variations of the super structure to suit the affordability of the user communities. On the other hand, instead of proposing a single type of latrine, it is necessary to develop and allow several low cost options with further consultation of the user groups, this is especially needed with poor people to fulfil their needs and expectations with the lowest cost possible.

59. Similar to dug wells, the cost of a latrine may also vary with the ground conditions and the type of soil at the overburden where the pit is located. In sandy or collapsible ground formations the cost of excavations are high and masonry walls or Hume pipe casing is compulsory for the pits. In the water logged areas the situation may become worse and the size of the pit and the above-ground depth may need to be modified to suit the ground water table. Hence developing a single unit rate for village level latrine is not an easy task at the proposed locations, since there are significant variations at the ground formations amongst each other or even within a district.

60. However, it is essential to maintain the principles of rural sanitation policy in Sri Lanka which state that the beneficiaries must contribute up to their optimum level, to have individual safe sanitation facilities and the projects or government shall facilitate the strategy with uniform subsidiaries for sanitation programs.

61. According to the cost estimates[1] prepared by the PO for pilot rural water supply and sanitation sub project in Cheddikulam small town, the unit cost of a single pit, pour flush latrine (PFL) with permanent super structure can cost up to Rs 65,500, out of which 54% is the community contribution from labour and other locally available construction materials. The above unit cost is a lot higher than the PFL unit cost applied for similar works in other NWSDB sanitation sub-projects. The table below gives the estimated cost of a PFL toilet prepared by the 3 Pos carrying out studies for the PPTA.

GND	Estimated Cost	Community Contribution
Cheddikulam	65,500/-	54%
Phala Puliyankulama	51,533/-	40%
Thodaveli	44,320/-	40%

62. The PO's Cost breakdown of PF latrine in Cheddikulam is given below

Table 2.5.1: Estimated Labour & Material cost of PF latrine – Cheddikulam

Item	Qty	Units	Description	Rate	Amount
1	0.56	cubs	150x225 rubble	3,500.00	1,960.00
2	0.2	cubs	20 Metal	7,000.00	1,400.00
3.	0.94	cubs	River Sand	5,000.00	4,700.00
4	16	Bags	Cement	740.00	11,840.00
5	1403	Nr.	Burnt clay bricks	5.50	7,715.50

[1] The PO [PDF] has prepared cost estimate, based on current material and labour rates applicable for private contractors in Vavuniya district.

6	122	nr	Cement block-110x225	28.00	3,416.00
7	14.5	rods	10Y- Tor bars	340.00	4,930.00
8	84.5	Sq ft	Formwork – 25mm planks	38.00	3,211.00
9	1	nr	Timber door -6'x2'-9" & Frame	400.00	4,000.00
10	1	nr	Squatting pan , pipe & fittings	2,400.00	2,400.00
11	10	Day	Skilled labour	700.00	7,000.00
12	22	day	Unskilled labour	500.00	11,000.00
13	1tem	sum	transport	1,200.00	1,200.00
14	item	sum	Miscellaneous		726.50
			Total		65,499.00

63. **However the estimated cost of a PFL toilet based on 2007 NWSDB[2] rates is Rs 35,915.00.** (See appendix 2). The Board feels that the costing developed by the POs is far to high and has recommended the use of their unit rate. The sanitation component for PFLs is therefore assessed assuming a unit cost of Rs 35,915.00, with a 48.25% community contribution.

3. Technical Choices for Water Supply Facilities

Available Technical Options and Applicability in Urban Water Supplies

64. In broad context, the type of domestic water supply facilities could be one of the followings depending upon the ground suitability and the applicability for the intended expectation of the user communities.

- Common pipe water systems (house connections/ stand pipes)
- Individual pipe water systems (from own water sources)
- Common shallow dug wells
- Private or individual shallow dug wells
- Tube wells with hand pumps
- Rain water collecting systems
- Spring water collection galleries/boxes

65. Urban water supply facilities are normally confined to the city or town limits and adjoining peripheral urban areas where the population densities are comparatively higher than the rural or semi-urban areas. In the nature of urban characteristics in general, water supply to the beneficiaries through a pipe network would be the appropriate technology choice rather than supplying from individual point sources. The following factors govern the decision of choice.

- High water demands & limitations at the secondary water sources
- Limited land availability at the individual premises and thereby restrictions at placing safe water sources
- Susceptibility on polluting individual point sources (GW /surface water) from the complex urban environment and their effluents.
- Limited time available for maintaining the individual or group water systems due to complexity at urban life.

66. Hence, the basic and appropriate way of connecting the consumers (domestic or non-domestic) would be through a service line connecting to the distribution branch mains of a common pipe system across a water meter. Level of service may from individual connections, yard taps or public stand posts. According to the current practice of NWSDB, which is the maintenance authority for large or integrated pipe water systems, provision of

[2] **Cost breakdown.**

stand/yard posts are restricted to the public places such as bus stands, markets etc. The stand posts are metered and the bill payment responsibility lies with the respective local authority or a designated party.

67. Consequently, the urban water supplies are mainly confined to common pipe water systems and the discussion herein after is based on the "Options & technical choices" available in formulating the urban pipe water system. The proposed urban water supply facilities under the project would mainly be known as augmentation of the existing pipe water schemes

Selection of Water Sources

68. Where project options in the selection of the water sources for utilization, probably for use as a supplementary water source, the following requirements have been looked into.

69. The assessment of **Source Reliability** is the prime factor of importance in water supply systems, it is associated with changes in weather pattern, resource use, ground features and based on the history of the source.

- Ability to extract desired quantities with minimum disturbance to the other end users and the environment.
- Possibility of improving the source, in collaboration with other relevant authorities in order to ensure the capacity of the source for long term utilisation and control of pollution.
- Keeping the distance between the user and the possible extraction points to a practical minimum, in order to economise the capital costs for transmission pipelines. Wherever feasible, gravity transmissions are given priority to minimise the overall O&M costs of the proposed scheme.
- Adherence to beneficiary acceptance on the selection of water sources with due consideration to social, cultural and religious aspects.
- Confirmation of water sharing rights from the relevant authorities with due consideration to the possibility of fulfilling the conditions of agreement.
- Low seasonal raw water quality fluctuations within the source are preferred. This ensures the possibility of selecting a consistent treatment process, with reasonable operational costs for production of treated water of acceptable quality.

70. Apart from all above factors, the least cost economic need would be the final decisive factors for selection of water sources for the intended purpose.

Selection of Water Treatment Options

71. In accordance with reports of variations in the water quality parameters, different water treatment scenarios can be formulated. The principal issue would be whether the treatment procedure is to be based on average water quality of the sources (average water quality throughout the year) or for peak variations (few days per year). It is clear that the capital cost involvement would be high if the process is to be decided on rare peak quality variations with optimum value of certain quality parameters.

72. The treatment process proposed are based on average values of water quality variations. An approximate treatment process for a typical surface water source is discussed below and would need slight modifications at the detailed design stage, depending upon the nature or environment at the water sources at that time with further water quality analytical records. In any case it is important to avoid complex treatment processes which are inappropriate to the local conditions and the capacity of the O&M bodies.

73. Treatment options can broadly be classified as full treatment or partial treatment and in some instances limited to disinfection only (eg: good quality deep ground water) Conventional treatment process is the preferable option in many instances, by the O&M authorities due to their simplicity in operation and maintenance. However, combination of other advance technologies such as “tube settlers” with the conventional process have been adopted to suit the water quality variation at the selected water sources for augmentation of urban schemes.

74. All treatment processes are intended to achieve the water quality in par with Sri Lanka Standard (SLS) for drinking water quality (Potable water).

3.3.1 Treatment Options Surface Water Sources

75. Surface water sources could be either streams & rivers or the medium to large scale irrigation tanks. For all these surface water sources the water quality may vary with the seasonal inflows. The following table indicates general treatment options to be considered depending upon the raw water quality. The sequence of the treatment process with its selected elements of the treatment process have been carefully decided, having reviewed the past records of the raw water quality of the proposed supplementary water sources and with the water quality tests carried out during the PPTA study. Individual selections of the treatment process for the proposed augmentations of four town schemes are discussed in the appropriate Part of Annex3. The table below indicates the necessity for each treatment component in the process, be it full or partial treatment.

Table: Treatment Options (Surface water Sources)

(a) Aeration	Aeration would be necessary, as a result of stagnation of water at the sources if the downstream control structure available or possible other means causes stagnation of water. Besides, if the extraction points locating at the anaerobic conditions then again the aeration would be essential. The type of aerator shall be decided depending upon the effective time required for aeration.
(b) Removal of Algae	Depend upon the active environmental features for algal booms. If the upstream discharges to the water sources are rich in Nitrates & Phosphates and the day time temperatures are favourable on algal growths then the alert is needed for algal removals. Pre-chlorination shall be proposed soon after aeration at a well designed pre-chlorination chamber. This would be done with a dosage range of 3.0 to 5.0 mg/l when there is an evident algal growth at the sources.
(c) Pre-settling	During rainy weather the sources could turn turbid. Hence it is recommended to include pre-settling facilities in such circumstances. However, this could be by passed during normal weather flows.
(d) Flocculation	Since suspended particles in the flowing surface water bodies in general have low density particles which are slow to settle under

	gravity, Coagulation with chemical treatment (Alum or Poly-Electrolite) would be appropriate. A Clari-Flocculator is proposed as an appropriate option. Type of Flocculator may depend upon many governing features such as particle density, land availability, O&M capacity etc. However, if the turbidity of the surface water sources reach >200 mg/l then the “plate settlers” or “tube settlers shall be introduced to optimize the removal efficiency.
(e) Filtration	Rapid gravity filters shall be proposed to be included with the TW in order to fine tune the clarified water. Filter backwashing arrangements are proposed (air scour and water). Average rate of filtration could be taken as 5.5 m3 per square meter of effective filtration. If the land availability is not a constraint pre-settling could be introduced and the turbidity variations could be lowered down to < 10 mg/l. Then the slow sand filters would be the appropriate option. However, if algae threats are prominent certain precautions need to be considered to avoid problems at the filter. Rate of filtration would be at the range of 0.15 to 0.2 m3 per square meter of the effective filter area. Slow sand filters have an added advantage of working as a biological filter.
(f) P^H correction and softening	P^H correction is essential after alum treatment if the P^H of treated water going down <6.0. Provision of a Lime saturator is recommended for emergency situations. If a gravity feed system could be established, it would be an added advantage
(g) Activated Carbon Galleries	If the water is taken from an ancient irrigation tank at anaerobic status then the bad taste & smell could be expected even after conventional treatment process. Introducing activated carbon galleries after filtration would facilitate as a better post treatment option. This would be suitable to absorb harmful substances in water contaminated through agro-chemicals. Since the activated carbon is expensive at its replacement, the gallery could be by-passed at favourable water quality instances.
(h) Disinfection	Gas chlorination is recommended for disinfection. Besides, bleaching powder arrangement (with constant head solution tanks and regulators) shall be provided at the storage points as a provision for emergency operations and for sterilization of pipelines after repairs.
(i) Sludge treatment	If the land availability is not a constraint in the project area, sludge-drying beds with sludge thickeners are recommended to be incorporated as a sludge removal facility. Treated out flows from the drying beds either could be re-circulated or be discharged downstream. Arrangement for the periodic removal of decomposed sludge from the sludge beds is an important matter to consider.

3.3.2 Treatment options - Ground water sources

76. Ground water extractions from production wells are in general at a depth greater than 20m and the water is generally anaerobic and rich in dissolved gasses and substances such as Iron, Fluoride or Manganese. In the project area the predominant features are basically

excessive Iron or Manganese and also the calcium hardness is the main critical quality issue. Excessive hardness is not an easy element to remove under the less complicated treatment options other than dilution with soft water. Hence laboratory analysis has been carried out to assess ratio of mixing treated surface water with hard ground water. These tests have revealed that 1:1 ratio is more appropriate for the available ground water sources to come down to the permissible levels of hardness for drinking water. Hence treatment process for GW sources at Chilaw, Puttalam & Vauvniya have been planned accordingly.

77. Effective aeration (with sufficient time for aeration) would facilitate the oxidation of Iron & Manganese to its precipitation forms. Type of aerator shall depend upon the concentration of the Iron or Manganese and thereby the selection of types from Cascade, Multiple tray or drop bubble would be appropriate. If the concentration of iron is above 4.0 mg/l then the additional treatment follows with chemicals shall be needed. In any case, removal of precipitated substances would be a problematic process in all scenarios. Upward flow Roughing filters followed by Rapid filters have been introduced at those situations as an appropriate treatment process.

78. Though the deep ground water is assumed to be free from pathogens and bacteria, avoiding disinfection as a treatment element would not be a wise decision because the contamination could be possible at the pipe systems and at the storage points. Hence disinfection with gas chlorination has been incorporated as a compulsory element.

3.3.3 Treatment options - Sea water

79. Since the towns of Chilaw, Puttalam & Mannar are situated along the coast, abstraction & treatment of sea water to the desired and acceptable limits of drinking water is considered as an appropriate option for those towns, irrespective to the high production costs.

80. It is a known fact that the desalinated water contains less minerals and normally requires the adding of minerals up to desired levels. All selected town schemes have their own ground water sources that are rich in minerals. Hence it is an advantage to make use such ground water for the purpose of adding minerals to the desalinated water. Further tests would need to be done to assess the ratios to be added.

81. “Reverse Osmosis” (Ion exchange process) has been proved in many applications in other countries as a favourable treatment process for desalination. Hence the same is proposed for the schemes.

82. Before feeding sea water to the reverse osmosis treatment process, it is essential to reduce the turbidity levels to less than 10 mg/l and the feed water should be free from floating particles as well. Therefore a pre-treatment process needs to be built into the overall treatment process. As the pre-treatment is to reduce the turbidity of sea water it is recommended to apply the treatment process of clari-flocculation with tube settlers followed by rapid filtration.

Selection of Transmission and Distribution Pipe Lines

83. Transmission pipes are mainly used in transmitting water between production units and the treated water transmission up to the main delivery points. Transmission pipe lines can either be gravity mains or pumping mains depending on the topography and its undulation. Operational flexibility, O&M costs involved during the design horizon, pipe trace and the overall capital costs for implementation etc were some of the governing features for selecting the transmission options. In all sub-projects, transmission models have been

formulated as the fundamental planning scenario, incorporating existing production units and supplementary units. In this planning process optimum utilisation of available facilities including transmission pipes have been taken into consideration.

3.4.1 Selection of Pipeline Materials

A. Transmission Pipe lines

84. Replacement or provision of new transmission mains will be made with properly specified modern material such as Ductile Iron and Poly-ethylene. Traditional materials used include asbestos cement, galvanised steel and cast iron are prone to corrosion, cast iron being more resistant than steel but nevertheless not appropriate any more. Unprotected steel pipes are more easily affected since the pipe walls are generally thinner than the walls of cast iron pipes. Internal corrosion introduces iron into the water and although not a health risk, high iron content reduces the aesthetic quality of the water, turning it brown in colour. Internal roughness coefficients also increase from what is expected in the design. Recent water quality requirements put more emphasis on aesthetic water quality and reduction of iron in water has therefore become more important. Since a substantial portion of transmission pipes would be laid along the coastal belt and in a corrosive environment, the suitability of the material matter needs reasonable attention.

85. A comparison of the advantages and disadvantages of different pipe materials is presented in table below. There are obvious advantages to coated steel (probably ductile iron) or polyethylene pipes than with the ordinary steel pipes. Asbestos pipes are nowadays not used due to potential health hazards for potable water and for working on the pipes.

Table: Comparison of Different Pipe Materials

Pipe Type	Advantages	Disadvantages
Ductile Iron	➢ Wide range of diameters between 75 mm and 1600 mm ➢ Wide range of fittings ➢ High internal pressure resistance ➢ Good resistance to corrosion and upgraded corrosion protection available ➢ Intrinsic socket and spigot joints providing flexibility in unstable ground condition ➢ Very good resistance to external loads	➢ Heavy material ➢ Expensive in small diameters and also pipe fittings ➢ Imports necessary and duties involve
Coated Steel	➢ Can be of any diameter ➢ Lighter than ductile iron ➢ Can be designed for high internal pressure ➢ Range of internal and external coatings available	➢ Expensive couplings or welding ➢ Imports necessary and duties involve ➢ Joints coupling require additional protection. ➢ Requires proper foundation and side support
Poly Ethylene (High or medium density pipes)	➢ Good range of diameters from 16 mm to 900 mm ➢ Lightweight and stands for internal high pressures up to 16 bars (PN 16) ➢ Smaller pipes can be supplied in long lengths to minimise joints.	➢ Expensive couplings ➢ Expensive in larger diameters ➢ Requires proper foundation and side support ➢ Cannot be used in ground contaminated by organic solvents

Pipe Type	Advantages	Disadvantages
	➢ Good resistance to corrosion ➢ Flexibility in unstable ground condition ➢ Suitable to lay at aggressive soils and water logged areas	
UPVC (type 600 or 1000)	➢ Light weight and easy to handle ➢ Suitable for corrosive environments and some what adverse soils ➢ Easy jointing mechanism and Technical know-how is not a constraint ➢ Locally available and comparatively less cost ➢ Fairly low internal roughness and friction losses limited	➢ Limited diameter range and large diameters above 315mm not available ➢ Susceptable to direct sunlight and laying above ground not possible ➢ Limited pressure range (up to 10bars) and high pressure applications limited ➢ Not suitable to lay in hard rock terrains
Concrete	➢ Suitable for hard ground terrains and high protection for external threats ➢ Could even lay under water and un stable grounds ➢ Stands for very internal high pressures (about 25 bars) ➢ Locally available and comparatively less cost ➢ Available in large diameter range (150 mm to 2000 mm or even more on request)	➢ Internal roughness high and more friction losses ➢ Heavy and handling & jointing not easy ➢ Joints weak and the leakages more prominent ➢ Pipe accessories limited and branching and fixing appliances difficult

86. Generally, the most cost effective pipe material for small diameters is polyethylene despite the additional costs for foundations and side support. The larger diameter polyethylene pipes require large quantities of backfill material as well as specially made fittings and thus become uncompetitive. Ductile Iron and Coated Steel are generally the cheapest materials for pipelines of 400 mm diameter and larger.

87. It is therefore recommended that for pipes up to and including 350 mm nominal internal diameter, polyethylene pipes be installed unless ground situations require even stronger pipes. For larger diameters, Ductile Iron should be used for transmission mains or even for distribution systems if required. Since it is often necessary to tap into the pipes for making service connections in distribution service mains, polyethylene or UPVC pipes are more suitable than steel pipes because they are less affected by corrosion than steel at the connection. Hence for transmission pipelines, either polyethylene or ductile iron has been selected depending upon the ground conditions and the relative costs. As explained before, for smaller diameters (below 225 mm) mainly UPVC would be used.

B. Distribution-Pipe Lines

88. According to the modelling, a distribution system has following major components.

- **Distribution mains** which connect the feeding point to the main branches of the zonal networks
- **Trunk mains** which link distribution mains to the GND level branch or loop networks
- **Branch pipes** are the segments of the GND or area networks
- **Rider mains** to provide facility to give connections from the side opposite of the roads which the distribution mains/ branch mains are laid

89. In general, UPVC would be the most appropriate pipe material for the entire

distribution system. However, if the distribution mains or trunk mains need to have larger diameter (> 225 mm) then other alternative pipe materials, mostly HDPE has been used, if the pipe traces are favourable. Since uPVC is being manufactured in Sri Lanka and available at more competitive prices than other pipe types, it is widely in use for distribution networks. Rubber ring type socketed joints have preferably been used for all uPVC pipes where the pipe diameters are greater than 63mm. In rocky areas, marshy areas and at the special crossings such as culverts it would not be appropriate to use uPVC as the pipe material.For above-ground pipe traces, uPVC cannot be laid in place as it is susceptible to the weather and deliberate damage. In such circumstances, DI or Poly-ethylene pipes and fittings would be used as the replacement material where appropriate.

3.4.2 Selection of Distribution Pipe Networks and NRW Controls

90. Under the proposed augmentations schemes there are two main areas, ie rehabilitation or strengthening the existing pipe networks to cater for the design demands of existing areas and for the expansions of the networks to cater for the new areas. In all these cases it is important to have proper plans to keep the NRW at its lowest possible level throughout the design horizon (anticipated NRW is 15% from the production initially and increase up to the 20% after 10 years from the commissioning of the system). As stated before, one of the purposes of rehabilitation of existing distribution pipes is to reduce the leakage element of NRW up to the desired levels or even below.

91. Minimisation of leakage requires a systematic approach. The factors affecting leakage reduction & its management are broadly classified as follows

- Pressure management;(pressure zones)
- Mechanism for Leak detection and repair;
- Zonal metering for accurate computations
- Planned network replacement/rehabilitation

A. Pressure Management

92. It is a known fact that leakage increases with pressure and therefore managing pressures in distribution systems is an important part of leakage management.

93. The pressure in a network not only varies from zone to zone but also changes between day and night or with stipulated peaks of the system. Given this variation, pressure reduction scenarios cannot be generalised, and have to be individually engineered to the areas where high pressures are encountered in the network.

94. Pressure management is not a costly modification to the distribution system, and the provision of pressure reducing valves and frequency invertors to control pump speeds should be a first priority to achieve this objective.

95. Anyway, in the hydraulic modelling carried out in the design of the system, due consideration has been given to maintain optimum residual pressures at the end points of the distribution zones. Besides, suitable pipe types and its grade has been determined to prevent leaks due to frequent pipe bursts.

B. Leak Detection and Repairs

96. Different techniques are used in leak detection, from simple listening sticks to highly advanced electronic leak noise correlation to determine the locations of leaks. Other electronic equipment such as electronic sticks, noise loggers, pressure and flow loggers are also necessary in the localisation process. Techniques to rapidly narrow down the search

area have been developed and include zoning, step tests and pressure tests.

97. An active leak detection and repair programme would identify many leaks and reduce and maintain a lower leakage level. Leak detection should also be used to identify leaks in buildings or consumer premises. Wastage on consumer premises through broken internal plumbing equipment such as ball valves and taps can also be quickly identified. A public awareness campaign explaining the benefits of leak repairs should be initiated.

98. However, if the whole pipeline is in poor condition, it is often found that as soon as one leak is repaired another leak will appear at another location on the pipeline. In such cases, the whole pipeline will need to be replaced. A systematic leak location and repair programme, together with the maintenance of a leak incidence map, would quickly identify pipelines in need of replacement. Selection of pipes and fittings for such replacements shall be done vigilantly, taking into consideration the flow balance components of the network and the overall economy as well. As an example replacement of part of the old Cast Iron distribution with HDPE pipes would be a wise decision in a technical sense but finding step couplings to match Cast iron- HDPE joint is not an easy task because now cast iron is rarely in use and is out dated in manufacturing.

99. No such programme leakage programmes exist at present in the project areas and its introduction, as a permanent activity, is therefore a priority objective. The NWSDB would have the capacity to undertake this activity using their available trained staff and equipment if there was a cash provision in the project costs for mobilization & miscellaneous field expenses.

100. However during the PPTA study, physical inspections (walk through surveys) of almost all the pipe traces were made in order to identify the leaks and conditions of the system. In addition, past maintenance records of pipe bursts and their frequencies have been investigated. Based on such information the replacement components under the project have been determined in order to keep the NRW at the desired limits after rehabilitation.

C. Introducing Zonal Metering

101. Zonal metering (bulk water meters) overcomes the limitation of the discrete leak detection techniques described above by continuously monitoring the flow of water in the distribution networks.

102. Zonal meters or flow totalizers continuously measure flows, particularly night flows in the respective zone and the collected data can be analysed to detect anomalous night flows or sudden increases in flow that may indicate the presence of a leak in the area. Data collected by zonal meters can be either downloaded manually or it can be transmitted back to the control centre through an automated data transmission system.

103. Under the design of the system for all urban sub-projects the matter has been taken into account and zonal water meters have been incorporated into the cost estimates for each operational zones. Since most of the existing bulk water meters are not in operation at the moment, replacement of these with much more reliable types has been proposed. The pipe materials, where the meter is to be installed and its location shall be another important matter to be considered with regard to associated pipe fittings.

D. Planned Network Replacement/Rehabilitation

104. Most of the existing water distribution networks have suffered from lack of investment and most repairs have been of an emergency and ad-hoc nature.

105. Rehabilitating pipelines that are in poor condition would significantly reduce leakage and the large effort required to track the frequent leaks and to repair them. Depending on the extent of rehabilitation required, the pipe rehabilitation programme may have to be phased to minimise disruption of the continuous supply of water to the community during the rehabilitation work.

106. Prior to taking decisions on whether to rehabilitate or replace, it would have to be planned in correlation with the future water demand as well. The pipe sizes should have a capacity to cater for the future design demand unless a proper phasing is feasible. Despite the costs of rehabilitation or replacement pipes, another major factor involved in taking decisions would be the congestions at the pipe routes and the charges for road reinstatements.

107. The above principles have bee seriously considered while planning the rehabilitation of the existing pipe systems under the urban schemes and the hydraulic modelling was done accordingly. As stated above, the selection of pipe material for replacement or rehabilitation is important and thereby due consideration was given.. It is considered that the use of uPVC is the most appropriate pipe type to suit the existing network systems of the Towns.

Selection of Pumps

3.5.1 Considerations of Pump Selection

108. The investment in new efficient pump sets is often more cost effective than the high operating costs of old pumps.

109. The most important factor in improving energy efficiency is ensuring that the efficiency of the pumps is optimum for the pumping conditions. A second consideration is the unnecessary increase of pressure in the distribution system and hence increased leakage, as a result of pumping pressures. These undesirable conditions result in the common practice of using fixed head pumps to deliver directly into the distribution systems during periods of low demand in the network.

110. Selection of proper and appropriate pump type are also equally important. Some of the governing factors are noted below.

- Suitability in application (e.g. submersible for under water operations)
- O&M flexibility & the availability of the spares (standby arrangement)
- Competitive capital costs
- Range of efficiency & proven reliability

111. The most cost effective combination of pipe diameter and pump capacity can only be determined by a least cost analysis based on capital and operating cost for the pipeline and pumping system. Once the optimum pumping head has been established, the selection of pumps can be carried out using the following guidelines:

- Old pumps and motors wear out and become inefficient in the process;
- Larger pumps are generally more efficient and require less maintenance than smaller pumps;
- Low head pumps are generally more efficient than high head pumps;
- Pumps with flat characteristic curves provide a larger operating range and good efficiencies but can be difficult to control during parallel operation

- The cost of one large pump is less than that of two or more pumps with the same total capacity.

3.5.2 Pumping Conditions

112. Two types of pumping conditions exist in the proposed water supply systems:

- Fixed head pumping; and
- Variable head pumping.

A. Fixed Head Pumping

113. The transfer of water from one fixed location to another fixed location is usually a fairly efficient operation. Fixed head pumping should therefore be used for constant transfers between reservoirs or fixed storage points where the variability of pumping head will be limited.

114. In distribution systems, the demand and head evident in the system vary as consumers' access the system. As pumps cannot successfully operate under such circumstances, additional measures have to be taken to provide the correct operating conditions.

115. One such measure, to overcome this variation is to construct an elevated water tank of suitable capacity as a fixed delivery location for the pumps. Such construction is usually expensive and in many cases booster pumps with control valves and pressure switches are provided as a less expensive alternative. The necessity for control valves, inevitably means a less efficient operation. The range of flows that can be experienced in the network means that even with control valves the pressure produced by the pump can still be variable. During peak demand periods, low pressures can be expected in the system. On the other hand, during low flow periods at night, high pressures are experienced because of high pressure generating from the pumps.

116. Although a pattern of demand can be predicted from past observations, it is not always possible to design an efficient fixed head pumping system that can accurately match the pumping requirements.

117. However fixed head pumping has its own advantages due to inbuilt operational flexibility in the overall context of operations.

118. Under the proposed augmentations of water supply schemes two types of fixed head pumps were suggested for highlift operations namely, "Horizontal split casings" and "End suction vertical delivery", choice depends upon the rate of discharge and the delivery head. In general terms the fixed head pumps use in water supply systems are in following types.

- Submersible
- Turbine types
- Centrifugal, Types (end suction vertical delivery/ , horizontal split casing)

119. The following table indicates the advantages and disadvantages of each pump type

Table: Fixed head Pump types

Pump Type	Advantages	Disadvantages
Submersible	• **Highly suitable for submerge operations** • **Pump and motor together and very limited space required for installations(vertical or horizontal)** • **Comparatively light weight and easy to handle** • **No barriers at suction and could apply for fairly high delivery heads** • **Pump can be modified with a reasonable costs to change the design features (changing impellers for high heads)** • **Efficiency at reasonably high range**	• Comparatively high capital costs • Risks at low water level operations (effective water clearance needed) • O&M difficult even at the preventive maintenance because the pump is in submerge. Also the operators cannot see the operation of pump and always suspicious.
Turbine	• **Since the pump & motor coupled together at closer and in vertically oriented position, limited space required for installation. Can install at top slabs of the vertical shafts** • **Normally high rate of pumps and highly suitable a s low lift pumps at intakes** • **Pump efficiency comparatively high in low head operations**	• Comparatively heavy weight and at the maintenance need lifting devices and more labour needed • Not perform well in high head operations • Perfect alignments needed at their vertical shfafts through their inter lock bearings and it is a difficult task • Reasonably high skills needed for O&M
Centrifugal	• Familiar type and technology transfer easy • Selection of suitable pumps to suit the required capacities fairly easy and plenty of models available than other types • Suitable for even village or remote area installations • Less risks at operations since the suction side detached from the pump direct components • Comparatively less costs and some models available locally as well • Suitable to operate with different energy modules other than electrical power (e.g. diesel power, wind power etc) • Preventive maintenance straight forward and easily supervise the work	• If the positive suction not possible as a result of ground limitations then the energy consumption comparatively high • Required fairly large space for installations and always need safe margin to protect the pumps & motor from floods or high water levels at the area • Fairly high weight and need more persons for repairs, especially in large capacity pumps

120. The above features have been considered while selecting the pumps for the proposed augmentations.

B. Variable Head Pumping (variable speed drives)

121. In order to overcome the above mentioned deficiencies of fixed head pumps, the speed of rotation of the pumps can be varied to change the discharge capacity and delivery head. This would be more appropriate where operating at the well defined distribution zones.

122. Variable frequency drives use electronic equipment to alter the frequency of the current applied to the motor and as a result control the speed of rotation, which can be adjusted from zero to its maximum design speed. The function thus provides the means to vary the discharge and pressure generated by a pump.

123. Although variable frequency drives and pump sets are more expensive than normal fixed head pumps, the energy savings over the life of the pump would outweigh the initial higher cost. Theoretical calculations for a typical day, indicate an electrical energy saving of about 25% following the installation of variable frequency drive pumps. This translates into a minimum 10% gain on discounted cost, when compared to fixed speed pumps.

124. Under the proposed augmentations, variable speed drives have been proposed for the town zones of Puttalam & Chilaw water supply systems.

4. Technical Choices for Urban Sanitation

Available Sanitation Technologies

125. Apart from the sanitation technologies that are already in use in Sri Lanka, there are several other systems that have been devised for the disposal of domestic excreta and wastewater. Sanitation technologies are inextricably linked with the service standard of the water supply that is available. Some systems that require large quantities of water, such as conventional sewerage, cannot be implemented in areas that rely on hand-carried water supplies from a communal standpipe. On the other hand, pit latrines could not cope with the large volumes of wastewater that are produced from a house with an individual water connection and internal plumbing. It is convenient, therefore, to broadly classify alternative sanitation technologies into dry and water-dependent systems. The different technologies that are available for use in these two situations are described briefly in the following sections.

4.1.1 Dry Systems

A. Unimproved Pit Latrines

126. Apart from open defecation, this form of sanitation is the simplest, and probably the most common, facility in use around the world. It comprises a hand-dug pit, a cover slab with a squat hole, and a superstructure. Excreta falls into the pit and when the pit contents are within about one metre from the top, the superstructure and squatting plate are removed and the pit is filled with soil excavated from a new pit site.

127. Unimproved pit latrines are the most basic of structures and often have associated odour and insect problems. Due to poor design and the use of inferior construction materials and methods, they are often unstable and they tend to fill up with rain water during the rainy season, spilling excreta over the surrounding ground. They are an inexpensive form of sanitation but, unless they are well designed, built, and maintained, they are usually unacceptable on public health grounds.

128. They are very common in many African countries, particularly in rural areas. No pit latrines of this type were found in any of the four Project Towns during the field surveys, although they might be used in the surrounding rural areas and in sparsely populated fringe areas of towns. Their use cannot be recommended in urban centres.

B. Ventilated Improved Pit (VIP) Latrine

129. Most of the disadvantages of pit latrines can be easily overcome by carrying out some simple improvements. A properly designed cover slab will not only improve the safety of the user and provide a solid base for the superstructure, but it also prevents the ingress of rainwater into the pit. The provision of a vent pipe covered with gauze will reduce odours from the superstructure and will also reduce the insect nuisance. These simple improvements add to the cost of the pit latrine, but the overall cost of a VIP is still very low while the acceptability is much improved.

130. VIP's can either be emptied when full of sludge or abandoned and replaced by a new pit. An alternative to the single pit is the alternating double pit latrine (Ventilated Improved Double Pit, VIDP). It comprises two pits separated by a common wall that are covered by the same slab and superstructure. The two pits are used alternately. When one is full, it is then sealed while the other is brought into use. When the second pit is almost full, the first pit is emptied and put back into use once more. Due to the long retention time (normally two years) of the sludge in the sealed pit before it is emptied, the organic matter is fully digested

and any pathogenic organisms will have been destroyed (Kalbermatten et al, 1980).

131. The VIDP allows the user to safely empty the pit himself without having to rely upon, and have the expense of paying for, a vacuum tanker service. This reduces the overall requirement for a large fleet of vacuum tankers or the use of manual pit emptiers. Moreover, the groundwater is not polluted by the use of a VIDP.

132. VIP's are most appropriate in rural communities, but they have also been used in some urban situations, such as in Gaborone in Botswana. It is not considered that their use is appropriate in the urban context in Sri Lanka. The Draft National Policy for Rural Sanitation (Feb 2006) supports their use and this should be encouraged in water-scarce rural areas.

C. Composting Toilets

133. These toilets use the process of composting to degrade excreta in combination with vegetable matter. The procedure of adding organic waste in the form of leaves, grass, sawdust or household refuse, helps to achieve the correct Carbon:Nitrogen ratios and provides the right conditions necessary for composting. If the moisture content is properly controlled, the excreta and added organic matter will decompose into a good soil conditioner.

134. Composting latrines need care in their operation: additional organic matter has to be added at the correct rate, the moisture content must be kept at the appropriate level, and the humus must be removed on a regular basis.

135. This form of latrine is widely used in rural areas in the Far East, notably in Vietnam, and China where no cultural barriers exist as to the reuse of human excreta. A commercial, plastic manufactured, composting latrine (Ecosan) is available in Sri Lanka and it has been employed in pilot scale trials. Already 108 Ecosan latrines are constructed in various parts of Sri Lanka by the NGO called Practical Action. From discussions with relevant agencies, it does not appear that the use of these composting latrines will gain wide public support, although the Draft National Policy for Rural Sanitation (Feb 2006) supports their use.

D. Pour-Flush Latrine (PFL) Toilets

136. The main advantage of the pour flush latrine is that it provides a water seal between the pit or tank and the toilet cubicle. The water seal reduces odours in the toilet cubicle and prevents insect nuisance. Small amounts of water, or sullage, are required to flush the faeces into the pit and to replenish the seal.

137. The most common type of pour flush toilet is a simple upgrading of the unimproved pit latrine, where a water seal is incorporated into the pit cover slab. The bowl that provides the water seal can be of many different designs and can be pre-fabricated using ceramic or fibreglass, or it can be cast in situ by local masons using cement mortar. They also have the major advantage of being able to locate the pour-flush bowl inside the house, while locating the soakage pits outside. Double-pit pour flush toilets are a more permanent facility that can be used without interruptions for pit emptying or relocation.

138. The pour-flush waterseal latrine with soakage pit was first developed in India in the 1940's in Calcutta. It is now used extensively in India, in South East Asia, and in Sri Lanka. Its use is particularly suited to societies that use water for anal cleansing. A disadvantage that is often quoted is that it requires about 4-6 litres of water per person per day for flushing. That is not seen as a disadvantage in Sri Lanka, where most households have individual water connections or yard taps. The only areas that are supplied by public standpipes rather

than piped connections are the slum dwelling areas.

139. In Sri Lanka, pour-flush latrines with soakage pits are in very common use. Their main disadvantage is that they require separate sullage disposal facilities. This technology is one of those that has been recommended in the Draft National Policy for Rural Sanitation (Feb 2006) for use in rural areas.

E. Bucket Latrines

140. The removal of nightsoil from individual houses in an urban area using buckets, carts or trucks is a well established practice. The simple bucket latrine comprises a squatting plate or seat, directly below which is located a bucket or basket in which the excreta is collected. The bucket is routinely emptied by a manual labourer into a larger collection bucket which, when full, is carted to a nightsoil collection depot. From the depot, the nightsoil, or septage, is normally taken by tanker to a treatment or disposal site.

141. The system is most applicable in densely populated urban areas, but it requires efficient organisation and close monitoring for it to be successful. The system has fallen out of favour in most countries because of the potential for spreading disease, but is still used extensively in the Far East. The father of the Indian nation, Mahatma Gandhi, expressed a wish to see the end of the degrading practice of scavenging, considering it to be a demeaning task for human beings to perform. Unfortunately, his dream was not realised during his lifetime, mainly because no other suitable, and inexpensive, technology was identified. However, in 1968, the Ministry of Works and Housing directed all states to convert the existing latrines into pour flush latrines and to connect them to sewers where available, or to soakage pits where sewers were not available. This was followed by the banning of the construction of any new bucket latrines by the Government of Bihar in 1970.

142. Simple bucket systems are common in the slums of East Asia, but they tend to be objectionable and very unhygienic. In areas with more permanent housing structures, larger conservancy vaults are found, with the emptying and transport largely mechanised. These systems are common in Japan, Korea, and Taiwan.

143. There are very few bucket latrine systems still in existence in Sri Lanka, most of them having been replaced by pour flush latrines and soakage pits.

F. Communal Toilet Facilities

144. The technical requirements of communal sanitation facilities can be readily achieved by the use of sewered facilities, VIP's, septic tanks, etc. The facilities provided can range from a minimum service level of sanitation only to a combined latrine/bathing/laundry unit. Their principal advantage is their low per capita cost due to the large number of people that are served. However, they have several disadvantages which make them susceptible to misuse or non-use. The main disadvantages are:

- the lack of individual ownership and privacy, and
- the problems of defecation at night, during illness, or in bad weather.

145. Since a communal facility often seems to belong to no one, individual users have very little feelings of responsibility or commitment to keeping it clean. Under these circumstances the latrines can very quickly become unhygienic and insanitary and people will stop using them. It is essential that a paid attendant/cleaner is always on duty to keep the facilities clean and in good condition. Security must also be provided to prevent vandalism and theft.

146. If the facility is too far from the house, or if it is not lit, people will not use it during the night or in bad weather. Similarly, it will not be used during illness. Education will be needed for the community in the subsequent disposal of excreta collected under such conditions. However, because of the reluctance to be seen carrying "potties" to the communal latrines, proper disposal is not always carried out.

147. The use of communal toilet facilities in Sri Lanka is usually confined to public places such as bus stations, railway stations and markets. Few ablution blocks have been built for use in residential areas and those that have are usually located in the very poorest communities.

4.1.2 Water-Dependent Systems

A. Septic Tank (ST) Systems

148. A septic tank system comprises two separate components:

(i) the septic tank itself, and
(ii) an effluent disposal system.

149. The septic tank is a watertight underground tank comprising two or more chambers into which both foul sewage and sullage from the household are discharged. The solids settle to the bottom of the tank where they are anaerobically digested, thus reducing the volume of the sludge. Over a period of time there is a build-up of sludge so that the tank must be desludged every few years. The desludging interval depends upon the design of the tank and the number of people using it.

150. The effluent from the tank is a polluting liquid that contains high levels of organic materials and enteric organisms. It should not be discharged to surface drains or streams without treatment, nor should it have a direct route into the groundwater aquifer. If it is disposed of in an underground percolation system, safeguards should be taken to ensure that the soakage system is located at least two metres above the highest level of the water table.

151. Properly designed and constructed septic tanks are expensive and are only suitable for houses that have an individual water connection and sufficient land with permeable soil for effluent disposal. In practice, this means that septic tanks are normally restricted to high cost residential areas with low population density.

152. Where no sewerage system is available, septic tanks are the most common method of disposal of the considerable volume of toilet wastes from individual schools, hospitals, government buildings and the like. Their use is common in Sri Lanka.

B. Conservancy Tanks

153. A conservancy tank is a watertight, underground tank into which all wastewaters from a household are discharged. There is no outlet from the tank and, hence, no effluent. The contents of the tank are emptied by a vacuum tanker at regular intervals and taken to a treatment site. The size of the tank is designed on the frequency of emptying. Conservancy tanks are used in similar situations to septic tank systems, but where the soil conditions are not suitable for disposal of the liquid effluent by seepage trench or soakage pit.

154. This system is technically acceptable, particularly in locations with difficult ground conditions, but it requires a well organised fleet of vacuum tankers and a willingness, and ability, on the part of the user to pay for the regular emptying service. It is not currently in

use in Sri Lanka and, because of the institutional requirements and the affordability issues, it is considered that this system should only be introduced in exceptional circumstances when the protection of groundwater quality is paramount.

C. Aquaprivies

155. Aquaprivies are essentially small septic tanks built directly beneath a squat plate which has an integral drop pipe extending below the level of the liquid in the tank so as to form a simple water seal. As with conventional septic tanks, the aquaprivy needs to be desludged at regular intervals and the effluent from it needs to be disposed of through a seepage trench or pit.

156. To prevent odour and insect nuisance, the water seal in an aquaprivy needs to be maintained. This means that the pit must be watertight and the user must pour sufficient volumes of water into the pit to ensure that the water level is maintained. The biggest disadvantage of the aquaprivy is that the water seal is often broken, either due to shortage of water, due to the users' ignorance of its importance, or because they dislike being seen to carry water into the toilet. Many variations of the aquaprivy have been promoted, such as the self-topping aquaprivy, but with varying success. In Sri Lanka, the common use of a pour-flush bowl with a water seal makes the use of aquaprivies unnecessary.

D. Conventional Sewerage

157. Conventional sewerage, comprising a water-flushed toilet connected to a system of gravity-flow underground pipes which transport the wastewaters to some form of treatment and disposal facility, is probably the best sanitation system in terms of convenience, social acceptability and health considerations. However, it is expensive to construct and it uses large volumes of water. It can only be used where there is a reliable water supply and where buildings have individual piped water connections. Its use in many countries is now often restricted to densely built-up urban areas, particularly where the house construction is of more than one storey.

158. Very few piped sewerage schemes have been built in Sri Lanka.

E. Small Bore Sewers

159. Small bore sewers, like conventional sewers, are designed to collect the wastewater from individual households and transport it to a central location for treatment and disposal.

160. There are three basic components of a small bore sewerage system:

- (i) house connections,
- (ii) individual solids interceptor tanks, and
- (iii) the small bore sewer network.

161. All of the household wastewaters, including sullage, are discharged into the interceptor tank, where the solids are retained and are anaerobically digested. The solids-free liquid effluent is connected through the small bore sewer network into the downstream sewer system. Since most of the solids are removed by the interceptor tank prior to entering the sewerage system, it is not necessary to design the pipes for a self-cleansing velocity as in conventional sewers. The initial lengths of sewers can be much smaller in diameter and can be laid at much flatter gradients than conventional sewers. As a result of their smaller diameters, less steep slopes and shallower trenches, small bore pipes are claimed to be less expensive than conventional sewers. Because of the inclusion of an interceptor tanks, these systems are sometimes referred to as “settled sewerage” systems.

162. Small bore sewers are often considered to be a relatively recent technology, but they have been used for many years in the form of the sewered aquaprivies that were built in Chad and Zambia many years ago. Installations within Zambia at Mazabuka, Kafue, Lusaka and Ndola were described as working satisfactorily before Independence in 1965 by Professor G Marais. However, in 1978, Pickford et al carried out site inspections of all Zambian installations. In a report to the UK Overseas Development Administration they commented upon the insanitary conditions prevalent with sewered aquaprivies through neglect of emptying the interceptor tank, thus causing blockages and sewage flooding. They have been used with success in the USA and in Australia.

163. The cost of the individual interceptor tank is usually a high proportion of the overall cost of the system. The systems also require the provision of conventional primary sewers into which they will drain, and sewage treatment works to treat the wastes. Satisfactory operation is entirely dependent upon the regular emptying of the interceptor tanks, particularly when these are initially constructed with a small volume to reduce the cost of the system. Small bore sewers and sewered aquaprivies therefore require a high maintenance commitment. They also require a very strong commitment to the control of unauthorised connections. Such connections are likely to be made without the provision of an interceptor, thus encouraging blockages. Both of these controls are often difficult to enforce in practice.

164. Small bore systems are not generally recommended in Sri Lanka due to their high maintenance and monitoring requirements. They could, however, prove to be viable in particular locations where ground conditions for soakage pits are difficult and where the maintenance commitment can be guaranteed. The last factor is most important, as it is considered unlikely that the satisfactory operation of the facilities could be guaranteed for individual housing areas.

F. Shallow Sewers

165. Much of the expense involved in the construction of conventional sewers is in the cost of trench excavation. In order to maintain self-cleansing velocities in the sewers, engineers have adopted particular design parameters that have been found to be satisfactory from many years of experience. The use of these design parameters reduces the maintenance requirements, but increases the initial construction costs due to the steeper slopes and, hence, deeper sewers.

166. By relaxing the design standards, sewers can be made smaller in size, can be laid at flatter gradients, and can be laid at shallower depths, thus reducing the cost of construction. However, because the flat gradients are critical, very strict control over construction practices is essential. Any lowering of the design standards must also be accompanied by an assessment of the acceptable risk of increased maintenance requirements. Examples of shallow sewers are:

(i) Flat Grade Systems - which are based upon changes to recognised design standards that affect the minimum diameters and minimum slopes of the system.
(ii) Condominial Sewerage - which is based on modified design parameters for minimum depth, minimum diameter, and minimum slopes.
(iii) Simplified Sewerage - where the standards for several design parameters, including minimum depth, minimum slopes, minimum diameters, and manhole spacing have been modified.

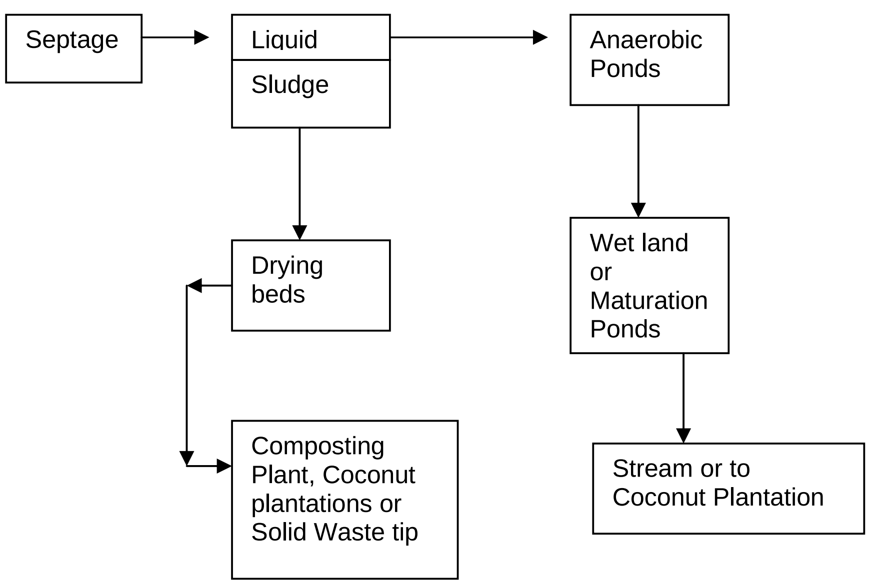
167. Since interceptor tanks are not part of these systems, unlike small bore sewer systems, the maintenance aspects are more concerned with the routine and regular clearing

of pipe blockages rather than with the emptying of interceptor tanks. This means that the maintenance requirements are transferred from the individual to the community. These systems therefore rely on a high level of community participation in the maintenance of the systems. Their introduction in Sri Lanka is not recommended as the population has no experience of sewerage systems, particularly ones that require individual communities to take an active role in the cleaning and maintenance of the pipes.

G. Septage Treatment Facility

168. The introduction of septage treatment is an alternative approach to the provision of a full sanitation system in Urban areas. It is a partial solution to wastewater problems because the only the septage is removed from the Septic Tanks or Conservancy Tanks and treated**.** These systems are rare in Sri lanka[3] and the experience of such system is limited. The system that has been adopted in Accra, Ghana, is proposed as a concept design for the PPTA with suggested further modifications during detailed design. The parameters adopted in the document "Sanitation in Developing Countries" (SANDEC) are use for preliminary sizing of elements of the treatment system. For details see Annex-3

169. The schematic of the proposed septage treatment is given below.



170. Septage treatment is considered to be an economical solution to Urban sanitation problems, but it is not a complete solution to all municipal wastewater. Septage treatment is recommended as alternative solution to the traditional piped sewerage and sewage treatment schemes where the high development and operational costs make it economically unviable.

Selection of Appropriate Sanitation Alternatives

4.2.1 Technical Comparison

171. From the previous section, it can be seen that there are many alternative forms of sanitation technology that are available. Each technology is appropriate under a particular set of circumstances, and not every method can be successfully applied to all situations.

[3] **Nuwara Eliya MC operates one septage treatment plant**

The factors affecting the choice of technology are discussed in the following sections:

A. Soil Conditions

172. Subsoil conditions are important from three aspects: the ease of excavation, the stability of the walls of pits or trenches, and the ability of the soil to dispose of liquid effluent through seepage.

173. The soil conditions affect all sanitation technologies, as they are all dependent upon underground facilities, such as pits, tanks or pipes. The widespread presence of hard rock has affected the outcome of many sanitation schemes. Similarly, hard rock, clay, or other non-permeable soils pose problems for those technologies that need to dispose of liquid wastes by seepage into the ground. On the other hand, if the soil is too porous, the disposal of liquid wastes by percolation can affect the quality of local wells and of underground aquifers.

B. Service Standard of Water Supply

174. There are two broad standards of water supply service to be considered in Sri Lanka. For the purposes of this Report, these are defined as:

- (i) houses having individual connections and several taps with internal plumbing. These are known as house connections.
- (ii) houses having individual connections but normally serving only one tap in the household. These are known as yard taps.

175. NWSDB no longer implements water supply distribution schemes that include communal public standpipes as a service standard. However, there are still small urban areas in which public standpipes are the means by which the residents are supplied. These comprise the poorest communities, such as some of the fishing communities along the coastline.

176. The level of the water supply service affects the choice of sanitation technology. Different technologies will be applicable to different levels of household water usage, since several of the options can only operate effectively with a certain minimum water requirement. For example, conventional sewerage, septic tanks and aqua privies need a plentiful supply of water for their operation, whereas dry systems, such as pit latrines, need no water

177. Often the sanitation technology is dictated by the level of water supply service but, sometimes, the reverse is true. If, for example, the soils in a particular area are unsuitable for on-site disposal of effluent and sullage, but there are no funds available for the provision of sewerage, it might be necessary to restrict the water supply service level to communal standpipes or yard taps to curtail water demand until funds are available for the provision of sewers.

178. Normally, piped sewerage is only considered for those dwellings with house connections and for high density dwellings with yard taps.

C. Housing Type and Density

179. The type of housing construction will affect the choice of sanitation technology. In particular, double or multi-storied buildings are more easily served by flush toilet systems. This subsequently restricts the available technology to sewerage or septic tank systems.

180. Similarly, the density of housing very often dictates the available options. In very low density housing areas, conventional sewerage is very expensive when calculated on an individual plot basis. If the soil conditions are suitable, properly designed septic tanks and soakage pits provide an acceptable service for these plots.

181. The capacity of soils to accommodate pollution loads depends very much upon the housing and population density. The areas that will be most prone to pollution of the groundwater will be the high density housing areas and the commercial centre of the town. In some high density urban housing areas, there is often no physical space available for the construction of individual on-site facilities. The lack of space also restricts access to vehicles for the emptying of on-site facilities and the disposal of sullage in these very densely populated areas also poses a major problem. Under these circumstances, pit latrines and septic tank systems are not feasible and some form of sewer system is often necessary.

D. Socio-Cultural Aspects

182. Besides the engineering aspects of sanitation technology selection, consideration has to be given to the social habits and cultural preferences of individual communities. This a particularly important aspect of the selection process, since many sanitation improvement projects have been misused, or not used and eventually abandoned, through failure to confront this in the planning stage. There are several socio-cultural aspects that need to be appraised, such as:

- attitudes towards seeing or handling excreta,
- attitudes towards the reuse of excreta or sewage effluent,
- attitudes towards communal/shared facilities,
- religious/cultural practices,
- type of anal cleansing materials,
- the presence/absence of a community spirit.

183. The choice of anal cleansing materials is based upon religious, cultural and economic considerations and this, in particular, can affect the choice of technology. In countries where the use of toilet paper is common, commercially manufactured toilet paper is often expensive and so many other materials are in widespread use, particularly in the low income housing areas. These include water, maize cobs, stones, plastic bags, newspaper and cement bag paper. Pour-flush and cistern-flushed toilets cannot cope with some of these anal cleansing materials and the emptying frequency of pits and tanks will be increased by the use of non-biodegradable materials.

184. The most common anal cleansing material in Sri Lanka is water, which is one of the principal grounds for the wide acceptance of pour-flush toilets as a satisfactory option for non-sewered sanitation.

185. Non-conventional sewer systems, such as shallow sewer systems, require a community spirit to cope with the user maintenance commitments. The type of community structure that exists in the Far East and in South East Asia lends itself readily to the sustainability of such systems. It has not yet been proved that the way of life in Sri Lankan urban communities would also lend itself to the success of this technology. The exception could be small individual housing estates, either local authority or private, that have full-time maintenance staff and equipment or in densely populated slum areas.

E. Institutional Requirements

186. All sanitation systems require maintenance in order to operate effectively and hygienically. Depending on the technology, this maintenance is required to be provided

either by the user, by the operating authority, or both. In conventional waterborne sewerage systems, the user is required to keep the toilet clean and to keep the internal plumbing systems in good condition. The municipal (or other) authority maintains the off-site components of the system. With on-site technologies, the user is responsible for the cleanliness and maintenance of the facility and for paying for the emptying of the tank or pit. The authority's responsibility is to provide an efficient and affordable tank/pit emptying service. The failure of the authority to provide such a service is often one of the major causes of the failure of on-site sanitation systems.

187. In the lower income areas, where on-site technologies are most likely to be implemented, the users generally need to be educated in the necessity of maintenance. This should form part of an overall health and hygiene education programme that should be part of any sanitation programme planning.

188. Changing the attitudes of a community towards excreta disposal and environmental sanitation through an education programme can only be done slowly. Thus, institutional arrangements must be in place to take responsibility for implementing such a programme.

F. Environmental Considerations

189. The environmental impact of any sanitation option must be taken into account in the selection process. It must always be borne in mind that the reason for providing any sanitation system is to protect the health of the users. However, not only can wastewater harm humans, but it can damage the environment if not disposed of properly. Examples of this are readily seen in Sri Lanka at present:

- the disposal of sullage and overflows of wastewater to street drains provides a breeding place for insects such as mosquitoes, causes pollution of the drains, and can cause environmental pollution at the discharge point of the outfall.
- the widespread use of soakage pits has, in some areas, lead to pollution of the groundwater with consequent potential harm to public health through contamination of well and borehole water.
- the improper disposal of collected septage/nightsoil poses health and environmental risks.

G. Upgradability

190. As living standards in a community improve, the aspirations of the people also increase and more people want, and can afford, a better water supply level. This leads to an increase in water usage and a consequent increase in wastewater to be disposed of. Some on-site technologies, such as VIP's and pour flush soakage pits, cannot cope with large volumes of sullage and so need to be replaced as the volume of water increases.

191. If this aspect is considered in the planning stage, it is possible to select a sanitation technology that can be upgraded sequentially to meet the improvements in water supply. Pour flush toilets can be connected to a sewerage system without difficulty, thus allowing simple and inexpensive upgrading when funds are available for the provision of sewers.

H. Technology Comparisons

192. The technical suitability of the various sanitation options can be determined for a particular community by consideration of the foregoing aspects. As a first step in the selection process, a comparison of available technologies is shown in matrix form in the table overleaf.

193. By reference to the technology comparison table, many technologies can readily be excluded from further consideration. Systems based upon bucket latrines, composting toilets, conservancy tanks and aquaprivies are not considered to be appropriate in Sri Lanka and need not be considered further.

194. The selection of appropriate technologies from the remaining options has been considered for the principal water service standards already defined: those dwellings with a house connection, those with a yard tap, and those without a house connection. It is important that, wherever possible, a limited number of alternatives is implemented. Consideration of all the factors discussed in the previous paragraphs of this section and in previous sections has narrowed the technical choice of technologies to a few preferred alternatives. These are described in the following section.

Descriptive Comparison of Sanitation Technologies

Sanitation Technology	Urban Application	Costs:		Ease of Construction	Water Requirement	Required Soil Conditions	Complementary Off-site Invest'mt.	Health Benefits	Institutional Requirements
		Const'n.	O&M						
Ventilated Improved Pit (VIP) Latrines	Suitable in low density, low rise areas	Low	Low	Very easy except in hard ground or below WT	None	Stable, permeable soil, groundwater at least 1 metre below surface	None	Good	Low
Pour-flush (PF) toilets	Suitable in low/medium density areas	Low	Low	Easy	Water near toilet	Stable, permeable soil, groundwater at least 1 metre below surface	None	Very good	Low
Self-topping aquaprivy	Suitable in low density areas. Obsolete Tech.	Med.	Low	Requires some skilled labour	Water near toilet	Permeable soil; groundwater at least 1 metre below surface	Off-site treatment facilities for sludge	Very Good	Low
Septic tanks	Suitable in high income areas and for schools, etc.	High	High	Requires skilled labour	Water piped to house and toilet	Permeable soil; groundwater at least 1 metre below surface	Off-site treatment facilities for sludge	Very Good	Low
Conservancy Tanks and cartage	Suitable	Med.	High	Requires skilled labour	Water near toilet	None	Treatment facilities for night soil	Very Good	High
Sewered PF toilets, septic tanks and aquaprivies	Suitable	High	Med.	Requires skilled engineer/ builder	Water piped to house	None	Sewers and treatment facilities	Very Good	High
Conventional Sewerage	Suitable	High	Med.	Requires skilled engineer/ builder	Water piped to house and toilet	None	Sewers and treatment facilities	Excellent	High

Source: Adapted from Table 2.1, World Bank publication "Appropriate Technology for Water Supply and Sanitation: Technical and Economic Options.

Sanitation Strategy Proposals

195. It must be recognised that the development of a sanitation strategy requires the reconciliation of competing requirements. A sanitation technology that is to be a successful part of the strategy must be reliable, technically sound, socially acceptable to the users, and be environmentally friendly. It must also be affordable and sustainable. The achievement of all of these objectives is not simple and, usually, compromises need to be made.

196. The use of pour flush toilets combined with soakage pits for individual dwellings and pour flush toilets with septic tanks and soakage pits for institutional buildings is widely established in Sri Lanka. Pour flush toilets are socially and culturally accepted in Sri Lankan society and their use is so widespread that there is no need for the introduction of new technologies. Instead, the sanitation strategy must focus on reducing the negative impacts of the current methods of disposal of wastewater and sullage.

197. The main problems with the existing situation are mainly confined to urban centres. They can be summarised as:

- the inability of soakage pits in some places to cope with disposal of the wastewater from pour flush latrines, either because of impermeable soil conditions or because of high water table levels
- the potential contamination of groundwater from large numbers of soakage pits
- the health risks associated with the disposal of sullage directly into street drains.
- the inability of urban councils to provide an effective pit/tank emptying service
- major wastewater contributors such has public hospitals, fish markets, etc. do not have adequate facilities to properly treat their wastewater.
- urban development and integrated infrastructure development are not compatible.

198. These problems could be solved by providing full waterborne sewerage to the entire urban area and connecting all wastewater, including sullage, to it. This would require huge capital investment and significant recurrent operating costs and is not considered feasible at this stage.

199. The problems caused by the disposal of sullage directly into street drains and the overflow of wastewater from septic tanks and soakage pits could be solved by compelling plot owners to construct conservancy tanks, which would be regularly emptied by a fleet of gully bowsers provided by the urban councils. This proposal is not considered viable because of the difficulties that would be encountered in encouraging plot owners to provide the conservancy tanks and to pay for their frequent emptying and also because of the financial and logistical demands that would be placed on the urban councils.

200. The areas of the towns where the problems resulting from the existing sanitation systems are most obvious are the high density housing areas and commercial centres. A compromise strategy for sanitation in small urban centres is allow for the phasing of a piped sewerage system by initially providing a sewerage system to the core central areas and also by providing a number of gully bowsers to improve the emptying service for pits and tanks in the unsewered areas of the towns.

201. In assessing the need for a piped sewerage system, several factors need to be taken into account. Although it is difficult to precisely quantify improvements in health resulting from the provision of a piped sewerage system, it is commonly recognised that there is a link between improved sanitation conditions and health benefits. This will become particularly relevant once the water supply system is improved and there is a corresponding increase in the towns' wastewater.

202. The following points indicate a strategy for the priority provision of sewers:

- Hospital wastewaters are a high priority due to their hazardous nature. Main hospitals that treat infectious diseases and that carry out surgical procedures are a main concern.
- Areas with a high concentration of schools, because of the possible health hazards to children due to inadequate sanitation facilities.
- High density housing areas, as sewers provided in these areas tend to have a lower per capita cost and produce greater social and environmental gains, maximising the number of people having access to improved sanitation and improving the local environment through reductions in odour and inconvenience from sullage in open drains.
- Urban development plan, national physical plan and priority areas indicated by the UDA and ULA.

203. Initial strategy proposals for the urban and rural areas of the Project are outlined below. The final Project will largely depend upon the funds available for the sanitation component and the strategy will need to be modified to suit the individual particulars for each town. Details of the individual components of the Proposed Sanitation Project for each town are included in Annex 3: Urban Water Supply and Sanitation Sub-Projects.

204. The proposed overall strategy for sanitation is:

(i) **For the central core area of the Project Towns**, including the central commercial area, institutional buildings, central residential areas with individual water supply house connections or yard connections, the provision of a piped sewerage system in stages, based on catchment areas. GNDs that has population density closer to or equal 100 persons per Ha- in year 2030 are recommended for coverage

(ii) **For low density residential houses with individual house connections and for institutional buildings outside the initially planned sewerage area**, the continuation of the use of septic tanks and soakage drains/pits.

(iii) **For medium and low density residential areas with yard connections and for houses served by public standpipe supplies**, the continuation of pour flush latrines with individual soakage pits.

(iv) **For the improvement of the emptying service to b) and c)**, the provision of an adequate number of gully bowsers (vacuum tankers) to the Urban Councils.

(v) **For sanitation in rural areas**, the use of pour flush latrines and soakage pits or, in water-scarce areas and areas with impermeable soils, VIP latrines.

(vi) **For disposal of septage** use the wastewater treatment facility or separate septage treatment facility.

205. The strategy outlined above, will considerably improve sanitary conditions in those urban areas where sewerage systems are implemented by collecting all wastewater, including grey water, in the underground pipes. The sanitation problems will not be entirely eliminated in all parts of the towns, but the quantities of wastewater that are currently disposed of into soakage pits or street drains will be reduced, as will the overall potential for pollution of groundwater.

Wastewater Treatment

4.4.1 Effluent Quality Standards

206. Wastewater is a highly complex mixture of biological and chemical constituents. It contains large floating or suspended solids (such as faeces, rags, and plastic bags), smaller suspended solids (such as partially disintegrated faeces, paper, vegetable peel, sand and grit) and very small solids in colloidal suspension. It also contains a huge range of bacterial organisms, some of them pathogenic, and, particularly if industrial effluent is included, a wide range of soluble chemicals.

207. The purpose of treating wastewater is to make it safe for disposal to the environment. The nature of the effluent disposal route will determine the quality to which the wastewater must be treated so that it does not pollute the environment or cause harm to flora or fauna. The theory of relating treated effluent quality standards to disposal route has been maintained in Sri Lanka's standards for the discharge of effluents.

208. The country's effluent standards were gazetted in 1990 as the National Environmental (Protection and Quality) Regulations under the National Environmental Act (No. 47) of 1980. The full effluent standards for discharge to inland surface waters, to marine coastal environments, and for irrigation purposes are given in Appendix 2.

209. The allowable upper limits of the most significant parameters of the standards are:

Parameter	Disposal Route		
	Inland Surface Waters	**Marine Coastal Environment**	**Irrigation**
BOD_5	30 mg/l	100 mg/l	250 mg/l
COD	250 mg/l	Not included	Not included
SS	50 mg/l	150 mg/l	Not included

210. The above limits for receiving waters are based upon a dilution factor for the effluent in the receiving water of at least eight times, otherwise the permissible limits are reduced proportionately. The DWSDB Design Manual defines marine coastal waters as the sea, ocean, creeks, and tidal waters extending out to 5 km from the mean high water mark and up to the low tide level in estuaries.

211. The standards have not yet been updated since they were gazetted in 1990, and a significant omission is any reference to bacteriological standards. The Regulations state that the Central Environmental Authority (CEA) may impose more stringent standards and criteria to protect the receiving environment. Revised Regulations are currently being drafted by CEA, and the revised effluent standards are expected to be published in the Government Gazette during 2008. The proposed effluent quality standards are similar to the current standards, but an important additional parameter that has been included is a standard for faecal coliforms. The proposed faecal coliform requirements for an effluent are shown in the following table. It is stressed that the proposed standards are, as yet, unofficial and, until they are published in the Government Gazette, they are subject to revision.

Parameter	Disposal Route		
	Inland Surface Waters	**Marine Coastal Environment**	**Irrigation**
Faecal Coliforms	$<$ 40 FC/100 ml	$<$ 60 FC/100 ml	$<$ 40 FC/100 ml

212. These standards are stringent and an effluent complying with these standards could only be achieved by a series of waste stabilisation ponds that includes at least three maturation ponds or by a combination of conventional treatment followed by maturation ponds or disinfection by chlorination. Chlorination of treated wastewater effluent should be avoided wherever possible and it is not recommended.

213. The National Regulations apply to everywhere in the country except North Western Province. This province has its own Provincial Environmental Authority (PEA), which is authorised to introduce its own effluent quality standards. The first provincial regulations regarding effluent standards, which are identical to the 1990 CEA Regulations, were gazetted in November 1992. The PEA for North Western Province also intends to introduce revised standards during 2008, which will be identical to those that have already been drafted by CEA. The Cost Conservation act 57 of 1981 requires a development permit from the director of CCD for construction of all sewerage treatment structures located within Costal Zone, as defined in the act. The effluent standard given in CEA regulation is applicable to CCD. The GOSL has gazetted[4] in 2006 the costal zone management action plan that should be complied.

214. One of the Project Towns is located inland and the other three are located on the coast. The disposal route for the treated effluent from Chilaw, Puttalam, and Mannar, the three coastal towns, is obviously to the marine environment. Of the four Project Towns, Vavuniya is the only town that is not located on the coastline. It lies in an agricultural area that is located in the water scarce "Dry" climatic zone. During the dry season, it is almost certain that treated wastewater effluent will be used, either officially or informally, as a source of irrigation water by local farmers. According to proposed arrangements the treated effluent will discharge into small tank[5] located upstream of Vavuniya tank. In that case, the quality to which the effluent is treated should comply with internationally accepted standards for the use of treated wastewater for irrigation.

215. The requirements of the two distinct disposal routes are discussed in the following sections.

A. Discharge for Irrigation Purposes

216. In the use of treated wastewater for irrigation of crops, consideration must be given to the physico-chemical quality of effluents to protect plant health and to maintain crop yields. The most often used guideline criteria for physico-chemical constituents in irrigation water are those proposed in the 1979 Food and Agriculture Organisation (FAO) Irrigation and Drainage Paper No. 29, Revision 1: *Water Quality for Agriculture.* The pollutants that can cause damage to crops are those that are mostly present in industrial effluents rather than in domestic sewage and, because of the nature of the wastewater in Vavuniya, the FAO recommended maximum concentrations are unlikely to be exceeded in the treated effluent.

217. Of more concern in Vavuniya are the effects of pathogenic organisms on the consumers of irrigated crops and on the field workers who tend the crops. In 1985, several major international agencies sponsored a meeting in Engelberg in Switzerland to evaluate the most recent research on the subject. The meeting culminated in the Engelberg Report, published by the International Reference Committee for Wastes Disposal (IRCWD).

218. The Engelberg Report considered that BOD criteria are not important and that faecal coliform standards are only significant for unrestricted irrigation use. Instead, the Report considered the potential hazards caused by helminthic pathogens, specifically intestinal nematodes, to have more significance. The Engelbert Guidelines therefore classified effluent for restricted and unrestricted irrigation use based upon nematode egg counts and faecal

[4] **Gazette No.1429/11 of January 2006.**
[5] **Menemaranchankulam. tank**

coliform populations. The microbiological quality guideline for treated wastewater reuse in the unrestricted irrigation of all crops, including vegetables, recommended in the Engelberg Report is:

(i) No more than one viable nematode egg (ascaris, trichuris, or hookworm) per litre.

(ii) A geometric mean of no greater than 1,000 faecal coliform bacteria per 100 ml

219. Where restricted irrigation is to be carried out on crops not for human consumption, only the nematode guideline (i) is recommended.

220. The conclusions of the Engelberg Report, and its guidelines, were confirmed by World Bank Technical Paper No. 51: Wastewater Irrigation in Developing Countries, Health Effects and Technical Solutions published in 1986.

221. In 1989, a World Health Organisation (WHO) Scientific Group studied the epidemiological evidence and endorsed the Engelbert Report and World Bank Technical Paper No. 51. The endorsement came in the publishing of *WHO Technical Report No. 778, 1989,* in which revised microbiological guidelines were proposed that are identical to those recommended in these previous two reports.

222. The 1989 Guidelines are still accepted as the definitive international guidelines for the use of treated wastewater in irrigation. It is recommended that the standards as presented in WHO Technical Report No. 778 should be adopted for use in Sri Lanka. These guidelines are shown on the following table.

WHO Guidelines for the Use of Wastewater in Irrigation, 1989

Category	**Reuse Conditions**	**Intestinal nematodes[b] (arithmetic mean no. of eggs/litre[c])**	**Faecal coliforms (geometric mean no. per 100 ml[c])**	**Treatment required to achieve the standard**
A	**Irrigation of crops likely to be eaten uncooked, sports fields, public parks[d]**	≤I	< 1000[d]	A series of stabilisation ponds designed to achieve the microbiological quality indicated or equivalent treatment.
B	**Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]**	≤I	No standard recommended	Retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal.
C	**Localised irrigation of crops in Category B if exposure of workers and the public does not occur**	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation.

Source: WHO Scientific Group (1989), Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. Technical Report Series No. 778.

223. If the above standards for intestinal nematodes are met, other standards, such as trematode eggs and protozoal cysts, will also be reduced to undetectable levels.

224. The WHO Guidelines in Technical Report 778 also includes guidelines for effluent quality for fish cultivation. These are:

(i) an absence of trematode eggs, and
(ii) less than 1 000 faecal coliforms per 100 ml in the pond water.

225. If the breeding of fish is restricted to the final pond in a series of 4 – 5 stabilisation ponds with an overall retention time of at least 30 days, then these standards will always be met. The design of the pond system should aim for a BOD in the final pond not exceeding 50 mg/l, otherwise deoxygenation could result in fish die-off.

226. From the foregoing, it can be seen that it is not considered necessary to achieve a FC count of < 40 FC/100 ml as proposed in the revised National Regulations. However, long retention periods assist in the removal of helminth eggs and protozoal cysts and so it is intended to comply with the proposed FC standard so that the complete removal of helminth eggs is assured. The resulting effluent can safely be used for unrestricted irrigation and also for fish cultivation.

B. Discharge to the Marine Environment

227. This standard will apply to the towns of Chilaw, Puttalam, and Mannar, which are located on the Sri Lankan coastline.

228. In any body of water, whether it be a river, a lake, a lagoon, or an ocean, the aquatic environment normally supports a wide variety of natural eco-systems and human activities. The quality of the water that is necessary to support these different uses may vary and, consequently, the quality standard that is required of a treated effluent must be determined in relation to the use, or "beneficial use", to which the receiving water is being put. The quality of the treated effluent must be such that it does not adversely affect the water quality requirements of the receiving water for a particular use.

229. "Beneficial use" means the desired use, or uses, for a particular water body. The common beneficial uses of a stretch of coastline are summarised in the following table.

Beneficial Uses of a Coastline Marine Environment

Category	Beneficial Use	Environmental Objective
1	Basic Amenity	To prevent public nuisance arising from visual and odour problems
2	Maintenance of the Ecosystem	To ensure that all physical, chemical and biological conditions defining the structure of the ecosystem are maintained.
3	Recreation: 1 Primary contact (swimming, diving, surfing, windsurfing, waterskiing, and wading) 2 Secondary contact (boating & sailing)	To ensure that water quality is suitable from aesthetic and health points of view.
4	Collection or culture of aquatic life for food: 1 Filter feeders 2 Non-filter feeders	To ensure that water quality is suitable for the collection and culture of aquatic life for human consumption (health and taste).

230. Guidelines can be set for the quality standard with which a treated effluent must comply to ensure that the quality of the receiving water are such that all the above beneficial uses are maintained. All properly designed wastewater treatment processes will treat domestic wastewater that will ensure compliance with the environmental objectives of the first two beneficial uses in the above table.

231. The quality of the receiving water for recreational uses is usually expressed in terms of the number of faecal coliforms that are present in the water. The NWSDB Design Manual recommends that a guideline FC value of 1,000/100ml not being exceeded in 80% of the samples should be adopted. The European Communities FC Standards for bathing waters (76/160/EEC of December 8, 1975) are:

Guidance level:	Not to exceed 100 FC per 100 ml in 80% of samples
Mandatory level:	Not to exceed 2,000 FC per 100 ml in 95% of samples.

232. The water quality requirements for direct contact recreation, such as swimming, snorkelling, etc., should be appropriate to the extent of the tourism industry. Because none of the Project Towns has a tourism industry that is based upon recreational use of beach facilities, standards for bathing waters are not considered to be relevant. However, Chilaw and Puttalam both have sensitive ecosystems in the shallow lagoons on which they are located. They both also have extensive prawn farming industries in the vicinity of the towns that provide a valuable export for Sri Lanka's economy.

233. The shallow waters and mangrove swamps around the towns are valuable natural resources that yield fish, crabs, and prawns. The species that are most sensitive to pollution are filter feeders such as oysters and mussels. Due to the health risk associated with human consumption of these species, higher water quality standards are required. Although no evidence of current cultivation or collection of filter feeders was found in either of the towns, it is appropriate that the wastewater should be treated to a standard that will protect the shallow marine ecosystems and that will also allay any fears of the prawn farming industry.

234. The NWSDB Design Manual suggests that marine waters for the cultivation of shellfish should not contain more than 40 FC/100ml in more than 10% of the samples. Guidelines that are used elsewhere (South Africa, Kenya, Mauritius) for the quality of the receiving water for the collection and culture of filter feeders that are appropriate for application to the shallow waters in Chilaw Lagoon and Puttalam Lake are:

Guidance Level:	not to exceed 20 FC per 100 ml in 80% of samples, and
Mandatory Level:	not to exceed 60 per 100 ml in 95% of samples.

235. The standard to which a wastewater must be treated to comply with these receiving water standards is dependent upon the dilution available in the receiving water and on the point of sampling. If the available dilution in the receiving water is assumed as eight times, then to achieve an FC count of less 20 per 100ml in the receiving water, the FC count of the effluent must be less than 160 FC/100ml. The available dilution in the receiving waters in all of the Project Towns will be much greater than eight times, but it is also known that the waters of Chilaw Lagoon and Puttalam Lake are not pristine in the vicinity of the towns. To allay any fears, particularly of the prawn fishing industry, it is recommended that the treatment systems should be designed to produce an effluent that can consistently achieve a FC count that will comply with the proposed revised National Regulations, i.e. less than 60 FC/100ml. This is a stringent standard and, at this level of FC removal, all other quality parameters will be satisfied and the quality of the receiving water will be safeguarded.

236. It is intended that all wastewater treatment plants, whatever the disposal route, should be designed to produce a treated effluent that complies with the proposed revised National Environmental Regulations that are expected to be introduced in 2008. Compliance with these standards will provide minimal negative environmental impact from the effluent.

4.4.2 Available Wastewater Treatment Technologies

237. The object of this appraisal is to establish a method of wastewater treatment to achieve the proposed effluent standards in the most economical and technically appropriate fashion for use in Sri Lanka, with particular application to the Small Towns of this Project.

238. The treatment processes must be capable of removing inorganic material and stabilising the organic fraction of the waste to produce both an effluent and a sludge that can be disposed of safely and without nuisance.

239. A detailed review of treatment processes is not necessary, but sufficient background information on each method will be presented to establish the context in which subsequent comparisons are made and conclusions are reached. The following sections evaluate the operating characteristics of the alternative methods of treatment that have been considered for small urban centres in Sri Lanka. They comprise:

(i) Waste stabilisation ponds
(ii) Aerated lagoons
(iii) Biological filters
(iv) Activated sludge
(v) Oxidation ditches
(vi) Sea Outfalls

240. In the initial stages of operation of the treatment plant, a common feature of all treatment options is an inlet pumping station to lift wastewater into the site. Where needed, an Archimedean screw lift pumping station is proposed.

241. Also, for all alternative treatment processes, an inlet works will be needed to remove debris such as grit, rags, plastic bottles, and other materials that might cause obstructions in pipes and channels and could damage mechanical equipment. The removal of plastic bags is particularly important where sludge treatment and mechanical dewatering equipment is installed, as the presence of such items can cause operational problems with the equipment. Where mechanical and electrical equipment is recommended for an inlet works, an emergency by-pass channel will be constructed upstream of the inlet works so that in the event of a power failure or mechanical breakdown the raw sewage will by-pass the inlet works. A coarse, hand-raked screen will be provided on the by-pass channel.

242. An access bay with washdown facilities will be provided to allow gully bowsers to discharge their loads of septage directly into the inlet channel.

243. The proposed inlet works will comprise:

A. Screens

244. Screens will be provided to take plastic bags, plastic bottles, etc., out of the flow. When the incoming wastewater flow is greater than about 10,000 m^3/day the volume of screenings makes it impractical to have manual cleaning and mechanically back-raked inclined bar screens are usually proposed. None of the Project Towns will have flows that approach this level and so it is intended that manually raked screens with 25 mm spaces should be installed. It is not proposed to install any form of treatment for the screenings, such as washing and compacting, as this would increase the M&E input with associated increase in capital and operational costs and maintenance requirements.

B. Grit Removal

245. Efficient removal of grit from the sewage at the preliminary stage of treatment is necessary prior to all methods of treatment. The operation of all forms of grit removal is based upon the theory that the density of grit is much greater than that of the organic solids in wastewater and if the velocity of flow of the wastewater is reduced to a predetermined level the grit will settle out, allowing the organic solids to remain in suspension.

246. The simplest effective grit separation method is the use of constant velocity channels with manual or hydrostatic removal of the settled grit. This arrangement is usually recommended for works of up to 15,000m^3/day but, above this size, the channels occupy a considerable area and grit removal becomes onerous. In larger works, some form of mechanical removal of the grit becomes necessary and this is often unsatisfactory. For the level of flows that are expected in the Project Towns, it is proposed that twin constant velocity channels should be installed with manual removal of the grit.

247. The volumes of screenings and grit at the treatment plants in the Project Towns will not be large and it is recommended that disposal of grit and screenings should be by burying on site.

C. Flow Measurement

248. Some method of measuring the inlet flow is needed to monitor the performance of the works and to provide data on which to base the design of future extensions. Usually a flume built into the concrete inlet channel is fitted with an ultrasonic reading and recording system to measure the incoming raw sewage flows. This type of system is very reliable. However, as a back-up, an aluminium alloy measuring gauge can be fixed to the channel wall upstream of the flume so that measurements can be taken manually.

249. In addition to the inlet works, there will also be facilities that will be common to all treatment options, but where the level of provision will change with the requirements of the various options. Such facilities include:

- Administration block
- site roads
- boundary fencing
- workshop and laboratory
- tools and equipment store
- site lighting.

4.4.3 Treatment Process Options

250. Brief descriptions of the various treatment processes listed in the previous section are given in the following paragraphs:

A. Waste Stabilisation Ponds (WSP)

251. Where climatic conditions are favourable and land is readily available, stabilisation ponds are generally the most suitable method of wastewater treatment. The units are open, shallow, flow-through lagoons. They require relatively large areas of land to provide the necessary long retention periods needed to stabilise the organic material in the waste. They operate without mechanical plant and with limited supervision. Maintenance requirements are minimal.

252. Waste stabilisation ponds are generally subdivided into the following types:

(i) Anaerobic Ponds:

253. Anaerobic ponds are, generally, deep ponds in the order of 3.0 - 4.5 m deep, where the treatment is a result of methane fermentation and intense anaerobic digestion. To sustain this action the pond temperature should be maintained at approximately 20 C, with a pH greater than 6.5 to ensure continued sludge digestion. The action is similar to that within a septic tank with solids settlement, high BOD removal, and digestion of the sludge.

254. The incorporation of anaerobic ponds in a pond system results in a decrease of the aerobic breakdown required in other units with a resulting saving in land. Such ponds are designed on a BOD loading of 100g - 400g BOD/m^3/day with a desludging frequency of two or three years - when the pond is half full of sludge. The process can take some months to reach full maturity and lower loadings should be applied initially. Anaerobic ponds can develop odours if subjected to a BOD loading in excess of approximately 400g BOD/m^3/day. If odours should develop, the recirculation of effluent from the final maturation pond can often be practised with good effect.

(ii) Facultative Ponds:

255. These ponds effect aerobic stabilisation of the waste in the surface layers and anaerobic digestion in the lower layers. Oxygen is supplied by the photosynthetic response of algae during daylight hours and at night the algae utilise the dissolved oxygen in the water for normal respiration. This action is clearly identified from the green appearance of the pond liquor. The non-motile algae require the action of wind across the surface of the pond to maintain a distribution of algae, bacteria, BOD, and oxygen in the top 150 - 300 mm of the pond depth where the photosynthesis occurs and to prevent the pond from stratifying. Design of the ponds should ensure the sludge is spread evenly on the pond base where some 30% of the BOD is converted to methane gas which passes to the atmosphere. The end products of anaerobiosis diffuse upwards and mix with the dissolved and colloidal material in the aerobic zone.

256. Facultative ponds are generally 1.5 - 2.0 m deep and can be designed so as to operate within this range at the optimum efficiency. The BOD loading depends mainly on the ambient temperature. Desludging of facultative units is infrequent and of the order of once every 10 to 15 years.

(iii) Maturation Ponds:

257. These ponds, usually around 1.0 m deep, act as polishing ponds to effect a marginal reduction in the BOD of the effluent from the facultative ponds. Their principal purpose is to achieve the necessary reduction of faecal coliforms. The effective kill of pathogenic organisms is attained mainly by prolonged exposure to a hostile environment. Their design is based on First Order Kinetics.

B. Aerated Lagoons (AL)

258. This more intensive system of treatment results in greater removal of organics per unit volume of treated wastewater than is achieved in stabilisation ponds. However, machinery and energy to drive it are necessary. Oxygen is supplied to the wastewater by mechanical surface aerators immersed in the liquor, supported either by floating pontoons or by fixed structures in the lagoon. Fully developed, the process is equivalent to the activated sludge process without a sludge return system. For a flow retention period of 3 - 4 days, the system can achieve a BOD removal greater than 90% with a sludge concentration in the order of 200 - 400 mg/l. The process is, however, not particularly efficient in the reduction of faecal bacteria.

259. In complete-mix aerated lagoons, a power requirement of about 5 W/m^3 is required to keep the contents of the lagoon mixed and most of the solids in suspension. There is no growth of algae in such lagoons and it is wrong to think of them as modified stabilisation ponds. They are, as suggested, simple activated sludge tanks. The process requires either a final sedimentation tank or a facultative pond to allow settlement of the considerable volume of suspended solids discharged from the aerated pond.

260. Aerated lagoons are normally considered where there is a shortage of land for the development of a straightforward system of waste stabilisation ponds. The construction requirements of the lagoons are very simple and so capital costs are low. Operation and maintenance procedures are simple.

C. Biological Filters (BF)

261. These comprise a permeable bed of media, of either graded natural stone or inert synthetic material, usually plastic, around which sewage flows. The filter is generally some 2.0 m deep and circular in plan. Sewage is evenly distributed on the surface and effluent is collected through underdrains in the base, while allowing circulation of air upwards around the material.

262. The units are preceded by primary settlement tanks and followed by secondary (humus) settlement tanks to collect the settleable organic solids delivered from the filters.

263. Efficiency of the units is assessed on the total reduction of BOD as the waste is oxidised while passing through the media. The process results in a gradual build-up of slime (aerobic bacteria and biota) on the media surface into which the organic fraction of the sewage is absorbed by the slime and degraded by the biota. The slime gradually sloughs off and is settled in the humus tanks, which action aids ventilation in the filters and allows renewal of the biota.

264. Percolating filters are able to withstand shock loads and provide a reliable means of treating wastewater with relatively little maintenance or skilled supervision. They are generally classified as high or low rate units according to their organic loading.

C. Conventional Activated Sludge Process (CAS)

265. The process basically involves the aeration of settled sewage mixed with return sludge within an aeration tank, the air being introduced by either surface aerators or by a diffused air system into the liquid. The settled incoming sewage is aerated for several hours, during which time the micro-organisms in the sewage multiply through assimilation of the organics in the influent wastewater. Part of this reaction synthesises new cells and the subsequent separation of the biological mass and oxidation reaction are the principal components of BOD removal in the process. The biomass generated is normally flocculent and settles out easily in the secondary settlement tanks. Part of this secondary sludge is then recycled to the aeration tank on a continuous basis as activated sludge. The mixed liquor suspended solids (MLSS) is taken as the measure of the mass of active micro-organisms in the aeration tank and is generally in the region of 2,500 - 5,000 mg/l.

266. The aeration tanks are usually large reinforced concrete units designed to encourage plug flow conditions by the introduction of baffle walls. The settled sewage and return sludge are introduced at one end of the tank and various combinations of liquid feed and air introduction can be adopted to ensure maximum utilisation of the applied air and thereby increase the efficiency of the plant. Additionally, the amount of aeration can usually be regulated and this, together with the regulation of the volume of return activated sludge to the aeration tank, allows some degree of control over the process.

267. Sewage is normally retained in the aeration tank for a period of 4-8 hours with a loading in the order of 0.3-07 kgBOD/m^3. The process is the most common aeration treatment system in use, but the plant has a high initial capital cost, high operating costs, and a high degree of technical expertise is required to operate the process successfully.

D. Extended Aeration using Oxidation Ditches (Ox.D.)

268. Extended aeration using oxidation ditches has the advantage of simple construction, relatively simple operation, no preliminary settling is required and the sludges produced tend to be stable.

269. An oxidation pond system would normally comprise an oxidation ditch with final clarifiers and recirculation pumps to recirculate return sludge to the inlet of the ditch.

270. Small oxidation ditches can be designed using lined earth embankments, but for larger works a more land efficient solution is achieved by constructing the ditches with reinforced concrete bases, channel walls and central baffle walls.

271. The F/M (food to mass ratio) has to be maintained by recirculation of activated sludge. This is usually carried out using a low lift screw pump. The operation, maintenance and running costs of this type of pump are low.

272. The final clarifier will receive treated effluent from the oxidation ditch and settle out sludges for thickening and dewatering or recirculation. A circular tank configuration allows for a simpler and more effective sludge scraping, sludge concentration and draw off arrangement when compared with a rectangular tank layout.

E. Sea Outfall

273. With the Indian Ocean surrounding the entire island, the obvious disposal option for wastewater from coastal communities is into the ocean. However, a sea outfall must not be regarded as only a disposal option. The enormous dilutions that are available in the ocean allow the wastewater to be assimilated and for its constituents to decay without any harm to the marine environment. A sea outfall should therefore be considered as a form of treatment rather than just a disposal option.

274. The minimum level of conventional treatment that is needed before discharge through a sea outfall is preliminary treatment, comprising screening and grit removal, and, depending upon local conditions, the discharge might need to be pumped.

275. The arrangement of a long sea outfall is site specific and requires specialist surveys and design input. Because of the expense of building a long sea outfall, the feasibility of this option is usually restricted to the wastewater flows from large coastal towns. This technology has not been considered further for the present Small Towns Project at this stage. For the Small Towns in this Project, the disposal of wastewater to the ocean will be preceded by full treatment.

Comparison of Treatment Technologies

276. An evaluation of the main treatment process options must consider a large number of important criteria. The most relevant of these are discussed in the following sections.

4.5.1 Standards of Treatment and Effluent Quality

277. The ability of each process to achieve a consistent quality of effluent with respect to the required effluent quality standards is obviously an important criterion.

278. All of the processes considered can achieve high reductions in organic strength to satisfy normal effluent standards. Processes that inherently have greater retention times and sludge settlement are preferred. Most systems score reasonably well, but WSPs score slightly lower due to the effects of algae. Approximately 80% of the BOD from typical WSP final effluent is due to algae. As a result, many countries accept higher BOD levels from WSPs or accept that the BOD of the final effluent should be judged on the results from filtered samples.

279. The ability to achieve a consistently high microbiological standard effluent is also an important criterion in effluent quality standards. Waste stabilisation ponds score highest here and suspended and fixed film reactors such as aerated lagoons, bio-filters, oxidation ditches and activated sludge plants score lowest, unless they are combined with maturation ponds or sand filtration and disinfection equipment.

280. Nutrient removal is important to prevent eutrophication in some particular occasions. In addition, nitrate removal is important from the public health point of view. Nitrates affect the ability of young babies and infants to utilise and absorb oxygen effectively, with the result that they die of suffocation, an illness known as methaemoglobinaemia (infantile cyanosis). A further concern with nitrates is that medical research has indicated a possible link with certain forms of cancer, although this has not yet been proved conclusively.

281. None of the basic treatment processes on its own can meet strict effluent quality requirements with regard to nutrient removal. They all require additional process units. There is very little information available on nitrogen and phosphorus removal in waste stabilisation ponds, although it is reported that up to 80% removal of nitrates can be achieved. The simplest of the other processes to modify for the removal of nutrients are the activated sludge process and the oxidation ditch. These modified activated sludge (MAS) processes can achieve a high degree of nutrient removal, but at the expense of additional process complexity and the increased skills required for their operation and maintenance.

4.5.2 Process Reliability

282. The process should be reliable. Processes least sensitive to electricity disruptions, operator errors, shock loadings, and lack of maintenance are preferred. Waste stabilisation ponds rate very highly in this context.

4.5.3 Process Complexity

283. The process, with regard to the complexity of the monitoring, control and operation, should be as simple as possible so that the scarce resource of trained manpower can be efficiently deployed. In general, systems with high maintenance requirements and the need for extensive skilled manpower are not appropriate. Operating staff will be required for all treatment processes, but processes requiring less trained manpower are preferable to those that need a lot of highly skilled manpower.

284. Operational experience in Sri Lanka is desirable if the operating authority is to recruit suitable operating staff. Proven systems for which there is a good availability of manpower with sound operational understanding are preferred. At present, there are no wastewater treatment plants in Sri Lanka other than a limited number of pond systems. There is therefore very little local expertise available in the operation and maintenance of mechanised wastewater treatment plants.

285. Of all the processed discussed in the previous section, waste stabilisation ponds are the simplest to operate and maintain.

4.5.4 Operational Considerations

286. The ease of day-to-day operation of a wastewater treatment plant depends upon its degree of sophistication. Stabilisation ponds require very little in the way of operating personnel, whereas for the activated sludge process, a high level of skilled supervision, usually including a biochemist and a full-time laboratory and technicians, is required. The ease of operation also depends upon the volume and the quality of the sludge that is produced. Processes that require sludge thickening and digestion, such as activated sludge plants, require greater operational skills.

287. Of the mechanised processes, aerated lagoons are by far the simplest option from the operational aspects. The maintenance requirements are very simple and no high levels of skill are required. Oxidation ditches require a higher level of maintenance and operation than stabilisation ponds, but the requirements are still relatively low.

288. Mechanised plants are well known and understood in most countries of the world and there are more CAS plants in operation than any other form of sewage treatment. However, there is no operating experience of any of these systems in Sri Lanka.

4.5.5 Land Requirements

289. As might be expected, any process that requires little or no mechanical assistance for treatment will require increased detention times for treatment and, accordingly, substantially increased land area. Waste stabilisation ponds will require the largest land area of all the processes under consideration. Some decrease in the land area required could be obtained by the introduction of anaerobic ponds, and a substantial decrease in the land area is achieved by the use of the aerated lagoon process. A further substantial decrease in land area results in a progression to more technically advanced and intensive systems where land acquisition ceases to be a major component of the total capital cost. The system with the lowest land requirement is an activated sludge plant.

290. The importance of this criterion depends on the availability and the cost of land.

4.5.6 Civil Construction Requirements

291. Simple construction leads to shorter construction periods, lower costs, and economic maintenance. Systems requiring fewer civil engineering structures, less inter-connecting pipework and less complex geometry of process units are preferred.

292. The engineering construction of waste stabilisation ponds is very simple and is usually limited to earthworks, installation of pipelines, and the construction of the inlet works and interpond connections. The lining of ponds to prevent seepage into underground aquifers is done by the use of clay layers in the pond bases and embankment slopes or by the use of synthetic linings. Erosion of the embankments is prevented by the use of concrete slab protection at the waterline.

293. The performance of aerated lagoons must be carefully analysed to ensure that erosion of the base and side slopes does not occur when the plant is under full load. It is normal practice to incorporate a lining to the base and sides to prevent erosion and subsequent seepage. Stone protection around floating aerators and at top water level to prevent wave attack might be necessary. Equally, a system that avoids any fixed structures for support or any associated access for maintenance is to be preferred, although the relative merits of floating or fixed aerators would be compared during detailed design.

294. In all high intensity treatment processes, there is invariably a large requirement for significant reinforced concrete water-retaining structures with complex interconnecting pipework and associated infrastructure. Those processes that require the largest and

deepest structures are likely to need correspondingly high skills for their construction and, hence, are likely to be more expensive. The geometry of the structures requires specialist construction techniques and often demands large pours of concrete to be undertaken for the integrity of the structure.

295. The main reactor units in the activated sludge process are large, deep reinforced concrete structures and they are normally preceded by primary settlement which takes place in reinforced concrete circular, radial-flow, hopper-bottomed tanks. Such plants also require similar tanks for final sedimentation purposes.

296. Oxidation ditches do not require primary settlement, but do require final sedimentation tanks. The ditches are reasonably straightforward to construct, with the structures generally in reinforced concrete. Construction of the ditches can be undertaken as lined channels, or earthen ditches with local protection being provided in the areas of aeration or high turbulence.

297. Where sludge treatment is needed, as in activated sludge plants, the tanks for sludge thickening and the digestion tanks and sludge drying beds would be constructed from reinforced concrete.

4.5.7 Mechanical and Electrical Plant

298. The mechanical/electrical content of a process is an important criterion that affects the operational and maintenance requirements. Fewer mechanical components reduce the operating authority's need to procure spare parts and dependence on third party suppliers. Electrical power is often a considerable recurrent operating expense in highly mechanised plants. Plants with less mechanical content are preferred to highly mechanised processes.

299. The aerators form the most important component in any aerobic treatment system that uses mechanical devices to increase the oxygen transfer and the power required for aeration dominates the overall power consumption. This is true for the activated sludge process, aerated lagoons, and oxidation ditches.

300. For the conventional activated sludge system and the oxidation ditch, the requirement to return sludge continuously to the main aeration reactor is a fundamental part of the process. This continuous pumping is best performed by a screw pumping installation.

301. The pumping plant for recirculation and sludge return and pumping in the biological filter treatment process is best undertaken by conventional pumping plant, which can accommodate the necessary intermittent flow pattern through the filters.

302. Waste stabilisation ponds need no mechanical or electrical equipment other than in the inlet works of plants treating flows greater than around 10,000 m^3/day, but this equipment would be common to all options.

303. With any mechanised plant, the reliability of each process must be evaluated against a power failure event and, where essential and continuous processes are identified, a provision for standby power should be incorporated. This places substantially greater costs on those plants that are heavily mechanised, such as activated sludge.

4.5.8 Sludge Production

304. The nature of sewage sludge renders its handling and disposal difficult. Processes that produce low quantities of predictable, stable and dense sludges are preferred.

305. The long retention times in facultative stabilisation ponds mean that the sludge is well digested with a consequent reduction in volume. This means that the ponds need only be desludged infrequently: every fifteen to twenty years. Provision must be made in the detailed design of the ponds to allow individual pond units to be removed from service while the desludging procedures are carried out. Whenever ponds need to be desludged, the desludging process can be carried out continuously or intermittently, whichever is more convenient. Once dried, the sludge is stable and is usually disposed of in a waste management facility or it is used as a soil conditioner without further treatment.

306. The sludge produced from aerated lagoons and oxidation ditches is also stable due to the long detention times and needs no further treatment other than drying on beds.

307. Activated sludge plants produce large volumes of sludge that needs to be treated before further use and disposal. All the sludge produced at these plants is usually collected in settlement tanks, the sludge settled in the secondary settlement tanks being returned to these units for sedimentation and subsequent removal. The dewatering and digestion of sludge is a major component of the capital and recurrent costs of activated sludge plants.

4.5.9 Environmental Considerations

308. Numerous key environmental criteria need to be taken into consideration in a comparison of the different types of treatment. The following criteria are by no means exhaustive, but are sufficient for this level of process selection. The criteria to be considered are described below:

- energy requirements for the treatment process. Low energy requirements are environmentally desirable and, in addition, there will be fewer environmental problems if interruptions of the power supply occur.
- fly and odour problems are more of a nuisance with certain treatment than others.
- methane gas is a by-product of anaerobic digestion of organic matter. In the anaerobic digestion of sludge, this gas is often captured and utilised as biogas in the plant, whereas the gases released in waste stabilisation ponds pass directly to the atmosphere.
- sterilisation of land and habitats for flora and fauna requires consideration of the land area that will be used for the treatment plant. The type of habitat that will be created by the treatment works also needs to be considered. For example, although waste stabilisation ponds require a large area of land, the ponds will create a habitat that is attractive to other flora and fauna.
- the chances of plant failure and the resultant impact are crucial criteria. If a treatment plant has a high chance of failure and the subsequent problems cannot be contained and rectified, it is environmentally undesirable.
- impact during the construction phase includes dust, noise, length of time for construction, and general disturbance. Noise pollution during operation includes the noise of machinery, truck movements, etc.
- aesthetic impact is the visual impact of the treatment plant after construction has been completed. Plants that are unobtrusive and that blend in with the surrounding environment are preferred.

Wastewater Treatment Strategy Proposals

4.6.1 Technology Selection

309. The correct selection of technology for a wastewater treatment plant is a very complex process, as the previous section has indicated. The correct choice is site-specific and is usually made for a particular site and a given set of conditions. However, by making broad comparisons between the various technologies, certain conclusions can be drawn.

310. To assist in this comparison, a descriptive correlation of the various methods of wastewater treatment is presented in the table on the following page.

311. It is obvious that the information given in the table is highly simplified and is subjective. However, it is sufficiently reliable to provide a useful tool to the planner in the technology selection process.

312. Reference to the technology comparison table shows that the advantages of waste stabilisation ponds for use in Sri Lanka over other technologies are so significant that they cannot be ignored. Their advantages can be summarised as:

- no mechanical and electrical equipment is needed (except, possibly, for the inlet works, which is common to all technologies), so no power is used in the process.
- the process takes place in simple lagoons and so the plant can be operated and maintained using only a small number of unskilled workers.
- bacterial reduction and the removal of helminth eggs are superior to any other technology.
- because of their long retention times, they are well able to absorb hydraulic and organic shock loads.
- continuous sludge handling is not necessary. Facultative ponds need only be emptied every 15-20 years. The sludge is stable and requires no treatment other than drying on beds or in situ.
- construction of the ponds is very simple and so the cost of construction is generally lower than other plants. If required, the land can also easily be reinstated at the end of the plant's useful life.
- pond systems can easily be upgraded by installing anaerobic ponds prior to the facultative ponds or by converting the ponds into aerated lagoons.
- ponds usually provide minimal negative environmental impact.
- the ponds can be designed to provide a final effluent that can be used for agricultural irrigation.

Descriptive Comparison of Alternative Wastewater Treatment Methods

Treatment Process	Standard of Treatment	Process Reliability	Process Complexity	Operation & Maintenance Requirements	Land Requirements	Civil Construction Requirements	M & E Equipment	Sludge Production	Environmental Considerations
Waste Stabilisation Ponds	Good, except for nutrient removal	Very good, but weather dependent	Extremely simple. No skills needed	Very limited and simple	Large areas of land needed.	Very simple	Almost none, except, possibly, at the inlet works	Limited sludge production. Sludge is stable and requires no further treatment	High environmental acceptance.
Aerated Lagoons	Good, except for nutrient and bacterial removal.	Good, but partly subject to power outages and mechanical failure	Very simple. No skills needed.	Limited and straightforward	High land requirements, but not as large as WSPs	Very simple	Apart from the inlet works, only the surface aerators	Limited sludge production. Sludge is stable and requires no further treatment	Moderate environmental acceptance.
Biological Filters	Very good, except for nutrient and bacterial removal.	Good, but subject to power outages and mechanical failure	Simple. Limited skills required.	Moderate, but straightforward	Moderate land requirements	Complicated RC structural requirements.	Moderate degree of M&E plant needed.	Sludge from primary & secondary settlement needs treatment	Some aspects need further environmental consideration.
Activated Sludge	Very good, except for nutrient and bacterial removal.	Good, but subject to power outages and mechanical failure	Complex. Highly skilled manpower needed	High requirement for O&M and skilled staff	Minimum land requirements.	Very complicated RC structural requirements.	High input of M&E equipment needed	Sludge from primary & secondary settlement needs treatment	Many aspects need further environmental consideration.
Oxidation Ditch	Very good, except for nutrient and bacterial removal.	Good, but subject to power outages and mechanical failure	Simple. Limited skills required.	Moderate requirement for skilled O&M staff	Moderate land requirements.	Moderate construction requirements.	Moderate degree of M&E plant needed.	Limited sludge production. Sludge is stable and requires no further treatment	Some aspects need further environmental consideration.

Notes:

1. All treatment processes except waste stabilisation ponds will require additional treatment, such as sand filtration and disinfection or maturation ponds, to achieve bacteriological reduction.
2. All the treatment processes considered will require additional process units to achieve nutrient removal.
3. The activated sludge process and the oxidation ditch most easily lend themselves to nutrient reduction using the Modified Activated Sludge (MAS) process.

4.6.2 Wastewater Treatment Strategy

313. As there is no industrial activity in any of the Project Towns that produces significant effluent, the main sources of wastewater are domestic dwellings, commercial premises, and institutional buildings such as schools, hotels, hospitals, and government offices. The wastewater can therefore be easily treated by any of the common treatment technologies.

314. The technology assessment of a wastewater treatment plant is normally site-specific. However, as described in the previous sections, the advantages of waste stabilisation ponds are so overwhelming that, wherever feasible, ponds should be the first choice where sufficient suitable land is available. The high, year-round, ambient temperatures in Sri Lanka and the simplicity of construction, operation, and maintenance of stabilisation ponds make them the preferred wastewater treatment technology.

315. Lessons learned from visits to existing water treatment plants and other installations where mechanical and electrical equipment has been installed indicate that high running costs, lack of maintenance, and metallic corrosion have combined to reduce the operating efficiency and to critically shorten the useful life of these installations. The coastal towns are particularly susceptible to corrosion problems because of the hostile atmospheric environment.

316. The main handicap of waste stabilisation ponds is the large land area that is required. If the decision is taken not to use a pond system because of land constraints, reference to the previous sections indicates that the extended aeration process using an oxidation ditch system is the next preferred alternative. This system needs more operational skills and costs more to run than stabilisation pond systems, but it takes up less land area. It can produce a consistently high quality effluent and the limited sludge produced is stable and does not need further treatment. The process is not as complex as the activated sludge process and it does not require the same level of operational skills.

317. The implementation of any conventional type of treatment process, including oxidation ditches, would have major cost implications, including high annual operating costs. There is also a continuous sludge treatment and disposal problem associated with all conventional treatment methods. It should also be borne in mind that conventional treatment processes are mainly designed to reduce the organic strength and the suspended solids content of a wastewater. They are very inefficient in reducing levels of bacteria and other micro-organisms. Any conventional type of process would need to be followed either by maturation ponds or by some other form of disinfection, such as chlorination.

318. The level of treatment given to the wastewater in each town will be dependent upon its disposal route. The effluent disposal route for each of the towns is discussed in the relevant sections of Annex 3. Detailed consideration has not been given to possible effluent reuse schemes, as these aspects would need a separate detailed study.

Waste Stabilisation Pond (WSP) Design Considerations

319. For all of the Project Towns, the preferred wastewater treatment technology is waste stabilisation ponds. The following paragraphs describe the design philosophy that has been used as a basis for the outline wastewater treatment designs.

4.7.1 Process Design

320. Many different methods have been proposed for the design of waste stabilisation ponds in hot climates, but the most widely accepted approaches have been those that have been developed by G. V. Marais and D. D. Mara. For the purposes of this Project, the methods suggested by Mara for use in India have been used for the preliminary design of pond systems in the Project Towns.

321. Because of their largely domestic nature and the relatively small quantities of the wastewater flows that are to be treated, anaerobic ponds have not been included in the design. This type of pond is more commonly used in situations where large flows of high strength sewage are to be treated. The outline designs have been based upon the provision of primary facultative ponds followed by a series of maturation ponds. The facultative ponds will provide the main process for reduction of the organic BOD, while the maturation ponds will reduce the bacterial concentration. In the future, it will be possible to add anaerobic ponds at a later stage of the development of the towns' sewerage systems to expand the capacity of the ponds to cater for increased wastewater flows.

4.7.2 Design Parameters

A. Facultative Ponds

322. The design of a facultative pond is based upon the allowable organic surface loading that can be carried by the pond before failure (i.e. overloading) occurs.

323. The allowable surface loading is critically dependent upon the ambient temperature and it is common to use the mean minimum temperature in the coldest month for design purposes. From a study of the climate records of the Project Towns, a design temperature of 25°C has been selected as being a suitable value for all of the towns. The adoption of this temperature indicates an allowable organic surface loading of 350 kg BOD/ha/day.

324. The depth of facultative ponds is based upon a compromise of being deep enough to prevent the emergence of weed growth, but without being too deep to allow anaerobic conditions to prevail. They should also be deep enough to allow for a build-up of sludge over a period of years. Depths are usually within 1.2 m and 2.0 m, with a commonly chosen depth of 1.6 metres, resulting in a retention time of 24 days for the proposed organic surface loading criteria.

B. Maturation Ponds

325. BOD is also removed in maturation ponds, but at a much slower rate than in facultative ponds. The primary function of maturation ponds is the reduction of bacterial concentrations, but efficient removal of the eggs of parasitic worms is also achieved. Bacteria are removed by providing a hostile environment that is unsuitable for their survival and helminth ova are removed by sedimentation.

326. The removal of bacteria in maturation ponds follows the laws of first order kinetics in a completely mixed reactor as suggested by Marais. The bacterial reduction in a single pond is given by the equation:

$$Ne = Ni/(1+K_T\theta)$$

Where,
- Ne = number of FC/100ml in the effluent
- Ni = number of FC/100ml in the influent
- K_T = first order rate constant for FC removal, d^{-1}
- θ = retention time, days

327. The rate constant is highly temperature dependent and for a temperature of 25°C it has a value of 6.2 days^{-1}. The usual range of the faecal coliform concentration in raw sewage is 10^7-10^8 faecal coliforms per 100 ml, and a suitable design value is 5×10^7 FC per 100 ml.

328. Maturation ponds are normally constructed as a series of ponds, the size and number of ponds to be provided being governed mainly by the required bacteriological quality of the final effluent. A common design retention time for individual maturations ponds is five days.

329. Using the foregoing design values, the faecal coliform concentration in the effluent from a series of maturation ponds can be calculated and the number of ponds chosen to match the effluent quality requirements.

330. Protozoan cysts and helminth eggs are removed from the wastewater by sedimentation and so retention times are the most important criteria. Most of the helminth eggs are removed in the facultative ponds, with further reduction in maturation ponds. Overall retention times greater than around 20 days are sufficient to remove all helminth ova.

C. Septage Treatment Plant

The design parameters adopted by the SANDEC report for preliminary designs of sludge thickening ponds are used for concept design. The analysis of septage strength and quantities will need to be carried out during detailed design.

Volumetric loading assumed	- 2	l/cap/day
BOD of septage	- 1500	mg/l
Dying bed area	- 0.05	m2/cap
Sludge Thickener area	- 0.006	m2/cap
Depth of thickening tank is	- 2.8	m

4.7.3 Treatment Efficiency

331. The efficiency of treatment provided by a system of stabilisation ponds is generally judged on the degree of BOD and FC reduction that is achieved. Because much of the BOD in the final effluent from stabilisation ponds is associated with the presence of algae, it is important to distinguish between "organic" BOD and "algal" BOD. It is now widely accepted (including in the European Union) that the BOD of a pond effluent should be measured on samples from which the algae has been filtered out. On the basis of filtered samples, a BOD removal of 90% can usually be achieved in facultative ponds at temperatures above 20°C, with a further 25% removal in each subsequent maturation pond.

332. Using the design parameters suggested in the previous section, the following treatment efficiencies can be achieved:

	BOD		Faecal Coliforms	
	mg/l	**% Removal**	**FC/ 100 ml**	**% Removal**
Raw Wastewater	521	-	$5x10^7$	-
Final Effluent from:				
Facultative Pond + 1 Maturation Pond	39	92.5%	10,498	99.979%
Facultative Pond + 2 Maturation Ponds	29	94.4%	328	99.9993%
Facultative Pond + 3 Maturation Ponds	22	95.8%	10	99.9999%

333. The provision of a facultative pond followed by three maturation ponds in series can achieve a very high degree of treatment in terms of BOD, faecal coliform and helminth egg removal. The effluent will comply with the proposed revised National Environmental Regulations. This standard of effluent is suitable for all disposal routes that can be considered for the Project Towns, including discharge to tidal lagoons and for agricultural irrigation purposes.

4.7.4 Physical Considerations

334. The layout of the proposed pond systems will comprise two facultative ponds operating in parallel followed by three maturation ponds in series. In small ponds, shape is not critical, but it is normal for all ponds to be rectangular in shape with length to breadth ratios of 2 or 3:1.

335. The construction of the ponds mainly comprises simple earthmoving. Earth embankments are provided to retain the wastewater in the ponds and connections between ponds are provided to allow gravity flow through subsequent ponds in the system. Connections between ponds can be simple pipe connections through the embankments, although properly designed concrete structures are preferred.

336. Embankment slopes can be designed according to established principles of soil mechanics, but slopes of 1:2.5 can be readily achieved with most soils. In large pond systems, vehicle access to all parts of the embankments necessitates an embankment top width of 3.0 m, but this is not necessary in small ponds and a top width of 2.0 m is acceptable.

337. If no suitable soil is available locally for the construction of embankments, it might be necessary to include a sealing layer of impermeable clay material on the pond bases and in the embankments for the control of seepage. It is not thought that special seepage prevention measures will be needed at Chilaw, Puttalam, or Vavuniya, but provision has been allowed in the cost estimates for an impermeable clay layer. To protect the inner embankment slopes from the erosive effects of wave action, and to discourage the breeding of mosquitoes, it is normal to line the slopes with concrete slabs. These are required on all ponds. The need for drainage works to protect the outer embankment slopes will need to be assessed at a later stage once the pond layout has been properly designed. Meantime, an allowance has been included in the cost estimates for erosion protection of the outer embankments.

338. Over a period of years, sludge will accumulate on the base of the facultative ponds and the ponds will need to be taken out of service and desludged when the depth of sludge reaches about half of the water depth. This is usually done by providing the required facultative pond area in two parallel ponds so that one can be kept in service while the other is being cleaned. Although desludging of the facultative ponds will only need to be done at around twenty year intervals, provision will be made to allow each of the facultative ponds to be by-passed and taken out of service at any time. If, for any reason, grit removal is not effective prior to the wastewater entering the pond system, there will be a build-up of sediment around the inlet to the facultative ponds, which will require them to be cleaned out at more frequent intervals than twenty years.

4.7.5 Ancillaries

339. Apart from the system of ponds, many other ancillary components need to be provided for the treatment plant to operate effectively.

A. Preliminary Treatment

340. Although it has been proposed that screens and grit removal equipment be installed at all pumping stations for the protection of the pumps, these facilities will not remove all of the debris from the wastewater flow. Unless screening and grit removal facilities are provided at entry to the treatment plant, floating debris will build up on the surface of the facultative ponds and grit will quickly accumulate in the base of the ponds with damaging consequences.

341. It is intended to provide screens and grit removal facilities at an inlet works at each treatment plant. Until the wastewater flow at a treatment works reaches about 10,000 m^3/day, the removal of screenings and grit in an inlet works can readily be done manually. The design flow at all of the project towns is well below this threshold value and so it is recommended that manually operated facilities should be installed at the new treatment plants. The inlet works will also include a flow measuring device to measure the incoming sewage flow and a V-notch will be installed at the exit of the final maturation pond to allow

manual measurement of the flow of final effluent. These measurements will be invaluable for process monitoring purposes and for estimating future expansion requirements.

B. Septage Discharge Point

342. A dedicated discharge point will be provided adjacent to the inlet works so that gully bowsers can discharge their loads of septage directly into the wastewater flow for treatment in the pond system. The discharge point will be located upstream of the screening, grit removal, and flow measurement facilities.

C. Office and Laboratory Block

343. An office will be needed for the plant supervisor and facilities for washing, toilet, and messing will be needed for the plant staff. As the numbers of operating staff based at the plants will be small, only basic facilities will be provided.

344. For pond monitoring purposes, samples of the raw sewage and of the pond effluents will need to be analysed in a laboratory. NDWSB has no facilities in any of the Project Towns for the analysis of wastewater. It might be possible to provide additional laboratory accommodation at the water treatment plants and have the NWSDB Chemist carry out the wastewater analyses, but this is a decision that needs to be taken by NWSDB at a later date. Meantime, provision will be included in the cost estimates for a small laboratory and associated equipment at each plant.

C. Maintenance Depot

345. Operation and maintenance of the treatment plants, sewerage systems and pumping stations will be the responsibility of NWSDB. Although there might be available space at the NWSDB water treatment plants to accommodate sanitation maintenance staff, it is recommended at this stage that, like the laboratory facilities, the water and sanitation maintenance facilities are kept separate. It is proposed to provide a small maintenance depot at the wastewater treatment plants from where the sanitation maintenance staff can operate. This will include the treatment plant, sewerage system and pumping station maintenance staff.

346. It is intended to provide a depot to accommodate the maintenance staff, a workshop, a tool room, a storeroom, and a garage. Costs for these facilities will be included in the cost estimates for the treatment plant for each Project Town.

D. Power and Lighting:

347. An allowance has been made in the cost estimates for a power supply to be taken to the site of treatment plants where none already exists. Because it is not proposed to install mechanical and electrical equipment at the plants, the power supply will only be needed for lighting and for small hand tools.

E. Fencing

348. A perimeter fence with a gate for vehicle access and a security shelter will be provided around the entire site to prevent access to the ponds by livestock or members of the public. Signs will be erected to inform the public that the water being treated is wastewater.

4.7.6 Operation & Maintenance

349. The operation and maintenance of waste stabilisation ponds is very simple. It is not intended to provide mechanical screening or grit removal facilities at the inlet works and the process is not reliant on any M&E equipment. The treatment processes are entirely natural

and cannot be influenced by operating procedures, so the operational requirements are not sophisticated and the work can be carried out by unskilled labour.

350. Almost all of the day-to-day operations are concerned with the inlet works in the form of removing rags, plastic bags, and suchlike from the screens and removing grit from the grit channels. The volume of screenings and grit will be small and it is intended that they are disposed of by burial on site at the end of each day. Supervision of the emptying of gully bowsers at the sludge discharge bay will also be needed.

351. Routine maintenance of the ponds comprises only the cutting of vegetation on the embankment slopes and keeping the surface of the facultative ponds free from floating scum. These routine tasks are very straightforward and can be carried out by unskilled labour using simple hand tools, but they must be done regularly. Routine maintenance tasks are as follows:

(i) removal of screenings and grit from the inlet works,
(ii) cutting the grass on the embankments and removing it so that it does not fall into the pond. This is necessary to prevent the formation of mosquito-breeding habitats,
(iii) removal of floating scum and floating macrophytes from the surface of the ponds. This is required to maximize photosynthesis and surface re-aeration and prevent fly and mosquito breeding,
(iv) removal of any accumulated solids in the inlets and outlets;
(v) repair of any damage to the embankments caused by rodents, or other animals.

352. The only major maintenance task that is normally needed on a pond system is the removal of sludge from the facultative ponds. This is unlikely to be needed more that once in twenty years. One of the facultative ponds is taken out of operation, the supernatant liquor is pumped into the adjacent pond, and the sludge is allowed to dry out in situ. After the sludge has dried, it can be removed from the pond manually or by machine. Because of the long retention in the ponds, the sludge is stable and odourless and needs no further treatment. It can be disposed of safely to coconut plantations.

353. If the inlet works does not operate properly, then there is a danger that grit will be carried into the facultative ponds and cause a build-up of sediment adjacent to the inlet pipework. This will need to be removed periodically and can be done in the same way as for sludge removal.

354. Monitoring of the performance of ponds is necessary to ensure compliance with effluent standards and also to provide information that can be used for future expansion of the pond system. Only basic parameters need be measured, such as temperature, pH, BOD, and SS. Ion small works, sampling and analysis can be done on a weekly basis.

355. The levels of staffing need for operating and maintaining stabilization pond systems reflect the simplicity of the O&M requirements. A pond system of the size envisaged in the Project Towns can efficiently be run with a minimum of staff. An indication of the staff requirement for a stabilization ponds system is:

Engineer:	1 (part-time)
Foreman:	1
Unskilled and skilled labourers:	4
Biochemist:	1 (part-time)
Security:	4

356. The O&M staff requited for the septage treatment faculty proposed is-

Forman	1
Skilled labourers	1

Unskilled labourers	2
Security	1

357. Generally the O&M cost of septage treatment plant is 32% of that of stabilization ponds.

4.7.7 Summary of WSP Design Parameters

DESIGN PARAMETER	UNIT	VALUE
General:		
Raw Sewage BOD, Li	mg/l	521
Bacterial concentration of raw sewage	FC/100ml	$5x10^7$
Design Temperature	°C	25
First Order Rate Constant for FC Removal	Days-1	6.2
Embankment sideslopes	1 in 2.5	
Embankment width	metres	2.0
Freeboard allowance	metres	1
Facultative Ponds:		
Organic Surface Loading, s	kg/ha/day	350
Depth of Facultative Ponds	metres	1.6
Retention time in Facultative Pond	Days	24
Maturation Ponds:		
Depth of Maturation Ponds	metres	1.2
Retention in each Maturation Pond	days	5

Oxidation Ditch (OD) Design Considerations

4.8.1 Process Design and Physical Considerations

358. The Oxidation Ditch process is a version of the activated sludge process in which the wastewater is subjected to an extended period of aeration. Primary sedimentation tanks are not required, but screening and grit removal of the raw wastewater should be included to avoid difficulties with the clogging of pipework and pumps. A final sedimentation tank is needed for the mixed liquor that comes from the aeration ditch to separate out the sludge. The clarified effluent from the sedimentation tank is the treated effluent from the ditch system. Because little bacterial reduction takes place in the aeration process, the effluent usually required tertiary treatment for disinfection before final disposal.

359. The ditch is constructed in the form of an endless channel fitted with mechanical aerators. The usual shape of the ditch is oval in plan with a rectangular shaped cross-section. It is normal to construct the ditch in reinforced concrete, but simpler, less expensive options can be considered to suit local conditions. The standard width of channel is 2.0 to 6.0 m and the usual water depth is 1.0 to 3.0 m. It is common to provide two channels to allow maintenance to be carried out, but the volume of the anticipated 2030 flows from the proposed sewered areas in the Project Towns do not warrant twin channels. It is intended to provide the required retention volume in a single ditch channel.

360. The aerators provide the necessary oxygen for treatment, mix the activated sludge with the incoming raw wastewater, and impart a flow velocity to the mixed liquor. The flow velocity is sufficient to retain the solids in suspension in the ditch. The usual type of aerators are brush rotors fitted on a horizontal axis.

361. The final sedimentation tank is normally a circular, radial-flow tank constructed in reinforced concrete. The tank is fitted with rotating scrapers to guide the settled sludge into a central hopper for removal from the tank by hydrostatic head. Part of the sludge that is withdrawn from the sedimentation tank is returned to the aeration ditch as activated sludge, while the excess sludge disposed of.

362. The extended length of aeration in the ditch provides effective oxidation of the organic matter and results in a stable sludge that needs no further treatment. It can be discharged directly to drying beds for air drying without fear of nuisance. However, it is normal to thicken the sludge in a thickening tank before discharging it to drying beds. The thickening process reduces the volume of the sludge that has to be dried and, hence, reduces the area of drying beds that are needed.

4.8.2 Design Parameters

363. The design parameters that are used for the design of an aeration ditch system are usually given as a range of values. The actual value of the parameter that is used for design is dependent upon local conditions and on the quality of treatment that is required. Ranges of common values for the most relevant design parameters are shown on the following table.

Parameter	Unit	Range
Sludge Loading (F:M) Factor	kgBOD/kgMLSS	0.05 – 0.15
MLSS	mg/l	2,000 – 5,000
Recycle Ratio		0.75 – 1.50
Retention at ADWF	Hours	24 – 48
BOD Removal	%	90 – 95
Sludge Age	Days	12 – 20
Sludge production	kgDS/kgBOD/d	0.7 – 0.8
Oxygen Requirement	kgO2/kgBOD/d	1.8 – 2.2

4.8.3 Treatment Efficiency

364. An oxidation ditch system could provide an effluent that can reliably comply with almost all of the limits in the proposed revised National Environmental Regulations. The most significant exception is the faecal coliform (FC) standard. Because conventional treatment plants are not designed for the reduction or removal of micro-organisms, the efficiency of the removal of faecal coliforms in an oxidation ditch system is very poor.

365. In order to comply with the FC criteria in the proposed CEA Regulations, the effluent from an oxidation ditch would need to be given tertiary treatment in the form of disinfection. Disinfection is the process of the reduction of pathogens of concern to humans and animals to acceptable levels of risks of transmission of diseases. The disinfection methods that are generally considered for use consist of chemical methods (chlorine, chlorine dioxide and ozone), physical methods (UV irradiation and membrane micro-filtration), and biological methods (ponds).

366. In relation to specific disinfection methods a number of conclusions have been reached through research studies. Briefly, the effectiveness of chlorine for the inactivation of viruses, helminths and protozoa is lower than for bacteria and depends to a large extent on having the appropriate conditions, viz. optimum pH, adequate chlorine contact time, and low levels of ammonia and suspended solids. Ultraviolet irradiation is effective for disinfection of bacteria and viruses, but has yet to be fully assessed for inactivation of protozoa and helminths. Maturation ponds with 3 - 4 ponds in series, giving an overall retention time of at least twenty days, will not entirely eradicate faecal coliforms, but will reduce their numbers to acceptable levels. Ponds will also reduce helminth eggs and protozoal cysts to undetectable levels.

367. Where there is insufficient land available for the construction of maturation ponds, the most commonly used disinfection method is chlorination.

4.8.4 Ancillaries

368. The ancillary components need to be provided for an oxidation ditch system to operate effectively are similar to those that are needed for any other treatment technology, including those previously described for waste stabilisation ponds. Reference should be made to Section 4.7: Waste Stabilisation Pond Design Considerations for a more complete description of the required ancillary components.

A. Preliminary Treatment:

369. Screening, grit removal, and flow measurement are all necessary at the inlet to all treatment technologies. The components needed for a ditch system are similar to those needed for a pond system, but the proper functioning of the facilities is much more important in an oxidation ditch system than in a system of waste stabilisation ponds because of the greater dangers of pipework blockages and pump damage in a treatment plant with mechanical equipment.

B. Septage Discharge Point:

370. A dedicated discharge point will be provided adjacent to the inlet works so that gully bowsers can discharge their loads of septage directly into the wastewater flow for treatment in the ditch system. The discharge point will be located upstream of the screening, grit removal, and flow measurement facilities.

C. Office, Laboratory Block and Maintenance Depot:

371. The facilities that are needed for a ditch system will be similar to those described for a pond system, but they will need to be larger and more extensive because of the higher numbers of operation and maintenance staff.

372. The mechanical and electrical components of the ditch system will need constant routine maintenance and the workshop facilities to enable repairs to be carried out will need to be more comprehensive.

373. The monitoring procedures for the mechanical treatment process will also need to be more thorough and wide-ranging for a ditch system than the simple monitoring requirements of a pond system. This will necessitate a larger, comprehensively equipped and staffed laboratory.

D. Power and Lighting:

374. An allowance has been made in the cost estimates for a power supply to be taken to the site of treatment plants where none already exists. Because of the range of mechanical and electrical equipment needed for a ditch plant, a high voltage power supply will be required.

375. If a power failure occurs at an oxidation ditch plant, the process will fail and no treatment will take place. This could result in a serious environmental hazard. It is essential to avoid power failures at a ditch plant and it is normal to provide a supply from two independent sources, if possible. Apart from that, standby electricity generation plant needs to be provided at the plant to be used in the event of a main supply failure.

E. Fencing:

376. A perimeter fence with a gate for vehicle access and a security shelter will be provided around the entire site to prevent access to the ponds by livestock or members of the public. Signs will be erected to inform the public that the water being treated is wastewater.

4.8.5 Operation & Maintenance (O&M)

377. To be able to meet the requirements for the quality of the treated effluent to be discharged into a receiving body of water, such as tank, river, sea, etc., the wastewater treatment plant must be maintained and operated to the optimum degree. The treatment plant can only fulfil its purpose if it is operated properly and regularly maintained by trained personnel. The frequency and the scope of the O&M requirements are dependent upon the type and size of the plant.

378. Oxidation ditches do not need the same high degree of operational and maintenance skills as some of the more complex treatment processes, but they still include mechanical and electrical equipment that needs to be serviced regularly and maintained in good condition. Unlike ponds, the performance of oxidation ditches can be influenced by the operators, i.e. by increasing the aerator depth or speed, by varying the rate of return sludge to the ditch, etc. The operational and maintenance skills needed for an oxidation ditch system are therefore much higher than for a system of ponds.

379. Operation and maintenance, including sludge removal, are usually carried out in accordance with detailed operating manuals and instructions that are provided by the designer or equipment manufacturer. The frequency and scope of routine tasks as well as the necessary servicing needs for all parts of the plant are usually described in the operating manuals. Defects and troubles that are observed must be attended to as soon as they are identified. Daily operation reports must be kept by the staff and any unusual events are to be reported to the management immediately.

380. The regular monitoring requirements of a ditch system are much more comprehensive and several samples and analyses are required on a daily basis. The plant therefore needs a fully equipped wastewater analytical laboratory with skilled staff.

381. Because of the higher level and the extent of the O&M requirements for a ditch system, there is a greater need for a larger number of staff and for employees with a higher level of skills. An indication of the staff requirement for a small oxidation ditch system is:

Superintendent:	1
M&E Technicians:	2
Unskilled labourers:	8
Biochemist:	1
Laboratory Assistant:	1
Security Guards:	6

Sewerage Design Criteria

4.9.1 General

382. The design criteria that have been used in sewer design are consistent with those that have been incorporated into the NWSDB Design Manual D7: Wastewater Treatment that was prepared in 1989 under a USAID Project. These design guidelines are in accordance with good practice and will ensure a sewerage system that will function in accordance with its intended use.

383. The Design Manual was prepared almost twenty years ago and, although most of it is based upon accepted engineering principles and is still relevant, some parameters have been modified to reflect modern thinking. Where the design criteria that have been used for design differ from those proposed in the Design Manual, clarification and justification for the amended parameters are discussed in the following sections.

4.9.2 Per Capita Wastewater Flows

384. Sewage flows from premises are closely linked to the quantity of water supplied. However, due to the water that is used for floor washing, cleaning, evaporation, seepage, wastage, etc., not all of the supplied flow will reach the sewers. The amount of water lost depends upon the characteristics of the housing type, the climate and ground conditions, with higher losses associated with high class housing, arid conditions and high ground porosity. The figure normally varies from 65% to 90% of the water supplied to premises.

385. Such losses and wastage can be minimised, particularly if a vigorous policy is adopted towards water and sewerage cost recovery. Nevertheless, an overall figure of 80% for the sewage contribution factor from all sources is considered appropriate. This factor is used in many other places and it agrees with the recommendation of the Design Manual.

386. The unit flow rates that have been used for preliminary design purposes are based upon a per capita water demand of 120 lcd. This is consistent with the figure used by NWSDB and it represents a per capita wastewater flow of 96 lcd, which is also consistent with that proposed in the Design Manual.

4.9.3 Wastewater Characteristics

387. No industrial processing or manufacturing premises will be served by the sewerage systems in any of the Project Towns, as it is common practice in Sri Lanka for industries to be located in Industrial Estates that are built outside the town boundaries by authorities such as the Sri Lanka Board of Investment (BOI). Those industrial estates have their own dedicated wastewater treatment facilities. The wastewater that will be collected in the new urban sewerage systems will therefore be derived almost entirely from domestic, institutional, and office premises, with some contribution from small scale commercial activities. The composition of the wastewater will therefore not contain any of the toxic chemical wastes that are associated with some industrial processes and it will be easily treated by any of the normal methods of wastewater treatment.

388. Because there are no existing sewers in any of the towns, it is not possible to carry out any programme of sampling and testing to determine the probable characteristics of the wastewater. Instead, it is proposed to use the following values to predict the sewage characteristics:

- Per capita BOD load: 50 g/day
- Per capita suspended solids load: 60 g/day

389. These values are internationally recognised parameters and are consistent with the NWSDB Design Manual. Their use, combined with a per capita wastewater flow of 96 l/day, indicates wastewater characteristics of:

- BOD: 520 mgBOD/l
- SS: 625 mgSS/l

390. In addition, it is proposed to use a value of $5x10^7$ FC/100ml for the concentration of faecal coliforms in the raw wastewater. This a commonly accepted value that is used elsewhere for design purposes, including India. These parameters will be used in the preliminary design of wastewater treatment facilities.

391. The main non-domestic wastewater flows that will be connected to the new sewerage systems will be those from the main hospitals as these have been identified as priority. Hospital wastewaters are often high in organic and bacteriological strengths and they may also contain pharmaceuticals and other chemical constituents. That is the main reason for their priority for inclusion in the sewerage schemes. It is more appropriate to collect these wastewaters and to treat them at a treatment plant than to allow them to be discharged directly to street drains.

392. None of the hospitals in the Project Towns has had any laboratory analyses carried out on their wastewaters. Because of the complexity of the internal hospital drainage systems and the constantly changing nature of the discharges, a valid understanding of the composition of the hospital wastewaters could only be achieved by carrying out an extensive sampling and testing programme over a period of time. Even this would not give a complete representation of the composition, as specialist laboratory expertise would be required to detect certain substances, including endocrine inhibitors.

393. Details of analytical testing that was carried out on samples taken from a number of discharge drains at Batticaloa General Hospital and prison in 2004 during the detailed design stage of the ADB Assisted Secondary Towns & Rural Community Based Water Supply and Sanitation Project are give on the following table:

Parameter	**Unit**	**Sample No.**				
		1	**2**	**3**	**4**	**5**
Temperature	°C	28.1	27.2	27	27.3	-
pH		6.5	6.7	6.5	6.8	6.7
BOD	mg/l	1206	743	537	19	438
COD	mg/l	1740	822	684	97	544
TDS	mg/l	1180	250	494	150	316
TSS	mg/l	1560	370	786	302	506
TS	mg/l	2740	620	1280	452	822
Total Phosphorus	mg/l	13.9	3.3	6.7	4.1	5.8
Organic Phosphorus	mg/l	9.4	2.3	5.0	2.8	3.9
Total Nitrogen	mg/l	283.6	66.7	141.3	36.4	121.7
Organic Nitrogen	mg/l	213.7	47.7	87.6	23.5	82.6
Heavy Metal Content (Hg, Cr, Cd, As, Pb)	Ppb	nil	nil	Nil	32	6

Time of sampling and location	
No. 1	09.45 am at Prison Drain (toilet wastes)
No. 2	10.25 am at General Hospital (Open Drain)
No. 3	10.55 am at General Hospital(Wards 7 & 8 toilet waste)
No. 4	11.17 am at General Hospital (drain from laboratory, kitchen, wards, etc.)
No. 5	Simple Composite Sample of 2, 3 and 4

394. The principal concern with hospital wastewaters is the high level of biological contamination, including pathogens and viruses. This contamination can be readily treated in a system of waste stabilisation ponds, although little is known about the method of virus removal in a pond system. It is common practice to connect hospital wastewaters into public sewerage systems and to treat the combined hospital/domestic wastewaters in a single treatment plant.

395. There is no literature available on the extent to which hospital wastewaters contain endocrine disruptors and toxic constituents and, in any case, every hospital is different. It is not only hospital wastewater that might contain endocrine disruptors, as normal domestic sewage in many countries contains endocrine disruptors that result from the increasing use of oral contraceptives and hormone replacement therapy by women. It is not thought that this is currently a problem in Sri Lanka, but there is no research literature available on the subject. Neither is there any literature available on the ability of treatment processes to assimilate or to remove endocrine disruptors. The concentration of most other constituents, such as heavy metals, is reduced in stabilisation ponds by processes of assimilation and/or adsorption and sedimentation.

4.9.4 Minimum Size of Sewers

396. Sewer blockages can occur in the top ends of sewerage systems where there are only a few houses connected to the sewer and the flow of wastewater is not large enough to produce self-cleansing velocities. They can also occur due to misuse of the sewers by members of the public, usually due to a lack of awareness of what the sewers can accept.

397. Because the topography of the Project Towns is generally flat, sewers will need to be designed with relatively shallow gradients to avoid excessively deep sewers. The DWSM Design Manual recommends a minimum pipe size of 200 mm, but it is considered that the use of 200 mm diameter sewers at shallow gradients could result in problems with the deposition of solids. It is recommended that, to minimise blockages in the sewer reticulation system, the minimum pipe diameter for public sewer reticulation pipes should be taken as 150 mm.

398. Private connections from individual premises are normally 100 mm diameter.

4.9.5 Layout of Sewers, Services & Plot Connections

399. To permit access to sewers for connection and for maintenance, sewers shall be positioned within roadways or public open spaces, wherever possible. In an ideal situation, sewers should be laid at the rear of properties, where drainage connections are easier and where cover to sewers can be reduced. However, particularly in the central core areas of towns, most plots have already been developed and there is no space between buildings for sewer construction. In these situations, sewers will have to be laid within the roads in front of plots. This will minimise disruption to properties, but it will also have its own drawbacks:

- it increases the likelihood of disruption of other existing services, such as street lighting, surface water drains and water pipes, most of which are already located in the road servitude.
- the distance from the wet amenities, which are usually located at the back of the house, will be longer, and this could mean deeper inspection chambers and, hence, sewers.
- connections from plots on the opposite side of the road from the sewer will need to cross the road.

400. During detailed design, the exact location and depth of existing services will need to be surveyed as this will affect the final design.

401. Provision for plots to connect to the sewers will be served by the construction of a brick inspection chamber at a distance of one metre within the plot boundary. The depth of the chamber will be 800 mm. The provision of this chamber, including a cast iron cover, will be included in the sewerage construction contract.

402. The connection from the inspection chamber to the sewer will be made in 100 mm diameter pipes, either directly into a manhole or by a Y-branch. The plot owner is responsible for the provision of internal plumbing and for the connection from this plumbing to the inspection chamber.

403. One of the major risks associated with a newly installed sewerage system is low connection rates. Without an ample flow in the sewers, self-cleansing velocities will not be achieved and solids will settle out on the invert of sewers. These can lead to blockages, which in turn lead to public nuisance, inconvenience, and negative environmental impacts. The frequent clearing of blockages also leads to high maintenance costs.

404. Consumers are usually willing to pay for a connection to the potable water supply system, but often members of the public are less willing to pay for a connection to the sewerage system as they cannot readily perceive the same benefits. The Operator of the sewerage system will need to use a multi-faceted approach to encourage, and to enforce, plot holders within the sewered area to make the connection, otherwise the system will be unsuccessful and the public perception of it will be damaged. This is particularly relevant in Sri Lanka, where, because of the shortage of sewerage systems in the country, the public is generally uninformed.

405. The approach to achieving high connection rates must be a combination of:

- awareness programmes to alert the public of the advantages of being connected to a sewerage system and educating them in the correct usage of the system,
- the provision of some form of monetary subsidy to make the connection charge affordable to plot holders to encourage them to connect,
- the drafting of a suitable by-law that requires that plot holders connect to the sewerage system if it is laid within a certain distance of their plot,
- the inclusion of the plot connection in the construction contract for the main sewerage pipes,

406. As a last resort, the threat of legal action, or the threat of the disconnection of the plot's water supply, can be used as an incentive to connect.

4.9.6 Sewer Design Capacities

407. Sewers are generally designed to carry the peak daily dry weather flow plus some allowance for infiltration and stormwater inflow. Thus,

$$\text{Peak Flow} = Fp \times ADWF + I$$

where, Fp = daily dry weather peak factor
ADWF = average dry weather flow
I = Infiltration and Inflow

408. The daily dry weather peak factor is often taken to be a function of the contributing population and is calculated using standard formulae. The wet weather peak factor is a function of the portion of the design capacity of the sewer pipes that is allowed to carry rainwater flows.

409. The basis of sewer design that is given in the Design Manual is based upon the concept of "separate" sewers, i.e. sewers that are designed to carry only the anticipated dry weather sewage flows with only a nominal allowance in the pipe capacity for infiltration and stormwater inflow. If significant amounts of water from these other sources are allowed into the sewers, then the sewers will be robbed of their carrying capacities and treatment plants of their process performance capabilities. However, a certain amount of water will always manage to enter sewers from other sources and this flow is normally considered as infiltration and inflow.

(i) Infiltration is defined as the water entering a sewer system from the ground through such means as defective pipes, joints, connections, or manholes.

(ii) Inflow is defined as the stormwater discharged into a sewer system from such sources as roofs, yards, manhole covers, cross connections from storm drains, etc.

(iii)

(iv) There have been many methods proposed for estimating peak factors and the allowances that should be made for inflow and infiltration. Many of them are based upon spurious assumptions and the sophistication of others requires advanced computer programmes for their calculation. For the purposes of preliminary design, it is intended to use the following:

- Peak Dry Weather Flows: Sub-Catchment Sewers = 6 x ADWF
  Trunk Sewers = 4 x ADWF

- Infiltration/Inflow Allowance: 30% of Peak Dry Weather Flow

410. In the above definitions, sub-catchment sewers are deemed to be sewers equal to or less than 375 mm in diameter and trunk sewers are those above 375 mm diameter.

411. The infiltration/inflow allowance of 30% has been proposed for two reasons: the lack of experience in Sri Lanka in the laying of sewer pipes, and, more importantly, the difficult ground conditions in some places where the sewer pipes are going to be laid below the water table. Moreover, it is envisaged that, despite the efforts of the operating authority, there will inevitably be illegal stormwater connections to the sewerage system. The allowance can be considered as conservative, but the additional cost of increasing a sewer pipe size by one increment is a minor component of the overall unit cost of laying a sewer, the most significant costs of which are the excavation, bedding, backfilling, and reinstatement.

412. The sewer design capacity derived from the foregoing can be equated to the following table. The additional capacity in the pipe above the daily peak dry weather flows will be utilised to carry infiltration and stormwater inflows.

Percentage of the Full Flow Pipe Capacity to Carry Peak Dry Weather Flow

Pipe Diameter (mm)	Flow Depth	Flow Capacity
Equal to or less than 375 mm	60%	67%
Greater than 375 mm	50%	50%

4.9.7 Sewer Gradients

413. The depth of the on-plot inspection chamber will be 0.8 metres and it has been assumed that the internal plot drain will be laid at a slope of 1:80. Thereafter, the minimum gradients adopted for new sewers will be determined on the basis of a minimum flow velocity of 0.7 m/sec at the peak daily dry weather flows.

414. Because of the possible release of hydrogen sulphide, steeper sewer gradients are preferred to the use of backdrops at manholes.

4.9.8 Depth of Sewers

415. Sewers should be laid at depths that will accommodate not only all existing properties but also any future properties within the area that sewers are designed to serve.

416. Sewer pipes also need to be laid at such depths that will:

- prevent damage to the pipes due to traffic loads.
- not interfere with other below-ground services.
- not interfere with stormwater drains.

417. The minimum cover to sewer pipes should normally be 1.0 m, although this is normally increased to 1.2 m below roads.

4.9.9 Manholes

418. Manholes shall be provided at the head of all sewers or branches, at every change of alignment or gradient, at every junction of two or more sewers, and where there is a change in the size of the sewer. This will allow the sewer alignment to be visually inspected after construction and will also facilitate the cleaning of the sewer.

419. To allow for the unblocking of sewers by hand rodding, smaller diameter sewers will need manholes to be spaced no more than 60 m apart. This spacing can be increased with increasing sewer diameter.

420. The maximum spacing proposed for manholes is shown in the following table.

Maximum Spacing of Manholes

Sewer Diameter (mm)	Maximum Manhole Spacing (m)
150 – 225	60
300 – 450	80
500 – 750	100
1000 – 1500	120

421. Manholes will be constructed from precast concrete manhole rings surrounded by at least 150 mm of in situ concrete to make them watertight or from cast in situ concrete. If rings are used, the jointing materials must be specified carefully to ensure watertightness

4.9.10 Pumps and Pumping Stations

422. As the flow of sewage in sewers is by gravity, sewers should naturally follow the natural slope of the ground for the most economic layout. In areas where the ground slopes are flatter than the minimum gradients required for the sewage flows, pumping stations are needed to avoid very deep sewers that are expensive to construct.

423. The three main types of pumping station are:

- Submersible Pumping Stations: allow a reduction in the cost of the station because of the simplicity of their construction. They only require a wet well into which the submersible pumps are installed and, for small flows, they can be installed in a large modified manhole. They have significant O&M advantages if a sufficient stock of spares is maintained as it is easy to replace a failed pump/motor unit with a spare and remove it to a central maintenance workshop for repair. Many wastewater operators prefer submersible pumps as there is less need for on-site maintenance.

- Wet Well/Dry Well Pumping Stations: are generally more expensive to construct than submersible stations because they include a wet well in which the wastewater is collected and a dry well in which the pumps are installed. The construction requirements are much greater and they are usually used for pumping larger flows.

- Screw Pump Stations: are designed for use with Archimedean screw pumps that can handle varying flows and that have low power requirements. They are often used for lifting wastewater into a treatment plant downstream of conventionally pumped flows to even out the flow into the works.

424. The size of the pump will normally influence whether submersible or dry well pumps are selected. In general, submersible pumps should be considered for flows of up to 100 l/sec and heads of up to 15-20 m. Above these flows and heads, dry well pumps should normally be selected. There are exceptions, and submersible pumps are available with duty flows of up to 2,000 l/sec and heads of up to 40 m.

425. The anticipated wastewater flows in all of the Project Towns is small and, at this stage, it is proposed that all pumping stations should be of the submersible type. The cost estimates have been based upon this assumption, although the design can be changed during detailed design.

426. Both submersible and dry well sewage pumps are designed to handle solids. Normally the ability to pass 75 mm diameter solids is specified. This effectively limits the size of non-clog pumps to larger than 100 mm, as pumps smaller than this cannot pass 75 mm diameter solids. The solids vary in character and size and these solids and foreign materials can block and/or damage pumps. The question arises as to whether to provide protection to the pump in the form of screens and grit removal equipment, which will require on-going maintenance, or to suffer occasional blockages or damage to the pumps.

427. In Sri Lanka, it has been general practice to install screens and grit removal facilities in sewage pumping stations, even although it is reported that most of the equipment falls into disrepair after a short time. The cost estimates for pumping stations include allowances for the provision of such equipment at the stations in the Project Towns. It is recommended that detailed design of the stations should focus on best design practice to prevent grit accumulating or rags balling and that the provision of screens and grit removal facilities should be reviewed at that time. Consideration should be given to providing water jets to lift grit into suspension so that it can be pumped away with the sewage.

428. Because power supplies in the project towns are not reliable, it is intended to install standby power generation equipment at every pumping station to provide security of operation. In the event that both the power supply and the generator fail, or that all pumps fail, the pumping stations sites will be chosen so that any negative environmental impact due to overflowing wastewater is minimised.

4.9.11 Hydraulic Analysis

A. Gravity Sewers:

429. All the proposed sewer pipes are circular in shape and the preliminary sizing of sewers in Sri Lanka is normally carried out using Manning's hydraulic flow formula.

430. The Manning Coefficient applicable for hydraulic analysis is given in the following table:

Pipe material and inside finish	Manning's "n" [FF]	Manning's "n" [1/2FF]
Concrete pipe smooth finish	0.015	1.22 x 0.015
DI pipe with inside lining	0.014	1.22 x 0.014
VC, PVC and HDPE pipes	0.013	1.22 x 0.013

431. The use of these factors gives hydraulic gradients that compatible with those proposed in the NWSDB Design Manual

B. Pumped Flows:

432. In Sri Lanka, the Hazen William's formula is applied for sizing of pumping or forced sewers. The friction coefficient C adopted for preliminary designs of HDPE pipe lines is 120.

433. Head loss coefficient criteria are adopted for determination of minor losses in pipe fittings and specials. The flow velocity in reticulation sewers and pumping mains shall also be limited to following:

Minimum velocity	= 0.75m/sc
Maximum velocity	= 4m/sc

C. Bedding factor:

434. All sewers shall be bedded with granular materials and the depth and type of bedding shall be in accordance with bedding factors calculated using recommended strength of pipe.

Pipe materials

4.10.1 Available Materials and their Suitability

435. Pipes that are used for sewers are manufactured from a large number of materials, each with its own characteristics. In Sri Lanka, very few sewers have been laid and there isn't yet a consensus on the most suitable material.

436. The only sewer pipe materials that are manufactured in Sri Lanka at present are uPVC. Much of Colombo's original sewerage system was built with concrete pipes, but with cement mortar spigot and socket joints. At the time, rubber ring joints were not available. Recent sewer construction has been done with VC and ductile iron pipes.

437. There has been insufficient continual sewer construction in Sri Lanka to justify local industries investing in modern pipe making equipment to produce pipes to international specifications. The quality of the locally made clay and concrete pipes is reported to be variable and they are most often used in surface water drainage systems.

438. The following pipes would need to be imported:

- lined concrete pipes
- steel pipes
- ductile iron pipes
- vitrified clay pipes
- GRP pipes
- HDPE pipes

439. In considering the most appropriate pipe material for use in sewer construction, the following factors have to be considered:

- flow characteristics,
- availability of sizes and fittings,
- cost of materials and ease of installation,
- effectiveness of joints,
- durability - life expectancy,
- durability - resistance to chemical and biological attack,
- strength

440. No single material will meet all the conditions that may be encountered in sewerage

systems. Selection should be made for the particular application and different materials may be selected for different sections of a single project. However, the use of one pipe material for most of the system has the advantage for an operating authority of standardising the pipe material, so that only a limited range of pipe sizes and fittings needs to be kept in stock for maintenance purposes. The cost of the pipes is usually a small factor, particularly for smaller sewers; the differences in cost among the various pipe materials being a small fraction of the total project outlay.

441. The following paragraphs discuss briefly the common materials that are used for sewer construction.

4.10.2 Brickwork

442. Brickwork was often used in the past for the construction of sewers, particularly for large diameters. Many old brick sewers still exist in European cities and in some Indian cities, such as Kolkata and Mumbai. The main advantage of brick sewers is that they could be constructed to any required shape and size. Failures are mainly due to the disintegration of the bricks or the mortar joints. Because of the comparatively higher cost, larger space requirement, slower progress of the work and other factors, brick is now used for sewer construction only in special cases.

4.10.3 Concrete

443. The advantages of concrete pipes are the relative ease with which the required strength may be provided, the wide range of pipe sizes available, and the rapidity with which the trench may be opened and backfilled.

444. Disadvantages of concrete pipes include:

- the limitations on the availability and range of fittings
- the risk of corrosion following hydrogen sulphide formation in sewers.
- the need for good quality control and supervision over manufacture and jointing.

445. Concrete sewer pipes are not manufactured locally in Sri Lanka and they would have to be imported.

446. Reinforced concrete pipes can be manufactured to any reasonable strength requirement by varying the wall thickness, the percentage of reinforcement, and shape of the reinforcing cage. In theory, good quality control at the factory combined with rigorous acceptance testing on site should ensure that the pipes meet any required specifications. To prevent corrosion due to hostile industrial effluents or sulphide attack, concrete pipes can be manufactured with built-in corrosion protection, such as sulphate resistant cement, synthetic linings, and sacrificial wall thicknesses.

447. It is recommended that, due to the high ambient temperatures in Sri Lanka and the risks of sulphate corrosion, the specification for any concrete pipes used for sewerage should include corrosion protection.

4.10.4 Vitrified Clay (VC)

448. Stoneware pipes can be manufactured in sizes from 50mm to 600 mm, but sizes are usually not greater than 400mm diameter due to economic considerations. Pipes up to 2000mm diameter have been used in the Middle East in view of the need for high corrosion resistance.

449. Vitrified clay pipes are brittle rigid pipes that are susceptible to breakages during transport and handling. They are durable, but they are expensive and good quality high

strength pipes would need to be imported. The resistance of vitrified clay pipes to corrosion from most acids and to erosion due to grit and high velocities gives it the advantage over most other pipe materials in handling those wastes which contain high acid concentration. Modern high strength pipes are particularly reliable for sewerage systems though in poor ground conditions, they may require special bedding or concrete cradling to improve field support strength. This of course applies to all sewer pipes, except possibly DI.

450. The use of VC pipes as sewers is less common that it used to be, with the advent of HDPE and other corrosion resistant materials.

4.10.5 Iron and steel

451. Cast iron pipes have a range of sizes and use a variety of jointing methods depending on their intended use. Iron and steel pipes are used for pressure pipes, elevated pipelines, submerged outfalls, piping in wastewater treatment plants and, occasionally, on gravity sewers where water tightness is vital and absolutely watertight joints are essential. They are usually provided with an internal lining, such as an epoxy coating.

452. The advantages of ductile iron pipes are their long laying lengths with tight joints, ability to withstand relatively high internal pressures and external loads, and corrosion resistance in most natural soils.

453. In general, iron and steel pipes are often found to be too expensive to be considered for normal sewer runs. Exceptions include:

- lengths of sewers with shallow cover
- rising mains
- elevated sewers

4.10.6 uPVC Pipes

454. The use of uPVC for wastewater or sewage pipes is now common for small diameter applications such as house connections. Generally plastic pipes are advantageous in cases where wastewater with potential corrosion problems needs to be transported or where sulphate corrosion is a potential problem.

455. Some of the plastic pipe advantages are:

- resistance to corrosion,
- excellent flow characteristics resulting in flatter gradients and economy of excavation,
- light weight,
- longer lengths, and
- faster laying.

456. Some of the disadvantages of plastic pipes are the reduction of strength with increasing temperature, stress cracking and ductile failure. uPVC is particularly prone to bending when left exposed to heat and incorrectly stored. This makes it very difficult to lay to an accurate line and level in gravity sewerage systems.

457. uPVC pipes are manufactured in Sri Lanka in sizes from 63 mm to 280 mm inclusive. Larger sizes have to be imported. The pipes are delivered in 4m or 6 m lengths and are jointed using solvent in the smaller sizes and rubber gaskets for diameters above 90 mm.

458. uPVC is an inert material, and is suitable for carrying many corrosive effluents and for laying in aggressive ground conditions. However, they are susceptible to poor workmanship, when longitudinal warping, cross-sectional distortion and cracking have been experienced.

Many of these factors are exacerbated by thin walled sewer pipes and the use of Class B (6 bar) pressure pipes with rubber gaskets for all sewers is recommended, rather than sewer class (4 bar) pipework. Careful attention is needed with uPVC during installation and to pipe stacking, handling, trench bedding and backfilling.

459. It is normally advisable to use an alternative material for gravity sewers if one is readily available.

4.10.7 Asbestos Cement (AC) Pipes

460. Because of the health risks that have been associated with asbestos materials, many countries and funding agencies, including the ADB and those of the European Union, have ruled out the use of asbestos cement pipes in development projects on principles of health and safety.

4.10.8 High Density Polyethylene (HDPE) Pipes

461. These pipes are not manufactured in Sri Lanka and would have to be imported.

462. They are normally manufactured in diameters up to about 700 mm. The smaller diameters, which are suitable for water supplies, are supplied in coils 12 to 50 m long while the larger diameters are supplied in 8 m to 12 m lengths. After laying, the smaller diameter pipes tend to try to recover their original coil shape and it is difficult to avoid local high and low spots on the pipeline.

463. Reinforced HDPE pipes are now readily available in many countries and they are less prone to bending or heat damage than uPVC. They are provided with push fit rubber ring joints and are easy to lay. They are widely used in sewerage systems in hot climates such as prevailing in Iran and the Middle East, though some sewerage authorities are still reluctant to use them.

4.10.9 Glass Reinforced Plastic (GRP) Pipes

464. These pipes are not locally manufactured and would have to be imported

465. They have good flow characteristics, are durable, and are resistant to corrosion but, because of the nature of the material, they are flexible and care needs to be taken in their laying. They have been not been used for sewers in Sri Lanka and so their laying techniques are not known locally. It is unlikely that these would be economic in Sri Lanka.

4.10.10 Recommended Pipe materials

466. For the construction of sewers and rising mains, it is recommended that the following pipes be used:

- For small diameter gravity sewers which are the subject of this project, vitrified clay (VC) with rubber ring joints, HDPE pipes with soldered or rubber ring joints, or lined ductile iron (DI) pipes with rubber ring joints where high structural strength is required (e.g. railway crossings).
- For wastewater pumping mains, HDPE pipes, either 6 Bar or 10 Bar depending upon the situation, or DI pipes.
- For exposed sewers, shallow sewers and elevated sewers, imported steel or ductile iron pipes depending upon cost considerations.

467. Alternative materials that might be proposed by contractors may be approved, subject to evaluation and justification.

Appendix 1 of Annex 1

Pour Flush Latrine (PFL) Toilet – Unit Costing

APPENDIX 1 **Tentative Estimate for a Pourflush Toilet (Rural Sanitation)**

				Project comp.		Comm. comp.	
Item	**Descrition**	**Unit**	**Qty**	**Rate**	**Amount**	**Rate**	**Amount**
	Earth Wok						
1	Excavation in foundation	m3	0.5	8.50	4.25	209.50	104.75
2	Excavation in pits	m3	2.5	16.00	40.00	382.00	955.00
3	Earth work support	m2	8	540.00	4,320.00	160.00	1,280.00
4	Dry earth filling with available matterial	m3	0.35		-	250.00	87.50
	Concrete work						
5	Grade 15 - 75mm thick mass concrete	m2	1.5	556.00	834.00	34.00	51.00
6	Grade 20 - 100mm thick concrete in cover slab	m3	0.15	7,738.00	1,160.70	340.00	51.00
	Reinfocement						
7	10mm dia tor steel	kg	13	93.73	1,218.49	17.71	230.23
	Masonry work						
8	300mm thick Rubble work	m2	2.8	1,042.00	2,917.60	544.00	1,523.20
9	100mm thick Block work in wall	m2	8	486.00	3,888.00	100.00	800.00
10	115m thick perforated brick work	m2	8	327.00	2,616.00	171.00	1,368.00
	Finishing work						
11	External plsatering	m2	8		-	242.00	1,936.00
12	Internal platering	m2	8		-	299.00	2,392.00
13	Rendering	m2	1.1		-	232.00	255.20
	Doors & Windows						
14	Door (1650x600mm)	nr	1	-	-	3,700.00	3,700.00
	Roof work						
15	Asbestos sheet roofing with frame work	m2	4	-	-	470.00	1,880.00
	Miscellaneous						
16	Plumbing(110mm dia PVC)	m	2	301.00	602.00	266.50	533.00
17	Squating pan	nr	1	860.00	860.00	150.00	150.00
18	Vent Pipe (32mm dia PVC), 2.5m approx	nr	1	124.74	124.74	30.00	30.00
					18,585.78		**17,326.88**

PC 51.75 % **CC** 48.25 %

Estimate based on 2007 NWSDB Rate and Over head & profit not considered.

Total cost 35,912.66

Say total estimated cost is Rs. 35,915

Appendix 2 of Annex 1

National Environmental (Protection and Quality) Regulations, No. 1 of 1990

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இலங்கைச் சனநாயக சோசலிசக் குடியரசு வர்த்தமானப் பத்திரிகை
The Gazette of the Democratic Socialist Republic of Sri Lanka

අති විශෙෂ அதி விசேஷமானது EXTRAORDINARY

අංක 595/16 – 1990 පෙබරවාරි 02 වැනි සිකුරාදා – 1990. 02. 02.
595/16 ஆம் இலக்கம் – 1990 ஆம் ஆண்டு பெப்புருவரி மாதம் 02 ஆந் திகதி வெள்ளிக்கிழமை
No. 595/16 – FRIDAY, FEBRUARY 02, 1990

(ආණ්ඩුවේ බලය පිට ප්‍රසිද්ධ කරන ලදී.)

PART I : SECTION (I) – GENERAL

Government Notification

NATIONAL ENVIRONMENTAL ACT, No. 47 OF 1980

REGULATIONS made by the President under section 32 of the National Environmental Act, No. 47 of 1980, as amended by Act No 56 of 1988, read with Article 44(2) of the Constitution.

R. PREMADASA,
President.

Colombo, 08.01.1990

Regulations

1. These regulations may be cited as the National Environmental (Protection & Quality) Regulations, No. 1 of 1990.

2. No person shall, on or after the relevant date discharge, deposit or emit waste into the environment which will cause pollution, or cause noise pollution, except:

(a) under the authority of a licence issued by the Central Environmental Authority (hereinafter referred to as "the Authority"); and

(b) in accordance with the standards and criteria specified in Schedule I hereto:

Provided that, where a licensee who does not conform to the standards or criteria specified herein, is at the discretion of the Authority, directed to implement a programme of action within a specified period, so as to conform to the aforesaid standards and criteria and to observe certain conditions during such period such licensee shall, so long as he observes such conditions, be deemded to comply with the preceding provisions of this regulation.

3. Notwithstanding anything contained in regulation 2, the Authority may, by a direction issued under regulation 13, impose more stringent standards and criteria than those specified in Schedule I hereto in respect of any particular industry, operation or process, having regard to the need to protect the receiving environment.

4. Where an activity in respect of which an application for a licence is made is not covered by the standards and criteria specified in Schedule I hereto, the Authority will decide on such application on its merits and the applicant shall comply with all such directions as may be issued to him by the Authority for the protection of the environment.

5. The licence issued under these regulations shall be known as the "Environmental Protection Licence" (hereinafter referred to as "the licence").

6. (1) *An application for the licence shall be made :-*

(*a*) separately, in respect of each premises at which the acts authorized by the licence are carried out;

(*b*) Substantially in Form A in Schedule II hereto ;

(*c*) accompanied by a receipt for the payment of the fee specified in Schedule III hereto;

(*d*) at least 30 days prior to the relevant date or to the date on which the applicant is required to have the licence, whichever is earlier.

(2) For the purpose of these regulations "premises" means the totality of buildings and installations used separately or in combination to carry out the acts authorized by the licence.

(3) Every applicant shall furnish all such particulars as may be required to be stated in the aforesaid Form A and any other information that may be called for by the Authority for the purpose of deciding on the application.

7. *Every licence issued by the Authority shall be :-*

(*a*) in Form B in Schedule II hereto;

(*b*) valid for a period of one year, subject to any suspension or cancellation of the licence under section 23D of the Act; and

(*c*) renewable.

8. *The Authority shall issue the licence only if it is satisfied that:-*

(*a*) the licence will not be used to contravene the provisions of the Act or these regulations;

(*b*) no irreversible damage or hazard to man and environment or any nuisance will result from the acts authorized by the licence;

(*c*) the applicant has taken adequate steps for the protection of the environment in accordance with the requirements of the Law.

9. (1) *An application for a renewal of a licence shall be made:-*

(*a*) at least one month before the date of expiry of the licence or one month before effecting any changes, alterations, or extensions to the premises at which the acts authorized by the licence are carried out, as the case may be ;

(*b*) substantially in Form C in Schedule II hereto;

(*c*) accompanied by a receipt for the payment of the fee for the renewal of licence specified in Schedule III hereto.

(2) Every applicant for a renewal of the licence shall furnish all such particulars as may be required to be stated in the aforesaid Form C and any other information that may be called for by the Authority for the purpose of deciding on the application.

The Authority may, before issuing an order suspending or cancelling a licence under section 23D of the Act give the holder of the licence an opportunity to show cause why such order should not be issued:

Provided that, where, since the issue of the licence, the receiving environment has been altered or changed due to natural factors or otherwise or where continued discharge, deposition or emission of waste into the environment under the licence will or could affect any beneficial use adversely, the Authority shall forthwith issue an order suspending the licence for a period to be specified in the order or cancel such licence.

(1) Any applicant for a licence who is aggrieved by the refusal of the Authority to grant a licence, or, any holder of a licence who is aggrieved by the suspension or cancellation of a licence or the refusal to renew a licence may, within thirty days after the date of notification of such decision to him, appeal in writing against such refusal, suspension, cancellation or refusal to renew, to the Secretary of the Ministry in-charge of the subject of Policy Planning and Implementation.

(2) Such applicant shall be given an opportunity of making representations in person or by authorized representative in connection with his appeal.

(3) The Secretary may set aside, vary or confirm the decision appealed from, and the Authority shall give effect to the Secretary's decision.

(4) The decision of the Secretary shall be final and conclusive.

12. *The holder of a licence shall forthwith notify the Authority of :–*

(*a*) any changes made or proposed to be made in the particulars furnished in connection with his application for a licence ;

(*b*) any decision to terminate any activity to which the licence relates;

and shall comply with any directions that may be issued by the Authority to prevent or mitigate environmental pollution and hazards.

13. Every applicant or every holder of a licence shall comply with any direction given by or on behalf of the Authority for the purpose of protecting the environment.

14. Every person who acts in contravention of any regulations commits an offence punishable under section 31 of the Act.

15. *In these regulations* :–

"The Act" means the National Environmental Act, No. 47 of 1980 as amended by Act No. 56 of 1988.

SCHEDULE I

GENERAL STANDARDS FOR DISCHARGE OF EFFLUENTS INTO INLAND SURFACE WATERS

No.	*Determinant*	*Tolerance limit*
1.	Total Suspended Solids, mg/l, max	50
2.	Particle size of total suspended solids	shall pass sieve of aperture size 850 micro m.
3.	pH value at ambient temperature	6.0 to 8.5
4.	Biochemical Oxygen Demand–BOD_5 in 5 days at 20° C, mg/l, max	30
5.	Temperature of discharge	shall not exceed 40° C in any Section of the Stream within 15 m down stream from the effluent outlet.
6.	Oils and greases, mg/l max	10.0
7.	Phenolic Compounds (as phenolic OH)mg/l, max	1.0
8.	Cyandes as (CN) mg/l, max	0.2
9.	Sulfides, mg/l, max	2.0
10.	Flourides, mg/l, max	2.0
11.	Total residual chlorine mg/l, max	1.0
12.	Arsenic, mg/l, max	0.2
13.	Cadmium total, mg/l, max	0.1
14.	Chromium total, mg/l, max	0.1
15.	Copper total, mg/l, max	3.0
16.	Lead, total, mg/l, max	0.1
17.	Mercury total, mg/l, max	0.0005
18.	Nickel total, mg/l, max	3.0
19.	Selenium total, mg/l max	0.05
20.	Zinc total, mg/l, max	5.0
21.	Ammoniacal nitrogen, mg/l, max	50.0
22.	Pesticides	undetectable
23.	Radio active material	
	(*a*) Alpha emitters micro curie/ml	10^{-7}
	(*b*) Beta-emitters micro curie/ml	10^{-8}
24.	Chemical Oxygen Demand (COD), mg/l, max	250

Note 1 : All efforts should be made to remove colour and unpleasant odour as far as practicable.

Note 2 : These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.

Note 3 : The above mentioned General Standards shall cease to apply with regard to a particular industry when industry specific standards are notified for that industry.

TOLERANCE LIMITS FOR INDUSTRIAL EFFLUENTS DISCHARGED ON LAND FOR IRRIGATION PURPOSE

No.	*Determinant*	*Tolerance Limit*
1	Total dissolved solid, mg/l, max	2100
2	pH value at ambient temperature	5.5 to 9.0
3	Biochemical Oxygen Demand (BOD_5) in 5 days at 20 °C, mg/l, max	250
4	Oils and grease, mg/l, max.	10.0
5	Chloride (as Cl), mg/l, max.	600
6	Sulfate (as SO_4), mg/l, max.	1000
7	Boron (as B), mg/l, max.	2.0
8	Arsenic (as As), mg/l, max.	0.2
9	Cadmium (as Cd), mg/l, max.	2.0
10	Chromium (as Cr), mg/l, max.	1.0
11	Lead (as Pb), mg/l, max.	1.0
12	Mercury (as Hg), mg/l, max.	0.01
13	Sodium adsorption ratio : (SAR)	10 to 15
14	Residual Sodium Carbonate, mol/l, max.	2.5
15	Radio active material :	
	(a) Alpha emitters, micro curie/ml	10^{-9}
	(b) Beta emitters, micro curie/ml	10^{-8}

TOLERANCE LIMITS FOR INDUSTRIAL AND DOMESTIC EFFLUENTS DISCHARGED INTO MARINE COASTAL AREAS

No.	*Determinant*	*Tolerance Limit*
1.	Total Suspended Solids, mg/l, max.	
	(a) For process waste waters	150
	(b) For cooling water effluents	Total suspended matter content of influent cooling water plus 10 per cent.
2.	*Particle size of –*	
	(a) Floatable Solids, max	3 mm
	(b) Settlable solids, max	850 micro m.
3.	pH range at ambient temperature	6.0 – 8.5
4.	Biochemical Oxygen Demand (BOD_5) in 5 days at 20°C, mg/l, max.	100
5.	Tempeature, max	45°C at the point of discharge
6.	Oils and grease, mg/l, max.	20
7.	Residual Chlorine, mg/l, max.	1.0
8.	Ammonical Nitrogen mg/l, max.	50.0
9.	Chemical Oxygen Demand (COD) mg/l, max.	250
10.	Phenolic compounds (as phenolic OH) mg/l, max.	5.0
11.	Cyanides (as CN) mg/l, max.	0.2
12.	Sulfides (as S), mg/l, max.	5.0
13.	Fluorides (as F), mg/l, max.	15
14.	Arsenic (as As) mg/l, max.	0.2
15.	Cadmium (as Cd) Total, mg/l, max.	2.0
16.	Chromium (as Cr) Total, mg/l, max.	1.0
17.	Copper (as Cu) total, mg/l, max.	3.0
18.	Lead (as Pb) total, mg/l, max.	1.0
19.	Mercury (as Hg) total, mg/l, max.	0.01
20.	Nickel (as Ni) total, mg/l, max.	5.0

No.	*Determinant*	*Tolerance Limit*
21.	Selenium (as Se) total, mg/l, max.	0.05
22.	Zinc (as Zn) total, mg/l, max.	5.0
23.	Radio active material	
	(*a*) Alpha emitters, micro curie/ml, max	10^{-8}
	(*b*) Beta emitters, micro curie/ml, max	10^{-7}
24.	Organo – Phosphorus compounds	1.0
25.	Chlorinated hydrocarbons (as Cl), mg/l, max.	0.02

Note I : All efforts should be made to remove colour and unpleasant odour as far as practicable.

Note 2 : These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.

TOLERANCE LIMITS FOR EFFLUENTS FROM RUBBER FACTORIES DISCHARGED INTO INLAND SURFACE WATERS

No.	*Determinant*	*Tolerance Limit*	
		*Type I Factories**	*Type II Factories***
1.	pH value at ambient temperature	6.5 to 8.5	6.5 to 8.5
2.	Total suspended solids, mg/l, max	100	100
3.	Total solids, mg/l, max	1500	1000
4.	Biochemical Oxygen Demand (BOD_5) in 5 days at 20°C, mg/l, max	60	50
5.	Chemical Oxygen Demand (COD) mg/l, max	400	400
6.	Total Nitrogen, mg/l, max	300	60
7.	Ammoniacal Nitrogen, mg/l, max	300	40
8.	Sulfides, mg/l, max	2.0	2.0

* *Type I Factories* – Latex Concentrate

** *Type II Factories* – Standard Lanka Rubber; Crepe Rubber and Ribbed Smoked Sheets

Note I : All efforts should be made to remove colour and unpleasant odour as far as practicable.

Note II : These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.

TOLERANCE LIMITS FOR EFFLUENTS FROM TEXTILE INDUSTRY DISCHARGED INTO INLAND SURFACE WATERS

No.	*Determinant*	*Tolerance Limit*
1.	pH value at ambient temperature	6.5 to 8.5
2.	Temperature, °C, max	40 measured at site of sampling
3.	Total suspended solids, mg/1, max	50
4.	Biochemical Oxygen Demand (BOD_5) in 5 days at 20 °C mg/1, max.	60
5.	Chemical Oxygen Demand (COD) mg/1, max.	250
6.	Oils and grease, mg/1, max.	10.0
7.	Phenolic compounds (as phenolic OH), mg/1, max.	1.0
8.	Sulfides, mg/1, max.	2.0
9.	Chromium total, mg/1, max.	2.0
10.	Hexavalent chromium, mg/1, max.	0.5
11.	Copper, total, mg/1, max.	3.0
12	Zinc total, mg/1, max.	5.0
13.	Ammoniacal nitrogen, mg/1, max.	60
14.	Chloride (as Cl) mg/1, max.	70

Note I : All efforts should be made to remove colour and unpleasant odour as far as practicable.

Note II : These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.

TOLERANCE LIMITS FOR EFFLUENTS FROM TANNING INDUSTRY

No.	*Determinant*	*Tolerance Limits for Effluent* — *Discharged into Inland Surface Waters*	*Discharged into Marine Coastal Areas*
1.	pH value at ambient temperature	5.5 to 9.0	5.5 to 9.0
2.	Total suspended solids, mg/1 max.	100	150
3.	Biochemical Oxygen Demand (BOD_5) in 5 days at 20°C, mg/1, max	60	100
4.	Chemical Oxygen Demand (COD)mg/1, max.	250	300
5.	Alkalinity (as $CaCO_3$) mg/1, max.	750	not applicable
6.	Chloride (as C1), mg/1, max.	1000	not applicable
7.	Hexavalent chromium, mg/1, max.	0.5	0.5
8.	Chromium total, mg/1, max.	2.0	2.0
9.	Oils and greases, mg/1, max.	10.0	20.0
10.	Phenolic compounds (as Phenolic OH) mg/1, max.	1.0	5.0
11.	Sulfides, mg/1, max.	2.0	5.0

Note I : All efforts should be made to remove colour and unpleasant odour as far as practicable.

Note II : The value are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.

SCHEDULE II

Form A

National Environmental Act, No. 47 of 1980

ENVIRONMENTAL PROTECTION LICENCE APPLICATION

Application No. ....
Date ....

Sector :————
Category :————

Name of Industry :

Type of Industry : /Manufacture/Assembly/Formulation/Repacking/
Processing/Other (specify)/

Name of Applicant :

Postal Address :
Telephone No. :

1. GENERAL DESCRIPTION OF INDUSTRY

1.1 Nature of Industry :

1.2 Location of Industry :
(Location map and a clear route sketch with land marks to the site to be annexed.)
Address :

1.3 Name of local authority :

1.4 Is the site within an Approved Industrial Zone ?:

1.5 Amount of Capital Investment :
Local :
Foreign :

1.6 Date of commencement of operation :

1.7 No. of Shifts/Day and Times :

1.8 No. of Workers in Each Shift :

1.9 A List of permits obtained from Local or State Authorities permitting the Establishment and Operation of the Industry. (Please attach photocopies) :

Name	Date of Issue	Date of Expiry
(a)	....	....
(b)	....	....
(c)	....	....
(d)	....	....
(e)	....	....

1.10 Land use of the area within 5 km radius – Residential/Commercial/Agricultural/Open Space/Public area/Marshy land/salt Marshy Land/Mangrove/Natural Reserve/ Other (specify) :

1.11 List of existing industries/Institutions/Agricultural land within 2km radius :

1.12 Land available for treatment plant:

2. MANUFACTURING PROCESS

2.1 List of main manufactured products and capacities :

2.2 List of by-products :

2.3 Process Details :

2.3.1 A brief description of the processes used (attach process flow diagram):

2.3.2 Raw materials used :
(State item wise quantity/day at all stages of manufacture)

2.3.3 Chemicals used :

Chemical Name	*Trade Name*	*Quantity/ Day (in kg)*

2.3.4 Precautionary measures adopted in the transport and handling of any hazardous/toxic/flammable/explosive material :

2.3.5 Storage facilities for hazardous/toxic/flammable/explosive materials :

2.3.6 Do you have adequate fire fighting equipment ?

2.3.7 If so, details of such equipment :

3. WATER

3.1 Water—Requirement

Processing :	m^3 / day
Cooling :	m^3/ day
Washing :	m^3 / day
Domestic :	m^3 / day

3.2 Source of water :
1. Public Supply
2. Ground Water (Wells, springs)
3. Surface water (Stream, river)

3.3 Total daily discharge— m^3 / day :

3.4 Method of discharge : Open Channel/Pipeline/Covered Drains/Other :

3.5 Final point of discharge of waste water : Agricultural land/Marshy land/Sewer/ Lake/River/Ela/Estuary/Sea/Other

3.6 What other specific toxic substances are discharged ? (Specify nature and concentration—*e.g.* : Inorganics and Organics including Pesticides, Organic Chlorine Compounds, Heavy Metals etc.)

3.7 Methods of treatment of Waste Water (Diagrams of Treatment Process to be included) :

3.8 Methods adopted for recording characteristics of waste water before and after treatment :

3.9 Give details of water recycling, if any :

4. SOLID WASTE

4.1 Type and Nature of Solid Wastes :

4.2 Total quantity of solid waste—Kg/day :

4.3 Methods of disposal of solid wastes—Municipal collection System/Land Fill/Incineration/Compositing/Sold/Recycle :

5. ATMOSPHERIC EMISSIONS

Is there emission to the atmosphere : Yes/No — if ' Yes ' complete the following :

5.1 Possible emissions :

a. Oxides of Nitrogen —
b. Oxides of Sulphur —
c. Dust and Soot —
d. Any other —

5.2 No. of Stacks/Chimneys :
Height :

6. Does your industry cause Odour prob'
Source :
Method of abatement :

7. NOISE POLLUTION

7.1 Does your industry cause noise pollution : Yes/No
7.2 If 'Yes', source :
Method of abatement :

8. ENERGY REQUIREMENTS

8.1 Total Energy Consumption :
a. In-plant generation :
b. Public supply :

8.2 Details of Machinery used in the Industry and their Horse Power Ratings :

8.3 Types of Fuel Used :
a. Purpose :
b. Daily consumption :

9. RECYCLING/REUSE

9.1 Possible salvage of any waste material for reuse :
Specify :

10. EXPANSION OF INDUSTRY

Describe your plans for future expansion of the industry. State whether proposed expansion will alter the manufacturing process, raw material usage and finished products.

I hereby certify that the particulars furnished by me in this application are true and correct. I am aware that if any particulars herein are found to be false or incorrect, my application will be refused and the licence, if issued, will be cancelled.

....
Signature of applicant

......................,
Date

ADDITIONAL INFORMATION REQUIRED FROM CHEMICAL INDUSTRIES

Detailed information on the following has to be provided :

1. A site map extending 1/4 mile beyond the boundaries of the property depicting the facility, the discharge points for effluents, wells, springs and other surface water bodies and drinking water wells.

2. A description of the procedures, structures and equipment used at the facility to :

   (i) Prevent hazards in transport and unloading operations of chemicals :
   (ii) Prevent undue exposure of personnel to chemicals (protective clothing etc.)

3. A description of —
   (i) Precautions to prevent accidental fires resulting from storage of chemicals,
   (ii) available fire fighting equipment,
   (iii) training of personnel in fire fighting.

4. A description of storage system for bulk chemicals prior to use in the industrial process.

5. A description of recovery methods of used chemicals, if any.

FOR OFFICIAL USE ONLY

Licence Application No............
Sector ( )
Category ( )

1. Date of receipt of application : ....
2. Reference Plans, Reports and other documents received :
3. If any additional information was requested, details of such requests : ....
4. If the observation of any other Agency was requested, details of such requests : ....
5. Whether a Licence is granted : Yes / No
6. If a Licence is granted :—
   a. No. of the Licence : ....
   b. Date of Licence : ....
   c. Validity period : ....
   d. Date of expiry : ....
   e. Conditions attached (if any) : ....
7. If Licence is refused, reasons for refusal :

....
Signature and Designation of
Authorized Officer.

...................,
Date.

Form B

NATIONAL ENVIRONMENTAL ACT, No. 47 OF 1980
ENVIRONMENTAL PROTECTION LICENCE ISSUED UNDER SECTION 23B

We .... of .... situated within the area of authority of the Pradeshiya Sabha/Municipal Council/Urban Council of .... is/are hereby authorized to discharge/deposit effluents/waste and/or emit noise/vibrations/air emissions which may arise as a result of the operation of the said industry/process, in accordance with the standards and criteria prescribed by the National Environmental (Protection and Quality) Regulations No. 1 of 1990.

This licence shall be in force from .... to .... unless it is earlier cancelled or suspended.

This licence is subject to the general terms and conditions stated overleaf AND to the additional terms and conditions stated below.

1.
2.
3.
4.

....

Chairman,
Central Environmental Authority.

....

Date.

GENERAL TERMS AND CONDITIONS

1. The Licence shall be valid for one year from the date of issue. An application for renewal of the Licence should be made at least one (01) month prior to the date of expiry of the Licence.

2. The holder of the Licence shall permit the Director-General or any other officer duly authorized in writing by him at any time to enter the premises in respect of which the Licence is issued to examine and inspect any equipment or industrial plant ; and
   (*a*) to take samples of any pollutants that are emitted, discharged or deposited from or by such equipment or industrial plant ;
   (*b*) to examine books, records or documents relating to the performance or use of such equipment or industrial plant or relating to the emission, discharge or deposition from such industrial plant ;
   (*c*) to take photographs of such equipment or industrial plants as he considers necessary or make copies of any books, records or documents seen in the course of such examination ; and
   (*d*) to take samples of any fuel, substance or material used, in such trade, industry or process carried on in or on such premises.

3. The holder of the Licence shall comply with any requirement communicated from time to time by the Authority as regards :
   (*a*) the use of any techniques or installations in the production process, handling and storage of goods, material, fuel and waste products with a view to minimizing environmental pollution and hazards ; and
   (*b*) any additional technical measures for preventing or mitigating environmental pollution and hazards.

4. The holder of the Licence shall ensure that monitoring of environmental pollution or other acts that the Authority considers necessary to protect the environment, including the following are done :
   (*a*) measurements, calculation, registration of samples to determine actual levels of pollution and risk of exposure ;
   (*b*) recording and sorting of data and reporting to the Authority ;
   (*c*) issuing written instructions to persons employed with regard to handling of hazardous material and installations to protect the environment ;
   (*d*) assigning duties and responsibilities to management and staff with regard to protection of the environment ; and
   (*e*) ensuring that persons referred to in (c) above, and charged with duties and responsibilities referred to in (d) above are properly qualified persons.

5. This Licence is valid only for the type and nature of the industry/process/operation as stated in the preliminary application and to the information submitted by the Licencee.

6. Any alteration or extension made to the industry, process or operation should be indicated forthwith to the Authority.

....

Chairman,
Central Environmental Authority.

....

Date.

FORM C

APPLICATION FOR RENEWAL OF ENVIRONMENTAL PROTECTION LICENCE

Application No. ....
Date ....

Sector :————
Category :————

1. Name and location of Industry : ....
2. Name and address of applicant : ....
3. Previous Licence No. ....
   3. 1. Issued on ....
   3. 2. Valid until ....
4. Any changes/alterations/expansions of the industry since last licence was issued — (give details) :
5. State if manufacturing process/raw material usage/finished products have been altered in any way ?:
6. Details of monitoring reports submitted to the Central Environmental Authority during the year :
7. Any other additional information :

I hereby certify that the particulars furnished by me in this application are true and correct. I am aware that if any particulars herein are found to be false or incorrect, my application will be refused and the licence if issued will be cancelled.

....
Signature of Applicant.

....
Date.

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1. Was licence renewed — Yes/No
2. If renewed —

   No. of licence ....
   Date of licence ....
   Validity period ....
   Date of expiry ....
   Conditions attached (if any)

3. If renewal of licence is refused reasons for refusal :

....
Signature and Designation of
Authorized Officer.

....
Date.

SCHEDULE III

LICENSING FEE

A fee of Rs. 750 will be levied in respect of each application for the issue of the Environmental Protection Licence.

RENEWAL FEE

A fee of Rs. 750 will be levied in respect of each application for the renewal of the licence.

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