

CHAPTER 7

CONCLUSION

7.1 Main Conclusions

This research study has focused on using rainwater as a supplement to pipe borne water to alleviate socio economic problems in Colombo metropolitan area. Analysis has been carried out using ten years of daily rainfall data (1992-2001) for the station Colombo for the typical family of six members needing 155lpcd, while fulfilling 50% of the daily demand using rainwater harvesting for different roof areas harvested and storage sizes. Some useful results of practical significance have been found and presented in Chapter 5 and 6.

The success of a rainwater harvesting system not only depends on the temporal distribution of rainfall; but also on factors such as available storage, roof area to be harvested, daily demand, type of roof material and willingness of the consumer to use rainwater for non-potable demand.



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The analysis shows that for wet months like May, September, October and November the average number of days of success increase with increasing size of storage. During these months a 40% success rate could be expected. This increases to almost 50%-60% with increasing size of storage tank. However during drier months like March and August the degree of success is low and remains almost the same irrespective of the tank size.

Results show that the number of successful days increases with increasing roof area. However it is not proportionate to the increasing percentage of harvested roof area due to the effect of the available storage.

The number of successful days of a rainwater harvesting system can reduce domestic water bills thereby easing the socio economic burden among the population of Colombo metropolitan area. Furthermore at the national level this will also help to cater to the extra demand for pipe borne water of the growing population with the Colombo metropolitan area.

Based on the 2002 water tariff the monthly saving that could be expected is approximately Rs. 200.00 depending on the roof area and tank size. What should be noted is that with increasing water tariff savings will increase significantly.

Results based on the analysis of monthly rainfall data are misleading. These over estimate the degree of success of a rainwater harvesting system, unless there is enough storage compatible with the inflow of the entire month. Having storage for monthly demand in a household is impractical in Colombo metropolitan area considering the space and cost required for storage. For realistic results, the analysis should be carried out with daily rainfall data.



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7.2 Recommendation for Further Research

The following recommendations could be made for further research in the following areas to obtain optimum results.

- a) Analyze the economic benefits of rainwater harvesting systems for larger family units in Colombo metropolitan area.
- b) Study the economic benefits of practicing rainwater harvesting among the non-domestic consumers.

The present analysis has been based on the mutually exclusive rule between inflows and outflows. It is recommended that the simultaneous rule be also considered in future research.

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Annex I – This presents the degree of success of a rainwater harvesting system during the months of the year in Colombo metropolitan area based on daily rainfall data and monthly rainfall data. It speaks of a 6 member family, 155lpcd, 50% demand fulfilled and harvested roof area of 50m². Tank size is changed from 0.5m³, 1.0m³, 1.5m³, 2.0m³, 2.5 m³, 3.0m³, 4.0m³ and 5m³. Rainfall data is considered for the period of 1992-2001.



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6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 0.5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	0	0	2	13	7	7	4	9	10	10	4
1993	0	1	4	8	12	5	3	2	9	14	11	10
1994	4	3	4	5	16	5	6	5	13	14	12	2
1995	2	1	2	14	14	14	4	7	4	9	10	1
1996	3	4	0	7	5	8	8	3	9	9	7	6
1997	0	2	1	4	10	9	9	4	11	15	13	8
1998	3	0	2	3	5	9	14	9	7	10	7	11
1999	4	4	3	9	14	6	5	7	10	18	9	5
2000	3	7	4	6	6	8	2	10	12	6	4	4
2001	5	4	2	7	8	4	3	0	7	8	9	4
Mean	3	3	2	7	10	8	6	5	9	11	9	6
Standed Deviation	2	2	2	3	4	3	4	3	3	4	3	3
Monthly Average	6	8	14	27	30	20	13	13	27	30	30	19




6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 1m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	0	4	18	10	12	6	11	14	15	6
1993	0	1	6	11	19	2	4	3	11	19	17	17
1994	7	6	6	7	21	7	8	6	17	21	19	2
1995	5	1	2	20	20	20	9	9	7	16	13	2
1996	5	5	0	12	8	10	11	4	14	14	11	8
1997	0	3	2	6	16	11	12	6	16	23	17	11
1998	6	0	3	7	13	19	15	9	11	13	11	15
1999	6	7	4	14	17	8	7	9	11	25	13	7
2000	6	11	5	11	10	12	3	13	17	10	5	6
2001	9	6	5	13	11	7	5	0	10	11	11	6
Mean	5	4	3	11	15	11	9	7	13	17	13	8
Standed Deviation	3	4	2	5	5	5	4	4	3	5	4	5
Monthly Average	6	8	14	27	30	20	13	13	27	30	30	19

6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 1.5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	0	5	21	12	14	7	12	16	19	7
1993	0	1	7	14	23	8	4	3	13	23	19	21
1994	8	9	8	9	23	8	9	6	20	24	21	2
1995	6	2	2	21	25	21	9	11	9	17	15	2
1996	6	6	0	16	9	11	13	5	16	16	13	10
1997	0	4	2	8	19	13	13	7	18	26	23	13
1998	5	0	3	9	15	20	20	11	13	14	13	18
1999	8	9	5	18	19	10	8	10	12	27	18	9
2000	8	13	6	14	11	14	4	16	18	12	5	6
2001	13	8	6	17	13	10	6	0	11	13	13	8
Mean	6	5	4	13	18	13	10	8	14	19	16	10
Standed Deviation	3	3	3	7	9	6	5	3	7	9	8	7
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27



6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 2.0m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	0	6	22	14	14	7	12	17	21	7
1993	0	2	7	15	25	10	4	3	14	26	21	24
1994	8	9	10	8	25	8	10	7	20	27	24	3
1995	6	1	2	23	26	23	8	11	10	19	17	2
1996	7	6	0	18	10	11	15	6	17	17	14	13
1997	0	4	2	8	20	14	14	7	18	27	25	13
1998	5	0	3	9	17	20	22	11	14	15	14	21
1999	10	11	6	18	21	12	9	9	14	29	18	11
2000	9	15	8	14	13	16	5	17	19	13	5	6
2001	16	10	7	21	13	12	7	0	12	13	15	10
Mean	6	6	5	14	19	14	11	8	15	20	17	11
Standed Deviation	5	5	4	6	6	5	5	5	3	6	6	7
Monthly Average	6	8	14	27	30	20	13	13	27	30	30	19

6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 3m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	0	8	25	16	18	6	12	19	23	7
1993	0	2	9	16	27	12	4	4	15	28	23	26
1994	8	11	11	9	26	12	9	7	23	29	28	3
1995	8	1	2	25	28	26	9	11	10	19	19	2
1996	9	9	0	21	12	11	18	8	21	19	14	17
1997	0	6	2	9	22	17	18	6	21	27	30	13
1998	5	0	3	11	19	19	25	12	17	17	17	23
1999	14	12	6	23	24	14	9	10	13	31	23	15
2000	9	14	10	15	13	18	5	19	19	15	5	6
2001	20	13	7	22	16	14	7	0	12	15	17	13
Mean	7	7	5	16	21	16	12	8	16	22	20	13
Standed Deviation	6	6	4	6	6	4	7	5	5	6	7	8
Monthly Average	6	8	14	27	30	20	13	13	27	30	30	19


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6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 4m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	0	8	29	18	19	6	12	21	24	8
1993	0	1	9	16	28	14	3	4	15	31	26	25
1994	8	10	12	8	27	13	9	7	24	31	30	5
1995	8	1	2	28	30	27	10	10	10	19	21	2
1996	9	8	0	23	12	12	19	10	22	21	14	21
1997	0	6	2	8	24	17	18	6	22	29	30	15
1998	5	0	3	11	19	20	25	19	17	19	18	25
1999	16	11	6	27	24	15	9	10	13	31	27	16
2000	9	15	9	14	13	21	4	22	18	17	4	6
2001	21	13	7	22	19	16	6	0	12	17	20	12
Mean	8	7	5	17	23	17	12	9	17	24	21	14
Standed Deviation	7	6	4	8	6	4	7	7	5	6	8	8
Monthly Average	6	8	14	27	30	20	13	13	27	30	30	19

6 Members, 50m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	0	0	8	31	20	21	7	12	23	28	7
1993	0	1	9	16	28	17	3	4	15	31	28	25
1994	8	11	12	9	27	16	9	7	25	31	30	7
1995	8	2	2	30	31	30	9	10	10	19	23	2
1996	9	8	0	24	12	11	19	10	26	24	15	21
1997	0	6	2	8	25	17	17	6	21	30	30	17
1998	5	0	3	11	18	20	25	17	18	22	20	27
1999	17	11	5	29	24	14	9	10	13	31	30	17
2000	10	14	9	14	13	23	4	23	18	19	4	6
2001	21	12	8	21	18	16	6	0	12	18	21	12
Mean	8	7	5	17	23	18	12	9	17	25	23	14
Standed Deviation	7	5	4	8	7	5	8	7	6	5	8	9
Monthly Average	6	8	14	27	30	20	13	13	27	30	30	19



Annex II– This presents the degree of success of a rainwater harvesting system during the months of the year in Colombo metropolitan area based on daily rainfall data and monthly rainfall data. It speaks of a 6 member family, 155lpcd, 50% demand fulfilled and harvested roof area of 70m². Tank size is changed from 0.5m³, 1.0m³, 1.5m³, 2.0m³, 2.5 m³, 3.0m³, 4.0m³ and 5m³. Rainfall data is considered for the period of 1992-2001.




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6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 0.5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	0	0	4	14	8	8	5	10	12	10	5
1993	0	1	4	8	13	7	3	4	9	15	12	10
1994	5	5	3	5	17	5	6	6	14	16	12	2
1995	2	1	2	17	16	18	5	9	6	13	11	2
1996	4	4	0	8	5	8	9	3	13	11	9	6
1997	0	2	1	4	10	9	10	4	15	17	13	8
1998	4	0	3	6	11	16	10	7	7	11	8	11
1999	4	5	3	12	15	5	6	9	10	20	11	5
2000	3	8	5	7	8	9	3	10	13	7	5	5
2001	5	4	3	10	9	7	3	1	8	9	9	4
Mean	3	3	2	8	12	9	6	6	11	13	10	6
Standed Deviation	2	3	2	4	4	4	3	3	3	4	2	3
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27




6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 1m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	0	6	18	10	14	8	13	16	17	7
1993	0	2	6	11	21	9	5	4	11	22	18	18
1994	8	9	6	10	21	9	8	9	19	23	19	4
1995	4	2	2	22	23	21	10	12	9	19	13	3
1996	6	6	0	14	8	12	14	4	17	14	13	9
1997	0	4	2	6	16	14	13	7	18	25	20	13
1998	6	0	3	10	14	20	15	10	12	14	13	15
1999	6	8	4	16	19	8	8	11	14	26	16	7
2000	6	13	6	13	12	12	4	15	17	11	6	8
2001	9	7	5	15	12	9	5	1	10	13	11	6
Mean	5	5	3	12	16	12	10	8	14	18	15	9
Standed Deviation	3	4	2	5	5	5	4	4	4	5	4	5
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27

6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 1.5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	1	6	21	14	18	9	15	17	21	9
1993	0	2	8	14	24	10	5	4	13	26	22	24
1994	10	11	8	12	23	10	10	9	21	26	23	4
1995	6	1	3	24	28	22	14	13	11	21	15	3
1996	7	7	0	17	11	14	16	5	20	16	16	12
1997	0	5	3	8	20	16	15	8	19	27	24	15
1998	8	0	4	11	17	23	20	12	15	15	16	18
1999	8	10	6	17	21	11	9	13	16	28	19	9
2000	9	17	7	16	14	14	5	18	19	14	6	8
2001	14	9	7	18	14	11	7	1	11	16	14	8
Mean	6	6	5	14	19	15	12	9	16	21	18	11
Standed Deviation	5	6	3	5	5	5	5	5	4	6	5	6
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27


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6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 2.0m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	1	7	23	15	20	9	15	18	24	10
1993	0	2	9	16	25	13	5	4	14	27	24	28
1994	11	13	10	12	26	11	11	9	23	27	26	4
1995	7	1	3	25	30	24	15	14	13	22	17	3
1996	8	8	0	20	12	15	18	7	21	18	17	13
1997	0	6	3	10	18	16	18	9	21	28	28	16
1998	8	0	4	13	18	23	22	14	16	16	17	21
1999	11	12	7	19	23	14	11	14	16	30	21	12
2000	12	18	10	18	15	17	6	20	20	15	6	8
2001	16	11	9	21	15	14	9	0	12	17	17	10
Mean	7	7	6	16	21	16	14	10	17	22	20	13
Standed Deviation	6	6	4	6	6	4	6	6	4	6	6	8
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27

6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 3m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	1	8	26	18	21	9	14	20	27	10
1993	0	2	12	16	28	16	5	4	16	29	28	31
1994	13	15	12	12	30	13	14	9	26	29	30	5
1995	9	1	3	27	31	26	16	14	14	24	20	2
1996	10	10	0	23	13	17	23	9	24	20	18	16
1997	0	8	3	12	25	19	23	8	22	29	30	19
1998	7	0	4	13	23	22	25	17	19	18	19	23
1999	15	16	8	23	27	17	12	13	18	31	26	16
2000	13	19	14	20	15	19	6	24	21	17	6	8
2001	20	15	10	26	19	17	9	1	12	19	19	12
Mean	9	9	7	18	24	18	15	11	19	24	22	14
Standed Deviation	7	7	5	7	6	4	7	7	5	5	7	9
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27


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6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 4m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	1	8	29	20	24	9	14	22	29	10
1993	0	2	13	16	30	18	5	5	16	31	30	31
1994	15	15	14	13	31	15	14	9	29	31	30	6
1995	12	2	2	29	31	28	16	14	14	24	22	2
1996	12	12	0	25	16	16	25	10	28	22	19	23
1997	0	9	3	11	28	20	26	9	22	31	30	21
1998	7	0	4	13	27	22	28	20	21	20	21	26
1999	19	16	9	27	28	19	13	13	18	31	30	21
2000	13	18	15	20	15	21	7	25	22	19	6	8
2001	25	19	11	27	24	19	9	1	12	21	21	14
Mean	10	9	7	19	26	20	17	12	20	25	24	16
Standed Deviation	8	8	6	8	6	4	8	7	6	5	8	10
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27

6 Members, 70m ² Roof Area, 155lpcd, 1/2 demand fulfilled,	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	1	1	1	8	31	22	26	9	15	24	30	10
1993	0	2	13	16	31	20	5	5	16	31	30	31
1994	17	15	17	12	30	16	14	9	30	31	30	9
1995	12	2	2	30	31	30	16	14	14	24	23	2
1996	13	12	0	27	16	17	24	12	30	27	18	26
1997	0	9	3	11	30	21	28	9	22	31	30	23
1998	7	0	4	13	29	22	30	22	23	22	22	28
1999	22	16	8	28	28	20	13	13	18	31	30	23
2000	13	19	15	20	15	23	7	25	24	21	7	8
2001	26	22	11	27	26	20	10	1	12	23	22	15
Mean	11	10	7	19	27	21	17	12	20	27	24	18
Standed Deviation	9	8	6	8	6	4	9	7	6	4	8	10
Monthly Average	9	11	20	30	30	28	19	18	30	30	30	27



Annex III – This presents the degree of success of a rainwater harvesting system during the months of the year in Colombo metropolitan area based on daily rainfall data and monthly rainfall data. It speaks of a 6 member family, 155lpcd, 50% demand fulfilled and harvested roof area of 100m². Tank size is changed from 0.5m³, 1.0m³, 1.5m³, 2.0m³, 2.5 m³, 3.0m³, 4.0m³ and 5m³. Rainfall data is considered for the period of 1992-2001.



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6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 0.5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	0	0	4	16	8	11	6	13	12	13	5
1993	0	1	4	8	15	9	4	4	9	19	15	11
1994	6	6	4	7	18	8	7	6	15	17	12	2
1995	2	2	3	18	18	18	6	9	7	16	11	2
1996	4	4	0	8	5	9	12	4	12	13	10	6
1997	0	2	1	5	11	11	11	5	17	19	15	10
1998	4	0	3	7	12	17	10	9	10	11	11	12
1999	5	5	4	11	17	5	8	10	11	22	12	6
2000	4	8	6	8	9	10	3	13	15	8	5	5
2001	6	5	3	11	9	7	5	0	8	9	10	4
Mean	3	3	3	9	13	10	8	7	12	15	11	6
Standed Deviation	2	3	2	4	4	4	3	4	3	5	3	4
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30




6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 1m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	1	0	6	20	13	16	9	16	17	21	7
1993	0	2	8	12	22	11	6	6	13	25	21	18
1994	10	9	8	10	22	11	10	11	20	24	20	5
1995	4	2	4	23	24	21	11	13	11	21	14	3
1996	6	8	0	14	10	16	16	5	18	16	15	9
1997	0	4	2	8	18	15	15	8	19	25	21	17
1998	7	0	4	11	17	23	14	12	14	14	16	18
1999	7	8	6	15	21	8	10	14	15	26	18	9
2000	7	14	9	13	13	13	4	16	20	12	10	8
2001	10	7	5	16	15	10	7	0	10	14	12	6
Mean	5	6	5	13	18	14	11	9	16	19	17	10
Standed Deviation	4	4	3	5	4	5	4	5	4	5	4	6
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30

6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 1.5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	2	0	8	23	16	21	12	18	19	24	9
1993	0	3	10	14	25	14	7	7	14	27	24	24
1994	12	11	10	13	24	12	12	12	22	27	24	6
1995	6	2	4	26	29	22	16	15	13	24	16	4
1996	7	10	0	20	13	19	18	6	23	17	18	12
1997	0	5	3	10	22	17	17	11	20	27	26	19
1998	9	0	5	14	21	24	20	14	18	15	18	21
1999	9	11	7	17	23	11	12	16	17	28	20	11
2000	10	18	10	17	16	15	5	20	21	15	10	9
2001	14	9	7	20	17	13	8	0	11	16	15	8
Mean	7	7	6	16	21	16	14	11	18	22	20	12
Standed Deviation	5	6	4	5	5	4	6	6	4	6	5	7
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30


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6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 2.0m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	2	0	9	24	18	24	13	18	20	26	11
1993	0	3	12	15	26	15	7	7	15	28	26	28
1994	13	13	11	15	27	13	14	13	24	28	28	6
1995	9	2	3	27	31	24	19	18	15	26	18	4
1996	9	10	0	23	13	21	20	7	25	18	19	14
1997	0	6	4	13	23	19	21	11	21	30	29	20
1998	11	0	5	16	22	25	22	16	19	17	19	22
1999	11	13	8	20	25	14	13	18	19	30	22	13
2000	12	20	12	19	19	17	7	22	21	17	10	9
2001	17	12	10	22	18	16	9	0	12	19	19	10
Mean	8	8	7	18	23	18	16	13	19	23	22	14
Standed Deviation	6	6	5	5	5	4	6	7	4	6	6	8
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30

6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 3m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	2	0	10	27	20	26	14	18	22	29	15
1993	0	3	14	16	28	17	7	7	17	30	28	31
1994	17	16	13	18	31	15	16	13	28	30	30	8
1995	11	2	4	29	31	27	21	20	19	28	20	4
1996	11	12	0	25	16	23	25	9	27	23	22	19
1997	0	9	4	14	26	20	28	11	24	30	30	23
1998	11	0	5	16	26	25	26	20	22	20	21	24
1999	15	18	10	26	28	17	15	20	22	31	27	17
2000	14	24	15	23	19	19	9	24	24	19	10	9
2001	21	16	14	27	22	20	11	0	12	23	21	12
Mean	10	10	8	20	25	20	18	14	21	26	24	16
Standed Deviation	7	8	6	6	5	4	8	7	5	5	6	8
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30


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6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 4m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	2	0	10	29	23	28	14	18	24	30	17
1993	0	3	15	17	30	19	7	7	17	31	30	31
1994	20	19	14	19	31	17	18	13	30	31	30	10
1995	13	3	3	30	31	29	23	20	22	29	22	4
1996	13	14	0	27	18	24	28	12	29	27	22	23
1997	0	11	4	16	29	22	30	13	24	31	30	26
1998	10	0	5	16	28	25	28	24	24	22	23	26
1999	19	20	15	28	28	19	17	20	22	31	30	21
2000	17	25	17	26	22	21	11	26	26	21	10	9
2001	25	20	15	27	26	23	13	1	12	25	22	14
Mean	12	12	9	22	27	22	20	15	22	27	25	18
Standed Deviation	9	9	7	7	4	3	8	8	6	4	7	9
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30

6 Members, 100m ² Roof Area, 155lpcd, 1/2 demand fulfilled, 5m ³ Tank	No of successive days											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1992	2	2	0	10	31	25	30	14	18	26	30	19
1993	0	3	17	18	31	21	8	7	16	31	30	31
1994	23	21	16	19	31	20	19	13	30	31	30	12
1995	15	3	3	30	31	30	25	20	21	30	25	3
1996	16	16	0	29	21	22	28	14	30	29	22	27
1997	0	13	4	16	31	22	31	14	24	31	30	28
1998	10	0	5	17	30	26	30	27	27	23	25	29
1999	23	21	15	28	30	21	17	29	22	31	30	25
2000	19	25	20	26	23	23	11	26	28	24	10	9
2001	29	23	15	27	28	25	14	1	12	27	25	17
Mean	14	13	10	22	29	24	21	17	23	28	26	20
Standed Deviation	10	10	8	7	4	3	9	9	6	3	6	10
Monthly Average	13	16	28	30	30	30	27	26	30	30	30	30



Annex IV – This presents the comparison of the successful days based on mean value of daily rainfall for the period of 1992 – 2001Vs. average monthly rainfall for the different sizes of storages and roof area harvested in Colombo metropolitan area. It follows by a computation of percentage of saving per year in water bill in practicing rainwater harvesting using daily rainfall data and average monthly rainfall data.



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6 Members, 50m² Roof Area, 155lpcd, 1/2 demand fulfilled

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total Rs.	%
No of Successful days based on average monthly rainfall	6	8	14	27	30	20	13	13	27	30	30	19		
Quantity Saved (m ³)	3	4	7	13	14	9	6	6	13	14	14	9		
Monthly Consumption without RW Harvesting (m ³)	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90		
Monthly Consumption with RW Harvesting (m ³)	25	24	21	15	14	19	22	22	15	14	14	19		
Monthly Bill without RW Harvesting (Rs.)	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	4402	0%
Monthly Bill with RW Harvesting (Rs.)	229	191	135	77	72	98	145	145	77	72	72	101		
Amount Saved (Rs.)	138	176	232	290	294	268	222	222	290	294	294	265	2986	68%
0.5m³ Tank														
No of Successful days based on daily rainfall	3	3	2	7	10	8	6	5	9	11	9	6		
Quantity Saved (m ³)	1	1	1	3	5	4	3	2	4	5	4	3		
Monthly Consumption with RW Harvesting (m ³)	27	27	27	25	23	24	25	26	24	23	24	25		
Monthly Bill with RW harvesting (Rs.)	298	298	321	200	173	191	229	252	182	163	182	229		
Amount Saved (Rs.)	69	69	46	166	194	178	138	115	185	204	185	138	1685	38%
1.0m³ Tank														
No of Successful days based on daily rainfall	5	4	3	11	15	11	9	7	13	17	13	8		
Quantity Saved (m ³)	2	2	1	5	7	6	4	3	6	8	6	4		
Monthly Consumption with RW Harvesting (m ³)	26	26	27	23	21	23	24	25	22	20	22	24		
Monthly Bill with RW harvesting (Rs.)	252	275	298	163	126	163	182	200	145	107	145	191		
Amount Saved (Rs.)	115	92	69	204	241	204	185	168	222	259	222	176	2155	49%
1.5m³ Tank														
No of Successful days based on daily rainfall	6	5	4	13	18	13	10	8	14	19	16	10		
Quantity Saved (m ³)	3	2	2	6	8	8	5	4	7	9	7	5		
Monthly Consumption with RW Harvesting (m ³)	25	26	26	22	20	22	23	24	21	19	20	23		
Monthly Bill with RW harvesting (Rs.)	229	252	275	145	104	145	173	191	135	101	117	173		
Amount Saved (Rs.)	138	115	92	222	262	222	194	176	232	265	250	194	2363	54%
2.0m³ Tank														
No of Successful days based on daily rainfall	6	6	5	14	19	14	11	8	15	20	17	11		
Quantity Saved (m ³)	3	3	2	7	9	7	5	4	7	9	8	5		
Monthly Consumption with RW Harvesting (m ³)	25	25	26	21	19	21	23	24	21	19	20	23		
Monthly Bill with RW harvesting (Rs.)	229	229	252	135	101	135	163	191	126	98	107	163		
Amount Saved (Rs.)	138	138	115	232	265	232	204	176	241	268	259	204	2471	56%

3.0m ³ Tank														
No of Successful days based on daily rainfall	7	7	5	16	21	16	12	8	16	22	20	13		
Quantity Saved (m ³)	3	3	2	7	10	7	6	4	7	10	9	6		
Monthly Consumption with RW Harvesting (m ³)	25	25	26	20	18	20	22	24	20	18	19	22		
Monthly Bill with RW harvesting (Rs.)	200	200	252	117	95	117	154	191	117	92	98	145		
Amount Saved (Rs.)	166	166	115	250	271	250	213	176	250	274	268	222	2623	60%
4.0m ³ Tank														
No of Successful days based on daily rainfall	8	7	5	17	23	17	12	9	17	24	21	14		
Quantity Saved (m ³)	4	3	2	8	11	8	6	4	8	11	10	7		
Monthly Consumption with RW Harvesting (m ³)	24	25	26	20	17	20	22	24	20	17	18	21		
Monthly Bill with RW harvesting (Rs.)	191	200	252	107	89	107	154	182	107	86	95	135		
Amount Saved (Rs.)	176	166	115	259	277	259	213	185	259	280	271	232	2694	61%
5.0m ³ Tank														
No of Successful days based on daily rainfall	8	7	5	17	23	18	12	9	17	25	23	14		
Quantity Saved (m ³)	4	3	2	8	11	8	6	4	8	12	11	7		
Monthly Consumption with RW Harvesting (m ³)	24	25	26	20	17	20	22	24	20	16	17	21		
Monthly Bill with RW harvesting (Rs.)	191	200	252	107	89	104	154	182	107	83	89	135		
Amount Saved (Rs.)	176	166	115	259	277	262	213	185	259	284	277	232	2706	61%

6 Members, 70m² Roof Area, 155lpcd, 1/2 demand fulfilled

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total Rs.	%
No of Successful days based on average monthly rainfall	9	11	20	30	30	28	19	18	30	30	30	27		
Quantity Saved (m ³)	4	5	9	14	14	13	9	8	14	14	14	13		
Monthly Consumption without RW Harvesting (m ³)	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90		
Monthly Consumption with RW Harvesting	24	23	19	14	14	15	19	20	14	14	14	15		
Monthly Bill without RW Harvesting (Rs.)	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	4402	0%
Monthly Bill with RW Harvesting (Rs.)	182	163	98	72	72	75	101	104	72	72	72	77		
Amount Saved (Rs.)	185	204	268	294	294	292	265	262	294	294	294	290	3239	74%
0.5m³ Tank														
No of Successful days for daily rainfall	3	3	2	8	12	9	6	6	11	13	10	6		
Quantity Saved (m ³)	1	1	1	4	6	4	3	3	5	6	5	3		
Monthly Consumption with RW Harvesting (m ³)	27	27	27	24	22	24	25	25	23	22	23	25		
Monthly Bill with RW harvesting (Rs.)	298	298	321	191	154	182	229	229	163	145	173	229		
Amount Saved (Rs.)	69	69	46	176	213	185	138	138	204	222	194	138	1792	41%
1.0m³ Tank														
No of Successful days	5	5	3	12	16	12	10	8	14	18	15	9		
Quantity Saved (m ³)	2	2	1	6	7	6	5	4	7	8	7	4		
Monthly Consumption with RW Harvesting (m ³)	26	26	27	22	20	22	23	24	21	20	21	24		
Monthly Bill with RW harvesting (Rs.)	252	252	298	154	117	154	173	191	135	104	126	182		
Amount Saved (Rs.)	115	115	69	213	250	213	194	178	232	262	241	185	2265	51%
1.5m³ Tank														
No of Successful days	6	6	5	14	19	15	12	9	16	21	18	11		
Quantity Saved (m ³)	3	3	2	7	9	7	6	4	7	10	8	5		
Monthly Consumption with RW Harvesting (m ³)	25	25	26	21	19	21	22	24	20	18	20	23		
Monthly Bill with RW harvesting (Rs.)	229	229	252	135	101	128	154	182	117	95	104	163		
Amount Saved (Rs.)	138	138	115	232	265	241	213	185	250	271	262	204	2514	57%
2.0m³ Tank														
No of Successful days	7	7	6	16	21	18	14	10	17	22	20	13		
Quantity Saved (m ³)	3	3	3	7	10	7	7	5	8	10	9	6		
Monthly Consumption with RW Harvesting (m ³)	25	25	25	20	18	20	21	23	20	18	19	22		
Monthly Bill with RW harvesting (Rs.)	200	200	229	117	95	117	135	173	107	92	98	145		
Amount Saved (Rs.)	166	166	138	250	271	250	232	194	259	274	268	222	2693	61%

3.0m ³ Tank													
No of Successful days	9	9	7	18	24	18	15	11	19	24	22	14	
Quantity Saved (m ³)	4	4	3	8	11	8	7	5	9	11	10	7	
Monthly Consumption with RW Harvesting (m ³)	24	24	25	20	17	20	21	23	19	17	18	21	
Monthly Bill with RW harvesting (Rs.)	182	182	200	104	86	104	126	163	101	86	92	135	
Amount Saved (Rs.)	185	185	166	262	280	262	241	204	265	280	274	232	2838 64%
4.0m ³ Tank													
No of Successful days	10	9	7	19	26	20	17	12	20	25	24	16	
Quantity Saved (m ³)	5	4	3	9	12	9	8	6	9	12	11	7	
Monthly Consumption with RW Harvesting (m ³)	23	24	25	19	16	19	20	22	19	16	17	20	
Monthly Bill with RW harvesting (Rs.)	173	182	200	101	80	98	107	154	98	83	86	117	
Amount Saved (Rs.)	194	185	166	265	287	268	259	213	268	284	280	250	2921 66%
5.0m ³ Tank													
No of Successful days	11	10	7	19	27	21	17	12	20	27	24	18	
Quantity Saved (m ³)	5	5	3	9	13	10	8	6	9	13	11	8	
Monthly Consumption with RW Harvesting (m ³)	23	23	25	19	15	18	20	22	19	15	17	20	
Monthly Bill with RW harvesting (Rs.)	163	173	200	101	77	95	107	154	98	77	86	104	
Amount Saved (Rs.)	204	194	166	265	290	271	259	213	268	290	280	262	2964 67%

6 Members, 100m² Roof Area, 155lpcd, 1/2 demand fulfilled

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total Rs.	%
No of Successful days based on average monthly rainfall	13	18	28	30	30	30	27	26	30	30	30	30		
Quantity Saved (m ³)	6	7	13	14	14	14	13	12	14	14	14	14		
Monthly Consumption without RW Harvesting (m ³)	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90		
Monthly Consumption with RW Harvesting (m ³)	22	20	15	14	14	14	15	16	14	14	14	14		
Monthly Bill without RW Harvesting (Rs.)	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	366.80	4402	0%
Monthly Bill with RW Harvesting (Rs.)	145	117	75	72	72	72	77	80	72	72	72	72		
Amount Saved (Rs.)	222	250	292	294	294	294	290	287	294	294	294	294	3401	77%
0.5m³ Tank														
No of Successful days	3	3	3	9	13	10	8	7	12	15	11	6		
Quantity Saved (m ³)	1	1	1	4	8	5	4	3	6	7	5	3		
Monthly Consumption with RW Harvesting (m ³)	27	27	27	24	22	23	24	25	22	21	23	25		
Monthly Bill with RW harvesting (Rs.)	298	298	298	182	145	173	191	200	154	126	163	229		
Amount Saved (Rs.)	69	69	69	185	222	194	176	166	213	241	204	138	1946	44%
1.0m³ Tank														
No of Successful days	5	6	5	13	18	14	11	9	16	19	17	10		
Quantity Saved (m ³)	2	3	2	6	8	7	5	4	7	9	8	5		
Monthly Consumption with RW Harvesting (m ³)	26	25	26	22	20	21	23	24	20	19	20	23		
Monthly Bill with RW harvesting (Rs.)	252	229	252	145	104	135	163	182	117	101	107	173		
Amount Saved (Rs.)	115	138	115	222	262	232	204	185	250	265	259	194	2442	55%
1.5m³ Tank														
No of Successful days	7	7	6	18	21	16	14	11	18	22	20	12		
Quantity Saved (m ³)	3	3	3	7	10	7	7	5	8	10	9	6		
Monthly Consumption with RW Harvesting (m ³)	25	25	25	20	18	20	21	23	20	18	19	22		
Monthly Bill with RW harvesting (Rs.)	200	200	229	117	95	117	135	163	104	92	98	154		
Amount Saved (Rs.)	166	166	138	250	271	250	232	204	262	274	268	213	2696	61%
2.0m³ Tank														
No of Successful days	8	8	7	18	23	18	16	13	19	23	22	14		
Quantity Saved (m ³)	4	3	3	8	11	8	7	6	9	11	10	7		
Monthly Consumption with RW Harvesting (m ³)	24	24	25	20	17	20	20	22	19	17	18	21		
Monthly Bill with RW harvesting (Rs.)	194	196	200	104	89	104	117	145	101	89	92	135		
Amount Saved (Rs.)	173	171	166	262	277	262	250	222	265	277	274	232	2834	64%

3.0m ³ Tank															
No of Successful days	10	10	8	20	25	20	18	14	21	26	24	16			
Quantity Saved (m ³)	5	5	4	9	12	9	8	7	10	12	11	7			
Monthly Consumption with RW Harvesting (m ³)	23	23	24	19	16	19	20	21	18	16	17	20			
Monthly Bill with RW harvesting (Rs.)	173	173	191	98	83	98	104	135	95	80	86	117			
Amount Saved (Rs.)	194	194	176	268	284	268	262	232	271	287	280	250	2967	67%	
4.0m ³ Tank															
No of Successful days	12	12	9	22	27	22	20	15	22	27	26	18			
Quantity Saved (m ³)	6	6	4	10	13	10	9	7	10	13	12	8			
Monthly Consumption with RW Harvesting (m ³)	22	22	24	18	15	18	19	21	18	15	16	20			
Monthly Bill with RW harvesting (Rs.)	154	154	182	92	77	92	98	126	92	77	83	104			
Amount Saved (Rs.)	213	213	185	274	290	274	268	241	274	290	284	262	3068	70%	
5.0m ³ Tank															
No of Successful days	14	13	10	22	29	24	21	17	23	28	26	20			
Quantity Saved (m ³)	7	6	5	10	13	11	10	8	11	13	12	9			
Monthly Consumption with RW Harvesting (m ³)	21	22	23	18	14	17	18	20	17	15	16	19			
Monthly Bill with RW harvesting (Rs.)	135	145	173	92	74	86	95	107	89	75	80	98			
Amount Saved (Rs.)	232	222	194	274	293	260	271	259	277	292	287	268	3151	72%	

Annex V – This presents the paper of “Rainwater harvesting in the context of changing social and economical trends in Colombo metropolitan area, Sri Lanka” published by Adhihetty A., Civil Engineer, National Water Supply & Drainage Board, Sri Lanka and Wickramasuriya S.S., Department of Civil Engineering, University of Moratuwa, Sri Lanka in the proceeding of the XI international conference on Rainwater catchment Systems organized by International Rainwater Catchment Systems Associations and was held in Mexico from August 25-29, 2003.



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RAINWATER HARVESTING IN THE CONTEXT OF CHANGING SOCIAL AND ECONOMICAL TRENDS IN COLOMBO METROPOLITAN AREA, SRI LANKA

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Abstract

The paper demonstrates how rainwater harvesting can satisfactorily reduce the social and economic impact on the population, resulting from development and increasing water tariff within the Colombo metropolitan area of Sri Lanka.

The vision of the government of Sri Lanka is to stimulate substantial growth, by the development of the Colombo metropolitan area, which will be a hub of economic and development activities in the 21st century. This will result in a major increase in the demand for suitable water, which is presently met by surface water resources. The population in the area will encounter serious problems of using ground water due to a lack of lands to dig wells and the issue of increasing ground water pollution.



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Thus people will have to depend on pipe borne water for their domestic needs. However due to increasing water tariff, many have found difficulty in paying their water bills. Non-payment of water bills result in disconnection of water supply. Unlike other services such as electricity and telecommunication, water is a critical human need and people experience adverse social pressures without access to adequate amounts of water. Hence it is vital to seek alternative measures urgently.

The use of rainwater as a supplement to pipe borne water to fulfill the non-potable water demand, will be an attractive alternative for the water problem in Colombo metropolitan area. Developing rainfall frequency curves based on past rainfall data is a valuable tool for decision makers to make a rapid preliminary assessment about the likelihood of success of a rainwater harvesting project. The methodology requires daily demand, area harvested and storage capacity as parameters.

The cost effectiveness of using rainwater harvesting as a supplementary source to pipe borne water to alleviate the social and economic burdens of the population, is demonstrated by a cost analysis.

Introduction - Problems of Urbanization and Groundwater

Rainwater systems are one of the oldest systems used in the world to fulfill the water needs of the people. (Fujimura 1982; Smith 1984) In many isolated areas and islands it is the major source of water supply. There are other areas where rainwater is used as a supplementary source.

The paper demonstrates how effectively rainwater can be used as a supplement to pipe borne water to fulfill non-potable water demand with the changing social and economic trends in the Colombo Metropolitan area, Sri Lanka. In the analysis, graphical representation is used to make a rapid preliminary assessment for selecting an economical size of the storage tank for individual houses. The collecting system is considered as the available roof area of the household concerned.

The Colombo metropolitan area will be a hub of economic and development activities in the 21st century. This will result in a major increase in the population within the area and also change the land use pattern significantly. In addition, the demand for services such as water, electricity, telecommunication, health, and education etc. will continue to increase substantially. The water supply to the Colombo metropolitan area is presently met by surface water resources, which are utilized almost to capacity.

Population and land use pattern has a direct impact on the quality of life within the city. The Colombo city would have an estimated population of 2.5 million by 2010 (UDA 1998). According to Fig. 1, the population density in the area could be expected to be doubled or more every 50 years. Between 1921 and 1971 the population density increased from 73 persons per hectare to 146 persons per hectare respectively. Although there was a slight decrease in the rate of population growth during the period 1971 –

1981, it started increasing at a higher rate once again. Therefore by year 2010, population density is expected to be 195 persons per hectare or more.

According to Table 1, the urban built up area alone has increased by almost 50% during the 15-year period 1981 – 1996. Town planners have identified that there is a massive decrease in the extent of land under perennial crops and paddy cultivation, due to the increase in urban built up area.

The high population density combined with increasing urban built up area and homestead due to development activities in the area, has resulted in land being covered with rooftops, roads and parking lots. Therefore attempts to develop ground water, as a reliable source to meet the growing demand for water will encounter serious problems, due to a lack of land to dig wells and the risk of ground water pollution.

Pipe borne Water and Increasing Water Tariff

Due to the scenario just mentioned, people have no other alternative but to depend on pipe borne water for their domestic needs due to the problems of developing ground water resources in the area.

The price of pipe borne water increases frequently due to high capital and operational costs and therefore is becoming more burdensome to the consumer. According to an economic analysis of the National Water Supply & Drainage Board (NWS&DB), the cost of a unit of water (ie. 1 m³) was Rs. 20.20 in year 2001 and Rs.22.69 in year 2002. (Tariff structure, NWS&DB) However the NWS&DB subsidizes the cost of domestic water up to certain limits. In year 2001 the subsidy was up to 25 m³ for a household and in year 2002 it was reduced to 20 m³ for a household. There are no subsidies for the non-domestic tariff. Both domestic and non-domestic prices of water have increased with time. (Table 2 & Table 3) **Domestic** water tariff has continued to increase during the last twenty-one years period 1981 – 2002. There has been a drastic increase in water tariff from year 2001 to 2002 for the usage blocks between 21 –25 m³, 26 – 30 m³ and 31 – 40 m³ varying from 50% to almost 100%.

According to Table – 4 it is clear that the NWS&DB tariff structure shows an enormous price difference for the usage blocks of 15 - 20 m³ to 21 - 25 m³ exceeding 200% from year 1984 onwards.

In addition to the prices in the water tariff, NWS&DB applies value added tax for households whose consumption is more than 25 m³ per month. If the consumption is more than 25 m³ a tax applies from the first unit of consumption.

It is not surprising that due to increasing water tariff many have found difficulties in paying their water bills. Non-payment of water bills results in disconnection of water supply. According to Table – 5 in the year 2001 the number of disconnections varied between 5% - 10% of the total number of connections. The percentage number of disconnections has rapidly increased and more than doubled in four out of five Area Engineers' divisions over the three-year period 1998 – 2001.

Unlike other services such as electricity and telecommunication, water is a critical human need and people experience much hardship without an adequate quantity of water.



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Analysis of Water Demand

The demand for water has continued to escalate rapidly due to development of the Colombo metropolitan area. The average domestic water demand per capita per day (lcpd) varies between 135 liters – 169 liters in the Colombo metropolitan area. (UDA 1998)

The demand for pipe borne water has increased enormously by 70% during the period 1998 – 2002 as indicated by the number of connections. (Table 6) According to the concept paper published in July 2002 by the Planning Unit of the NWS& DB, only 80% of the projected water demand within the Colombo metropolitan area can be fulfilled in 2020 - 2025 even with maximum water extraction from the existing water supply systems. Therefore, it is vital to seek appropriate solutions urgently to meet the impending water shortage.

Domestic water demand includes;

- Drinking
- Cooking
- Personal Hygiene
- Toilet Flushing
- Laundry
- Washing of utensils

Additional **domestic** water uses may include;

- Watering gardens (trees, flowers, vegetables, etc.)
- Water for animals
- Recreational uses
- Washing of vehicles

Between half to two thirds of the domestic water demand per person could be considered as potable water demand, which is needed for drinking, cooking and personal hygiene.

Therefore, considering the potable demand as 110 lpcd, the monthly potable water consumption for a six-member household would be almost 20 m³. This clearly shows that the NWS&DB tariff structure, which includes a subsidy, has been formulated in a manner so that the potable water demand could be met at an affordable price.



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Rainwater Harvesting

Use of rainwater as a supplement to pipe borne water to fulfil the non-potable water demand will be an attractive alternative to alleviate the water problem in the Colombo metropolitan area.

In a rainwater harvesting system, the main components are the catchment, delivery system and storage arrangement. The storage tank is usually the most expensive component in the system. Hence the success of a rainwater system will depend to a large extent on determining the appropriate size of the storage tank according to the rainfall pattern, daily demand and catchment area available. In this analysis, the catchment and delivery system correspond to the roof area available and roof gutter system respectively.

Colombo metropolitan area belongs to the wet zone of Sri Lanka and receives an average annual rainfall of 2000mm. Rainfall in the area is primarily bi-monsoonal but also fairly uniform during several months of the year. According to Fig 2, January and February are relatively dry months. The months of May, October and November receive more than 300mm of average monthly rainfall. All the other months get an average monthly rainfall of more than 100mm. A frequency analysis of daily rainfall data shows that 25% of the time there is a rainfall of 5mm or more and 15% of the time there is a rainfall of 10mm or more. The numbers of wet days are 45% where a wet day is defined as a day with a rainfall greater than or equal to 0.1 mm. (Fig3 & 4).

The Lanka Rainwater Harvesting Forum, Sri Lanka has been engaged in checking the quality of rainwater in Colombo metropolitan area and the results are due to be published in the future. Many studies have revealed that bacteriological contamination of rainwater can be prevented by the proper construction and maintenance of roof catchments and storage tanks. This will result in the availability of good quality water.

The following analysis illustrates the methodology of determining the economic size of the storage tank according to the rainfall frequency, available roof area and daily demand. This is followed by the computation of cost saving due to rainwater harvesting.

The curves of rainfall frequency are based on the ten-year period (1992 – 2001) of daily rainfall data. (Fig 3 & 4)

The Roof area - Storage graph is obtained using the following equation. $S = RAC_r$

S - Available supply in m^3

R - Daily Rainfall (mm)

C_r - Runoff coefficient

A - Catchment area in m^2

EXAMPLE

Assumptions

Number in the family	-	6
Catchment type	-	corrugated asbestos or tile roof
Runoff coefficient	-	0.85 (Johan Gould, Erick Peterson – 1979)
Available area to be harvested	-	100 m ²
Daily demand per capita per day	-	152 litres
Demand fulfilled by rainwater harvesting	-	1/3 of Total demand
Size of storage tank	-	3 m ³ (3000 litres)

Let

P_i – Depth of daily rainfall in mm (Fig. 4)

f_i – Frequency of rainfall P_i (number of days) in the period of record (Fig. 4)

p_i – Proportion of effective number of days of rainfall depending on time interval d_i (Fig. 7)

d_i – No of days of supply per effective day. (i.e. time interval)

N_i – No. of days of supply.

N – Total number of days of supply.

$$N_i = \sum(f_i * p_i * d_i), \quad N = \sum N_i \text{ (i = number of class intervals)}$$

The following method enables one to make a quick approximate estimate of the number of days the non-potable demand can be met through rainwater harvesting. It considers the storage condition of the tank and the corresponding number of effective days of rainfall.

The computation makes use of Figs 3,4,5,6 & 7.

Tank Condition	Full (100%)	¾ Full – Full (75%-100%)	½ Full – ¾ Full (50% - 75%)	¼ Full – ½ Full (25% - 50%)	Daily demand
P_i in mm	≥ 35	26.5 – 35	17.5 – 26.5	9 – 17.5	9 - 3
f_i (days)	16	11	17	22	33
p_i (proportion)	0.6	0.59	0.56	0.74	1
d_i (days)	10	7.5	5	2.5	1
N_i (days)	90	49	48	41	33

Total no. days non-potable demand can be met through rainwater harvesting = $\sum N_i$

= 261 (72%)

The above preliminary method of analysis does not consider the overlapping effect of wet spells. Further refinements are being incorporated in order to account for this effect.

Cost Analysis:

Monthly consumption	= $6 \times 152 \times 30 / 1000$	= 28 m^3
Potable water demand (2/3 of total demand)	= $28 \times 2/3$	= 18 m^3
Non potable water demand (1/3 total demand)	= $28/3$	= 10 m^3
Cost for potable water consumption according to 2002 tariff (Table 2)	= $10 \times 6.25 + 5 \times 2.50 + 3 \times 6.50$	= Rs. 94.50
Cost for non potable water consumption according to 2002 tariff (Table 2)	= $2 \times 6.50 + 5 \times 20 + 3 \times 45.00$	= Rs. 248.00
Value added tax (10%)		= Rs. 34.25
Total		= Rs. 376.75
Monthly saving of water bill	= $72\% \times 248.00$	= Rs. 179.0
% saved	= 48%	

From the analysis it is clear that using rainwater as a supplement to the pipe borne water to fulfil non-potable water demand will yield substantial savings on the water bills. Selecting the economical size of the storage tank for the available roof area and daily demand can maximize savings.

Successful Rainwater Harvesting Project in Colombo Metropolitan Area.**Millennium Information Technology Centre**

One of the foremost development activities in the Colombo metropolitan area was the Information Technology Village at Malabe. As a result, the Millennium Information Technology Centre was started as a joint venture between local and foreign investors. The mission of the Millennium Information Technology Centre is to produce software systems for the local and foreign market.

The Center is located in a land of 6.5 ha. extent. There are 270-300 employees working and their normal working hours are from 9.00 am to 6.00 pm.

- The water supply requirement of the organization is fulfilled by two main sources.
1. Potable demand met by NWS&DB pipe borne water supply system.
 2. Non-potable demand for landscaping, recreation and toilet flushing is met by rainwater harvesting using the roof and ground catchments.

The total roof area harvested is about 4000 m². Harvested water from roof catchments collects in three large ponds of sizes 1008m³, 340m³ and 280m³. Each pond is constructed adjacent to the respective building. The water collected in these ponds is used for toilet flushing and recreational uses. Excess flows from these ponds, surface runoff and outflow from septic tanks flow into another pond, which is used for landscaping. The out-flow from septic tanks is subjected to a cleaning processes by natural filtering and aeration before collecting in the pond. The excess water from all ponds gets collected in another large pond of volume 2250m³ and released out in an environmentally friendly manner.

It is reported that as a result of rainwater harvesting, the Millennium Information Technology Centre reaps a 40% reduction in its water bill.



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Conclusions

The rapidly increasing demand for water in the Colombo metropolitan area results in considerable social and economic problems for the population in the area. This paper shows that the use of rainwater as a supplement to the pipe borne water, to fulfill the non-potable demand will be an attractive solution that deserves serious consideration. The population within the Colombo metropolitan area will be able to reduce their water bills considerably by using rainwater harvesting. Furthermore, at the national level it would enable an additional population to use pipe borne water to fulfil their potable demand. The use of a longer period of daily rainfall data would yield more realistic estimates of the degree of success of a potential rainwater-harvesting project

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Table - 1

General Land use pattern of the Colombo Metropolitan Region		
Land use Category	Percentage share of the total	
	1981	1996
1. Urban Built Up	12.2	17.6
2. Homestead	21.2	22.0
3. Trees & Other Perennial Crops		
- Tea	0.3	0.3
- Rubber	29.6	25.8
- Coconut	7.9	6.3
- Others	3.4	2.7
4. Cropland		
- Paddys	15.2	12.7
- Others	1.2	3.3
5. Natural Forest		
- Dense	1.9	0.9
- Open	0.3	1.9
- Plantation		0.3
6. Shrub & Grass	1.8	1.6
Wetland	1.6	1.3
8. Water	3.3	3.3
9. Barren Land	0.01	
Total	100	100

Source - District land use maps 1:100000, Survey Department

Computation based on reconnaissance survey and assumptions, UDA - 1996

Table - 2

Water Tariff - National Water Supply & Drainage Board - Rs. / Unit (m³)**Domestic**

Water Consumption (m ³)	81/83	1984	1990	1991	1991	1992	1993	1994	1997	1997	1998	1999	2001	2002
		Jan	Apr	Jan	Aug	Jan	Jan	Jan	Jan	Jan	Oct	Mar	Aug	Jan
0-10 (including service charges)	0.20	0.20	0.00	1.50	1.10	1.15	1.35	1.35	2.10	2.50	3.00	3.50	5.00	6.25
11-20	11-15	0.75	1.00	1.00	1.50	1.00	1.10	1.20	1.30	1.50	1.80	2.50	2.75	2.00
	16-20													5.00
21-25	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	5.00	6.00	7.50	9.50	13.00	20.00
26-30	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	9.60	12.00	15.00	18.00	24.00	45.00
31-40	1.75	5.50	5.50	8.00	7.00	7.50	8.50	9.40	12.50	15.00	18.00	20.00	30.00	45.00
41-50	1.75	5.50	5.50	8.00	7.00	7.50	8.50	12.00	18.00	20.00	20.00	25.00	40.00	45.00
Over 50	1.75	5.50	11.00	19.50	19.50	20.00	25.00	25.00	32.00	35.00	35.00	38.00	45.00	45.00

Source - NWS&DB

Table - 3

Water Tariff - National Water Supply & Drainage Board - Rs. / Unit (m³)**Non Domestic**

Water Consumption (m ³)	81/83	1984	1990	1991	1991	1992	1993	1994	1997	1997	1998	1999	2001	2002
		Jan	Apr	Jan	Aug	Jan	Jan	Jan	Jan	Oct	Mar	Aug	Jan	Jan
Govt. Institutions and Commercial	2.75	5.50	11.00	19.50	19.50	20.00	21.00	22.00	25.00	25.00	27.50	30.00	35.00	42.00
Tourist Hotels	9.00	9.00	16.50	25.00	25.00	27.00	27.00	27.00	27.00	27.00	30.00	30.00	35.00	42.00
Industries	5.50	9.00	16.50	25.00	25.00	25.00	25.00	25.00	25.00	25.00	27.50	30.00	35.00	42.00
Shipping	9.00	15.00	50.00	75.00	75.00	80.00	80.00	80.00	80.00	100.00	110.00	120.00	125.00	140.00

Source - NWS&DB

Table - 4

Tariff Increase - According to the Water Consumption**Domestic**

Water Consumption (m ³)	81/83	1984	1990	1991	1991	1992	1993	1994	1997	1997	1998	1999	2001	2002
		Jan	Apr	Jan	Aug	Jan	Jan	Jan	Jan	Jan	Oct	Mar	Aug	Jan
15 - 20 Rs / Unit (1m³)	0.75	1.00	1.00	1.50	1.00	1.10	1.20	1.30	1.50	1.80	2.50	2.75	5.00	6.50
% of tariff increase between 20 m ³ to 21 m ³ of water consumption	33	200	200	200	250	290	275	269	230	230	200	245	160	208
21 - 25 Rs / Unit (1m³)	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	5.00	6.00	7.50	9.50	13.00	20.00
% of tariff increase between 21 m ³ to 25 m ³ of water consumption	0	0	0	0	0	0	0	0	92	100	100	87	84	125
26 -30 Rs / Unit (1m³)	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	9.60	12.00	15.00	18.00	24.00	45.00
% of tariff increase between 26 m ³ to 31 m ³ of water consumption	75	83	83	78	100	88	89	96	30	25	20	11	25	0
31 - 40 Rs / Unit (1m³)	1.75	5.50	5.50	8.00	7.00	7.50	8.50	9.40	12.50	15.00	18.00	20.00	30.00	45.00

Source - NWS&DB

Table - 5

Disconnection due to non payment of water bills

Area Engineers' Divisions	No. Identified to be Disconnected due to non payment of bills											
	1998	Total No. of connections	% of disconnections from the total connections	1999	Total No. of connections	% of disconnections from the total connections	2000	Total No. of connections	% of disconnections from the total connections	2001	Total No. of connections	% of disconnections from the total connections
Colombo North (CB I)	874	23652	3.7	970	25526	3.8	—	29921	4.9	2436	32240	7.6
Colombo Central (CB II)	489	18589	2.7	590	21020	2.8	1279	22784	5.6	2231	23489	9.5
Colombo South (CB III)	749	21391	3.5	518	25395	2	1160	27842	4.2	2007	29222	6.9
Dehiwala	833	28073	3	1503	30752	4.9	1795	34412	5.2	1806	36832	4.9
Panadura	121	5896	2	104	6285	1.7	79	6599	1.2	649	6969	9.3

Source : NWS&DB - Disconnection Unit

Table - 6

**No. OF CONNECTIONS IN COLOMBO
METROPOLITAN AREA**

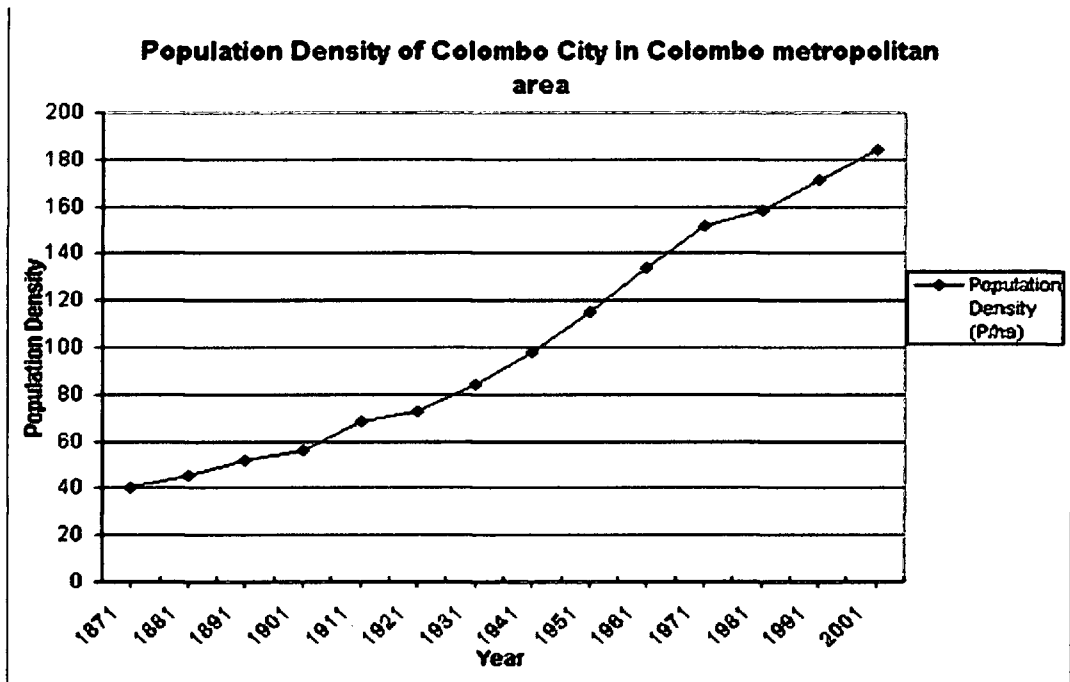
Year	No of Connections
1998	215327
1999	244926
2000	278714
2001	315938
2002	364878

Source : NWS&DB - COMMERCIAL SECTION



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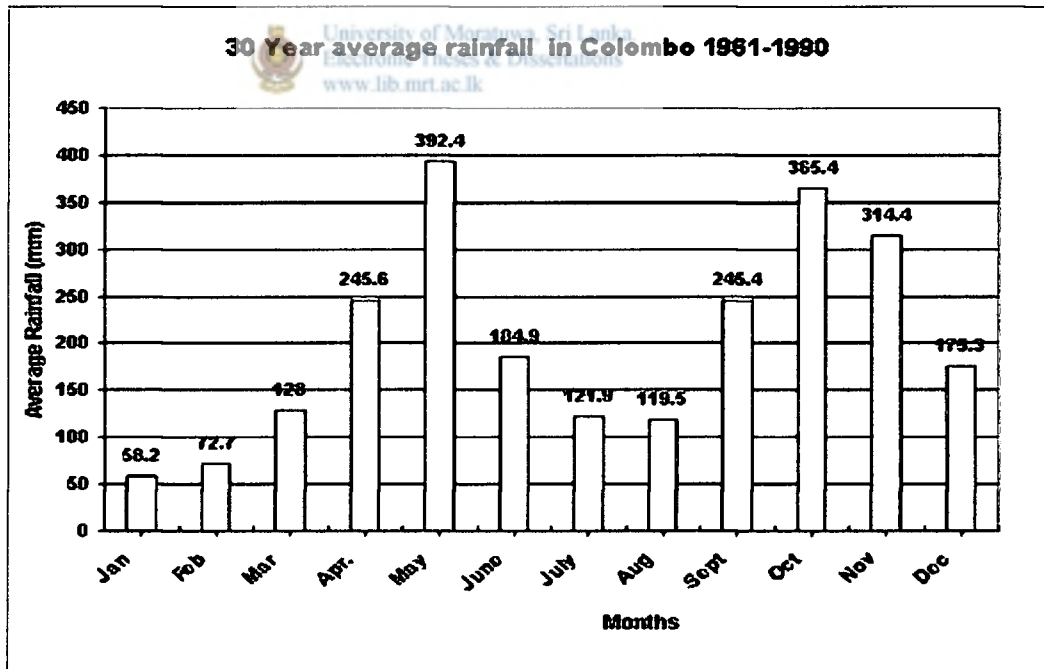
Fig - 1



Source :- Centenary Volume , CMC 1963

Urban Development Authority 1996

Fig - 2



Source :- Meteorology Department - Sri Lanka

Fig - 3

Probability Curve of Rainfall Frequency - Roof Area - Storage

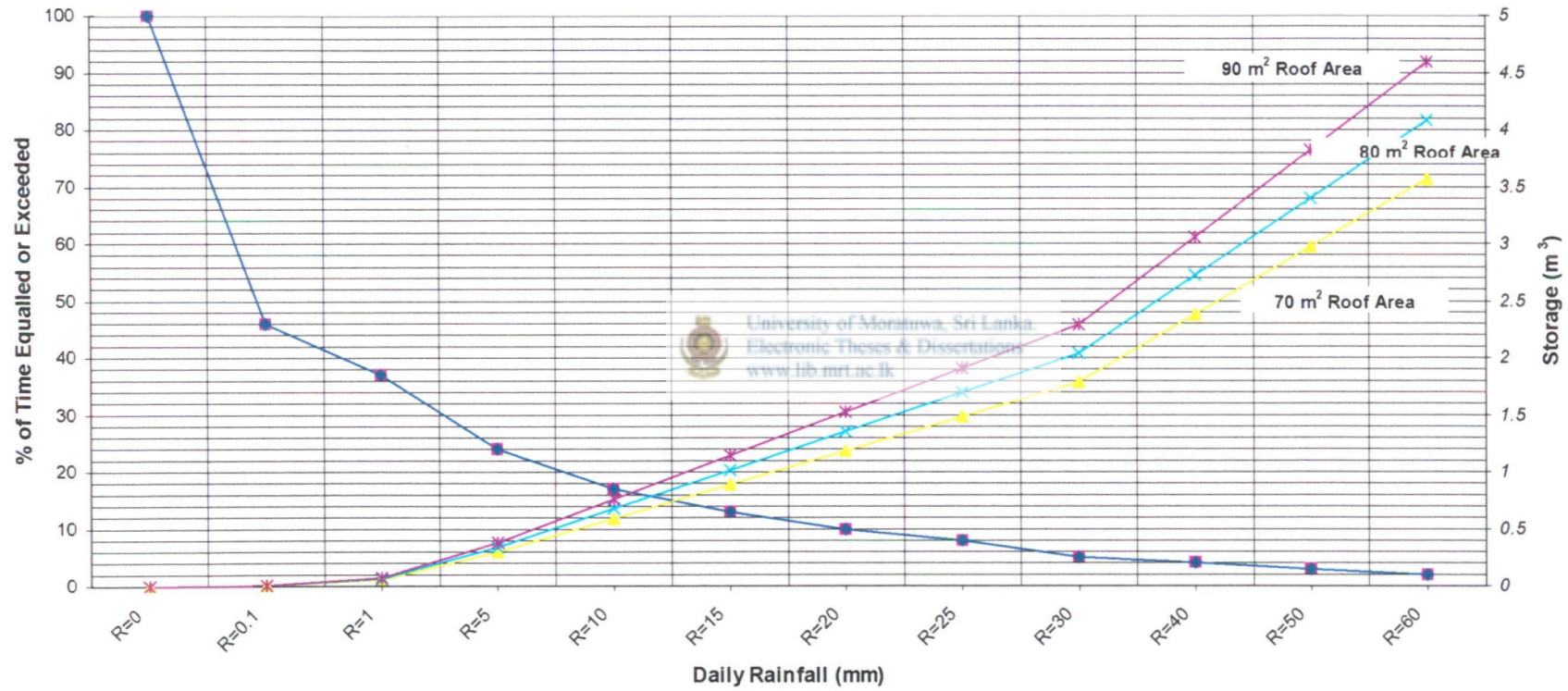


Fig - 4

Probability Curve of Rainfall Frequency - Roof Area - Storage

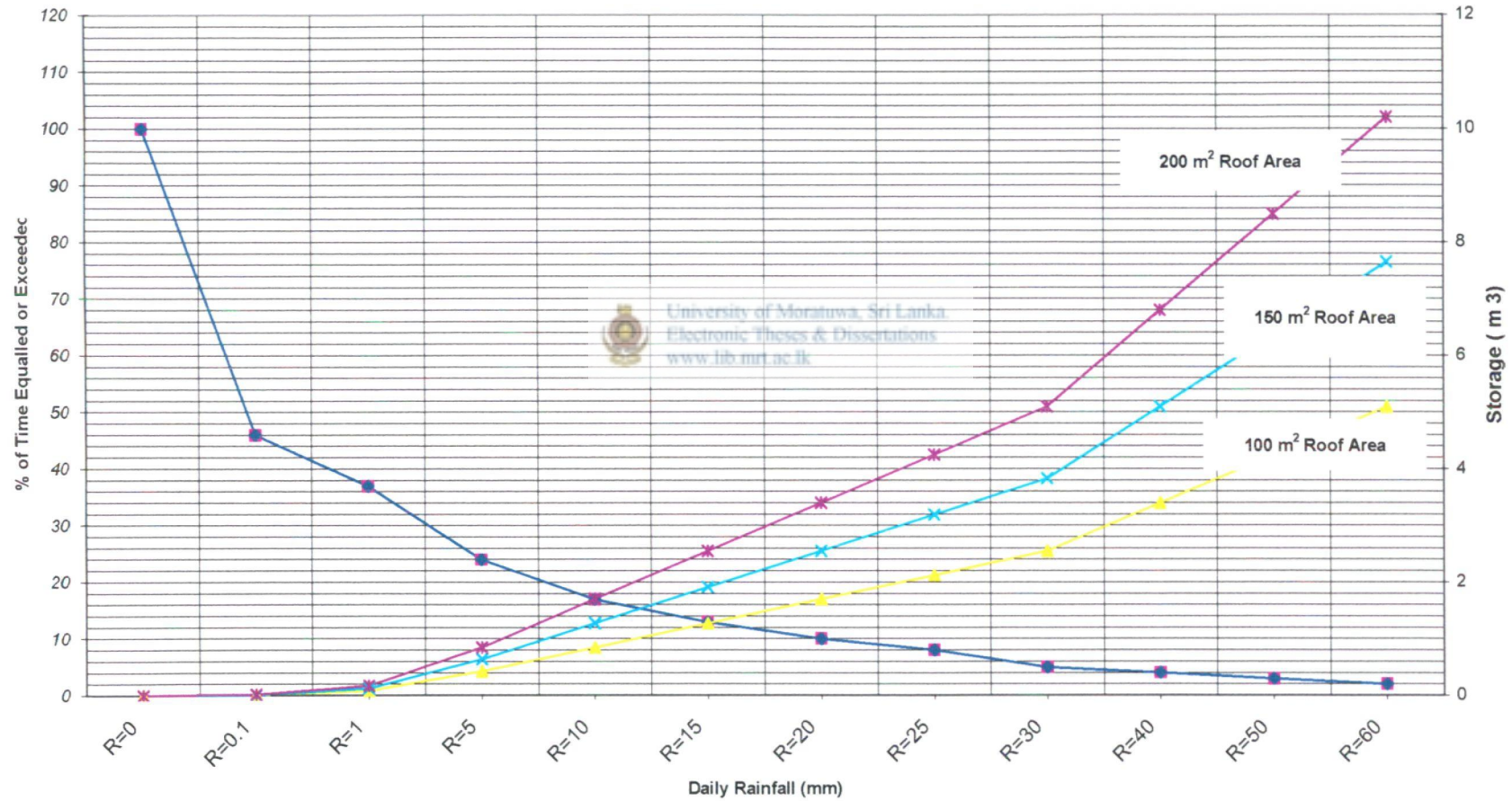
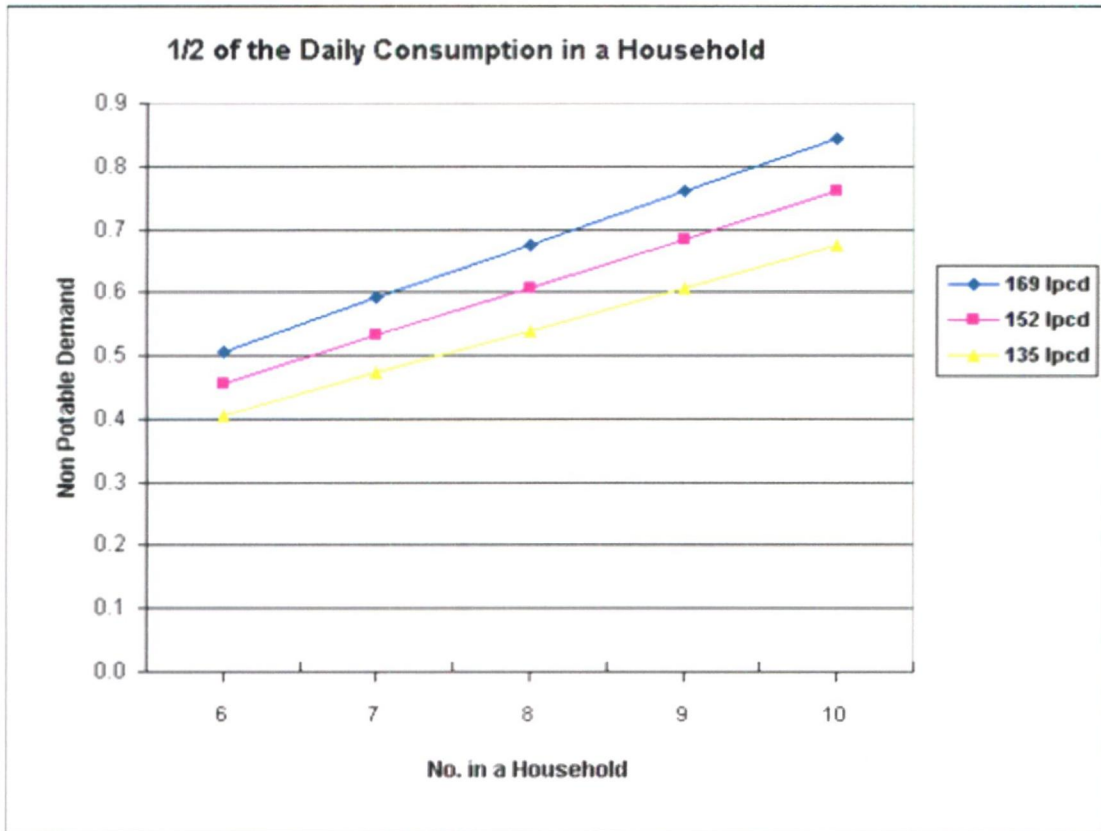


Fig - 5



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Fig - 6

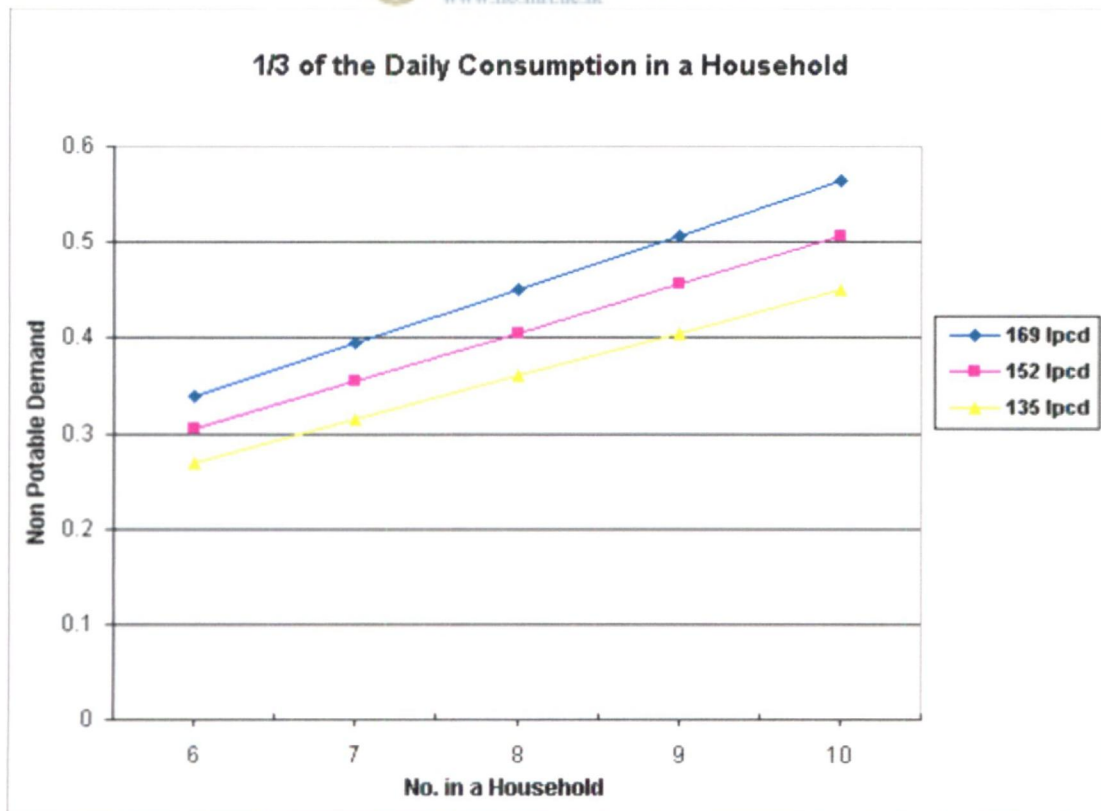


Fig 7

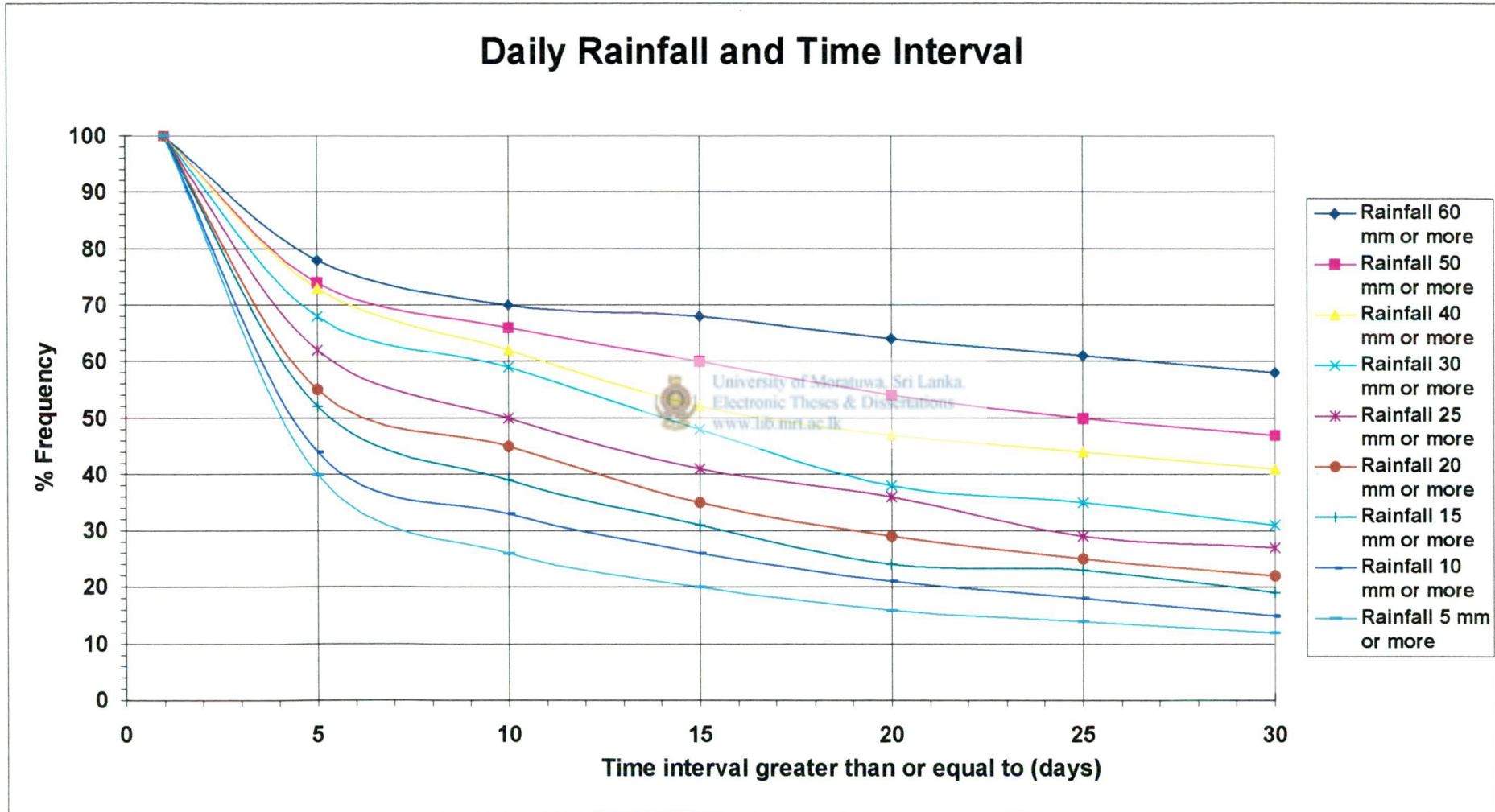


Table 2.1.1

Population in different centers of Colombo metropolitan area

Centre	Extent (Ha.)	Population 1996	Estimated Population 2010
Colombo	4,020	638,700	774,500.00
Kotte	5,990	110,450	161,000.00
Maharagama	-	121,000	176,000.00
Battaramulla	3,195	122,546	178,500.00
Piliyandala	3,817	97,225	141,500.00
Kolonnawa	2,440	65,000	82,000.00
Kotikawatta		60,400	76,500.00
Mulleriyawa		44,000	55,500.00
Biyagama	10,000	200,000	305,000.00
Homagama	9,450	166,000	254,000.00
Dehiwala-Mt. Lavinia	2,107	212,470	276,500.00
Moratuwa	1,990	190,400	265,500.00
Ekala	309	4,290	5,000.00
Ja-Ela	7,920	50,000	65,000.00
Kandana		44,500	56,500.00
Ragama		47,000	59,500.00
Peliyagoda		29,700	36,500.00
Dalugama	2,220	57,000	74,000.00
Kelaniya		43,000	56,500.00
Wattala-Mabole	4,620	35,300	43,000.00
Handala		55,500	67,500.00
Welisara		37,500	45,500.00
Grand Total	81,469	2,433,977	3,255,500

Source: Urban Development Authority

Table - 2.1.2

General Land use pattern of the Colombo Metropolitan Region		
Land use Category	Percentage share of the total	
	1981	1996
1. Urban Built Up	12.2	17.6
2. Homestead	21.2	22.0
3. Trees & Other		
Perennial Crops		
- Tea	0.3	0.3
- Rubber	29.6	25.8
- Coconut	7.9	6.3
- Others	3.4	2.7
4. Cropland		
- Paddys	15.2	12.7
- Others	1.2	3.3
5. Natural Forest		
- Dense	1.9	0.9
- Open	0.3	1.9
- Plantation		0.3
6. Shrub & Grass	1.8	1.6
Wetland	1.6	1.3
8. Water	3.3	3.3
9. Barren Land	0.01	
Total	100	100

Source - District land use maps 1:100000, Survey Department

Computation based on reconnaissance survey and assumptions, UDA - 1996

Table – 2.1.3

List of locations bacteriological examination of water samples give unsatisfactory results in Colombo metropolitan area.

Year 2002

Source	Location
Well	Cocacola Beverage Co.
Well	CBL Developments (Pvt) Ltd., No. 2A, Lake Drive, Colombo 8
Well	25, Main Street, Panadura
Well	15A, P.T. De Silva Mawatha, 1 st Road, Dehiwela
Tube Well	Bentota Power Generators (Pvt) Ltd., 395 1/1, Kelaniya
Well	No. 289, Bokundara Road, Makuluduwa, Piliyandala
Well	145/8, Bandaranayake Mawatha, Katubedda
Well	119, Galle Road, Henamulla, Panadura
Well	No. 161/1, Hewagama, Kaduwela
Well	No. 116, Wijerama Road, Udahamulla, Nugegoda
Well	80/07, Furmrod Kattuwa, Negombo
Well	157/9, Averiwatte Road, Wattala
Well	150D, High Level Road, Nugegoda
Well	Cliften Industries, Hekitta, Wattala
Well	Unical (Ceylon) Ltd., Lady Catherine Estate, Ratmalana
Tube Well	No. 360/A, Preethipura, Kalalgoda, Pannipitiya
Well	Navy Camp, Rangala, Colombo 01

Source	Location
Well	96/2, Watarappala Road, Mt. Lavinia
Well	20, Hendala Road, Wattala
Well	155/7, Messenger Street, Colombo 12
Well	175, Sri Saranankara Road, Kalubowila, Dehiwela
Well	341, Miriswatta, Piliyandala
Well	21, Desarun Road, Mount Lavinia
Well	683, Kattiyawatte Road, Mabole, Wattala
Well	Prajamoola Sansadaya, Weragala, Padukka
Well	Suduwella Road, Wekada, Panadura
Well	33, Amarasekera, Mawatha, Colombo 03
Well	11, Model Town, Katubedda
Well	17/A, Embillawatta Road, Boralessgamuwa
Well	No. 16, Bowitiya Road, Sirimal Uyana, Ratmalana
Well	11, Model Town, Ratmalana
Well	23, Charles Avenue, Colombo 03
Well	43/3, Yoyin Mawatha, Bellattanra, Boralessgamuwa
Tube Well	56, School Lane, Colombo 03
Well	Trend Setters (Pvt) Ltd., Modarawila, Panadura
Tube Well	142/12, Galle Road, Colombo 03
Well	Hotel Udawatte, Thulhiriya
Well	30/27, Sumeda Mawatha, Walpola, Mulleriyawa New Town

Source of Sample	Location
Well	59/1, First Floor, ICC Land Building, Galle Road, Colombo 3
Well	No.18,Shady Grove Avenue,Colombo 8
Well	Keththarama Road, Ganemulla
Well	Polhena, Madapatha
Well	100, Hotel Road, Mount Lavinia
Well	47/A, Horana Road, Galagedara, Padukka
Well	Engineer, Telecom Training Centre
Well	No. 33, Katukurunda Road, Moratuwa
Well	370/F2, Lake Road, Averihena, Hokandara South
Well	No. 183, Paraththa, Keselwatte
Well	123/5, Sri Dharmarama Road, Dematagoda
Well	293/4, Suramma Road, Gorokapola, Panadura
Well	490, Galle Road, Ratmalana
Well	Kolonnawa
Well	145, UDA Industrial Estate, Homagama
Well	No. 195, Bandaragama Road, Kesbewa, Piliyandala
Well	No. 109/4, Madampitiya Road, Mahawatta, Panadura
Well	No. 94A, Pamankada Road, Colombo 5
Well	No. 29/5, 4 th Lane, Ratmalana
Tube Well	29.3, 2 nd Lane, Yakkala

Source of Sample	Location
Well	245, Galle Road, Moratuwa
Well	Welisara, Rajagiriya
Well	Lotus Road, Colombo 01
Well	High Level Road, Nogegoda
Well	21/17, 3 rd Lane, Abeyratne Mawatha, Boralesgamuwa
Well	No. 21, New Lane, Darga Town
Well	No. 20, Sirimaniya Road, Horethuduwa, Moratuwa
Well	Pitipana Live Stock Farm, Pitipana North, Homagama
Well	No. 33, Angulana Station Road, Moratuwa
Well	Orit Apparel Lanka (Pvt) Ltd., Industrial Park, Avissawella
Well	Telecom Training Centre, Welisara University of Moratuwa, Sri Lanka
Well	262, Gangarama Road, Thumbowila, Piliyandala
Well	Fascination Exports (Pvt) Ltd., Kahapola, Piliyandala
Well	104/3, Katuwana Road, Homagama
Well	No. 128/6, Anderson Road, Nedimala, Dehiwela.
Well	DNP Garments Lanka (Pvt)Ltd., No. 33, Angulana Station Road, Angulana, Moratuwa

The samples are microbiologically unsatisfactory. Because No. of coliform present in water is >10 and present of E coli.

Source: NWS&DB Laboratory

Table 2.1.4

New Developments Requested Water Supply under Condominiums in the Colombo metropolitan Area

Item No	Developer	Date of Request	No of Housing units	Remarks
2003				
1	Ceylenco Homes International (Lotus Tower) Ltd No 79 Hydepark Corner,Colombo -02	18-Jun-03	176	Commercial Mixed developoment Project , No 116 , Galle Rd , Col- 03.
2	SLLRDC Lunawa Resettlement Project	4-Aug-03	700	Total Demand - 330 m ³ Other Improvements in the Site - 218 m ³
Total			876	
2004				
3	Premier Pacific Topaz (Pvt) Ltd No 6, 37th lane , Queens Rd ,Colombo - 03	29-Apr-04	164	No 265, Galle Rd., Col 03.
4	Havelock City Project - Col - 05 (Wellawatte Sawing Mill)			Details with DGM(CMR- Dev.) Mr.Ferdinando. Total Demand - 6750m³
5	Ceylenco Housing & Real Estate Company Ltd No 151 Dharmapala Mw,Colombo -07.	1-Jul-04	324	No 153 , Elvitigala Mw , Col - 08.
6	State Engineering Corporation of SriLanka.	9-Jul-04	100	Crescat Condotel Apartment Building , No 89 , Galle Rd , Col - 03 .
7	National Housing Development Authority.	16-Jul-04	400	Mixed Developoment Project. Kirimandala Rd , Col - 05
8	The Design Group Five International (Pvt) Ltd, Iceland Residencies at NO 49/4 Galle Face Terrace, Colombo - 03.	9-Nov-04	104	No 49/4 ,Galle Face Terrace , Col - 03.
Total			1350	
2005				
9	Hemaka De Silva , No 107/15 ,Buthgamuwa Rd , Rajagiriya.	17-Jan-05	68	No 107/15 ,Buthgamuwa Rd , Rajagiriya.
10	Pioneer Properties & Lee Hedges Ltd , NO 418 ,R.A.De.Mel Mw , Colombo - 03	28-Jan-05	307	No 418 R.A.D.De Mel Mw, Col - 03.
11	CT Properties Ltd , No 10, Station Road, Colombo - 04.	28-Feb-05	96	No 51 (Empire Residential) , Braybrooke Place,Colombo - 02. Commercial Mixed developoment Project
12	Sierra Property Development (Pvt) Ltd. No 62 , Dr.N.M.Perera Mw , Colombo - 08.	15-Feb-05	32	No 62 & 64,Dr.N.M.Perera Mw , Col - 08.

Item No	Developer	Date of Request	No of Housing units	Remarks
13	Mr.S.H.M.Jawahir, No 10, Clifton Lane, Colombo - 09.	10-Mar-05	12	No 58, Sri Mahinda Dharma Mw,Col - 09
14	Movi Engineers (Pvt) Ltd,1st Floor,Orchard Plaza,Colombo - 06.	11-Mar-05	24	No 181/1,W.A.Silva Mw , Colombo 06
15	Devi Property Development (Pvt) Ltd,No 131 , Sea Street , Colombo - 11.	21-Apr-05	32	No 754/7 , KollupitiyaRd,Col-04.
16	Good HopeProperty Developers (Pvt) Ltd,No 40 2/1 , Galle Rd , Colombo - 04.	6-May-05	34	No 37 , Sagara Rd , Col-04.
17	Land Maark Engineering (Pvt) Ltd, No 33 , Rudra Mw , Colombo - 06.	2-Jun-05	18	No 37 , Rudra Mw, Col-06.
18	Span Engineering (Pvt) Ltd, No 45/15 A , Fredrica Rd , Colombo - 06.	7-Jun-05	48	No 28 , Kinross Avenue , Col-06.
19	The Design Group Five International (Pvt) Ltd, Residential Development , No 34 Muhandiram Mw, Colombo - 05.	5-Jul-05	28	No 34 , Muhandiram Mw , Col-05.
20	Coral Construction (Pvt) Ltd , No 03, 1st Chapel Lane , Colombo - 06	4-Aug-05	28	No 18 , 37th Lane , Col - 06.
21	Sri Ram Property Developers (Pvt) Ltd No 140 , Main Street , Colombo - 11	24-Jul-05	28	No 30 , Kinross Avenue , Col-06.
22	Developer , No 23- 4/4 Arethussha Lane , Colombo - 06.	23-Aug-05	24	No 16 , 1st Chapal LANE , Col-06.
23	Sri Ram Property Development (Pvt) Ltd , No 140, Main Street , Colombo - 11	24-Jul-05	28	No 30 , Kinross Avenue , Col-04.
24	Lintan Investments (Pvt) Ltd , No 07, Kirimandala Mw ,Nawala	8-Sep-05	152	No 651/1, Bloemendhal Rd , Col-13.
25	Developer , No 40 Arethussha Lane , Colombo - 06.	29-Aug-05	18	No 40, Arethussha Lane , Col - 06.
26	Maga Developments Lanka (Pvt) Ltd , No 200 , Nawala Rd, Narahenpitiya, Colombo - 05.	10-Sep-05	42	No 8, Magazine Rd , Colombo - 08.
27	Ceylinco Housing Development Corporation (Pvt) Ltd , No 56 , Galle Rd , Colombo -03.	12-Sep-05	24	No 188, Havelock Rd , Colombo - 05.
28	Shanthinlayam Property Developers (Pvt) Ltd , No 7/5 Hamers Avenue , Colombo - 06	27-Sep-05	32	No 27, Fedrica Rd , Colombo - 06 .
29	City Construction Contractors (Pvt) Ltd , No 25 Galle Face Centre Rd , Colombo - 03	28-Sep-05	36	No 24 & 30 ,10th Lane , Colombo - 03 . Initial Filling Capacity of Swimming Pool is 89.00 m ³ and 0.2 Liters per Second
30	T F C Homes (Pvt) Ltd ,EML Buildings ,1st Floor ,No 61 ,W.A.D.Ramanayake Mw , Col -02	25-Oct-05	120	Rodney Street , Borella.
31	T F C Homes (Pvt) Ltd ,EML Buildings ,1st Floor ,No 61 ,W.A.D.Ramanayake Mw , Col -03	25-Oct-05	50	No 06 , Francis Rd , Col - 06.
32	PALAYAKAT Property Developers (Pvt) Ltd , No 5 Milagiriya Avenue , Col - 04	20-Oct-05	88	No 12 , Alexandra Rd , Col - 06.

Item No	Developer	Date of Request	No of Housing units	Remarks
33	Rush Builders (Pvt) Ltd , No 03 A , Dhammaraja Mw , Col - 03	12-Oct-05	64	No 209 , Grandpass Rd , Col - 14 .
34	Sunflower Engineering (Pvt) Ltd , No 71/1 C, 37th Lane , Col - 06.	24-Oct-05	18	No 55, 37th Lane , Col - 06.
35	Real Estate Exchange (Pvt) Ltd , No 27 , D.R.Wijewardena Mw , Colombo - 10	9-Sep-05	231	No 248 , Cyni Perera Mw , Col - 13. Mixed Developments
36	Real Estate Exchange (Pvt) Ltd , No 27 , D.R.Wijewardena Mw , Colombo - 10	9-Sep-05	179	No 48 , Watta , Baseline Mw , Colombo - 08. Mixed Developments
37	Arun "Z" Builders (Pvt) Ltd , No 06 , Hampden Lane , Colombo - 06.	7-Oct-05	36	No 8 , Hampden Lane , Col - 06.
38	Land Maark Engineering (Pvt) Ltd, No 33 , Rudra Mw , Colombo - 06.	4-Nov-05	27	No 27 & 29 , Rudra Mw , Col-06.
39	Jayampathy Herath Associates , No 53/7 , Horton Place , Colombo - 07 .	25-Nov-05	46	No 23 , Sagara Rd , Col-04.
40	Metropolitan Residencies (Pvt) Ltd, No 85 , Braybrooke Place , Colombo - 02.	10-Nov-05	12	No 45/1A , Baybrooke Street , Col-02 .
41	ECOHOMES Lanka (Pvt) Ltd, NO 49/9 , Fife Road , Colombo - 05.	24-Nov-05	27	No 208 , Kamathawatta Rd , Mediweelikade Rd , Rajagiriya.
42	Shanthinayam Property Developers (Pvt) Ltd , No 7/5 Hamers Avenue , Colombo - 06	12-Dec-05	28	No 119 , Manning Place , Colombo - 06.
43	Shanthinayam Property Developers (Pvt) Ltd , No 7/5 Hamers Avenue , Colombo - 07	12-Dec-05	32	No 7 , 40th Lane , Off Rajasinghe Rd , Colombo - 06.
44	Sikot Homes International (Pvt) Ltd , No 146 , Second Cross Street , Colombo - 11	14-Dec-05	32	No 15 , Clifford Place , Colombo - 03.
45	Developer , No 23- 4/4 Arethusha Lane , Colombo - 06.	22-Dec-05	24	No 14 , 1st Chapal Lane , Col-06.
46	Mr.M.M.Dhalib , No 27 , 1st Chapel Lane , Colombo - 06.	7-Dec-05	15	No 27 , 1st Chapal Lane , Col-06.
47	H.R.Residencies (Pvt) Ltd , No 90 , Maya Avenue , Colombo - 06.	6-Jan-06	26	No 90 , Maya Avenue , Col-06.
48	Muthukuda Property Developers (Pvt) Ltd , No 14 Maurice Place , Colombo - 05.	27-Dec-05	24	No 291/5 , Edward Avenue , Col-05.
49	Design PRO Chartered Architects , No G6 , Elvitigala Flats , Elvitigala Mw , Colombo - 08.	6-Jan-06	16	No 75 , Norris Canal Rd , Col-07.
50	Park Hall Developments (Pvt) Ltd , No 18 1 / 1 De Kretser Place , Colombo - 04.	16-Jan-06	17	No 15 , Charlemont Rd , Col-06.
51	Sun Grow Engineers (Pvt) Ltd , No 121 , Manning Place , Colombo - 06.	20-Dec-05	10	No 121 , Manning Place , Col-06.
52	Timoshonco Engineering Company (Pvt) Ltd , No 81/3 Manning Place , Colombo - 06.	25-Jan-06	28	No 7 , 55th Lane , Col-06.
53	Rayosun Construction (Pvt) Ltd , No 86/1 2/1 Fussels Lane , Colombo - 06.	27-Jan-06	42	No 36 , Shruberry Gardens , Colombo - 04.
54	Expo Property Developers (Pvt) Ltd , No 66 Park Street , Colombo - 02.	31-Jan-06	232	No 123 , Sangamitha Mw , Colombo - 13.
55	Sierra Property Development (Pvt) Ltd , No 20 , Skelton Gardens , Colombo - 05.	27-Jan-06	80	No 51 , Piyadasa Sirisena Mw , Colombo - 10.
	Total		2598	



Table -2.2

No. OF CONNECTIONS IN COLOMBO METROPOLITAN AREA	
Year	No of Connections
1998	215327
1999	244926
2000	278714
2001	315938
2002	364878

Source : NWS&DB - COMMERCIAL SECTION (2002)

Table 2.2a



Monthly pipe borne water consumption in different family sizes according to per capita demand and proportion of rainwater consumption

per capita demand	Monthly pipe borne water consumption with rainwater as a supplementary											
	180				155				135			
	0	1/3	1/2	2/3	0	1/3	1/2	2/3	0	1/3	1/2	2/3
Proportion of rainwater consumption												
N0 in the family												
12	65	43	32	21	56	37	28	18	49	33	24	16
11	59	40	30	20	51	34	26	17	45	30	22	15
10	54	36	27	18	47	31	23	15	41	27	20	13
9	49	33	24	16	42	28	21	14	36	24	18	12
8	43	29	22	14	37	25	19	12	32	22	16	11
7	38	25	19	12	33	22	16	11	28	19	14	9
6	32	22	16	11	28	19	14	9	24	16	12	8
5	27	18	14	9	23	16	12	8	20	14	10	7

Source - NWS&DB Design Manuals

Table - 3.1.1

Water Tariff - National Water Supply & Drainage Board - Rs. / Unit (m³)**Domestic**

Water Consumption (m ³)	81/83	1984	1990	1991	1991	1992	1993	1994	1997	1997	1998	1999	2001	2002
		Jan	Apr	Jan	Aug	Jan	Jan	Jan	Jan	Jan	Oct	Mar	Aug	Jan
0-10	0.20	0.20	0.00	1.50	1.10	1.15	1.35	1.35	2.10	2.50	3.00	3.50	5.00	6.25
11-20	0.75	1.00	1.00	1.50	1.00	1.10	1.20	1.30	1.50	1.80	2.50	2.75	2.00	2.50
21-25	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	5.00	6.00	7.50	9.50	13.00	20.00
26-30	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	9.60	12.00	15.00	18.00	24.00	45.00
31-40	1.75	5.50	5.50	8.00	7.00	7.50	8.50	9.40	12.50	15.00	18.00	20.00	30.00	45.00
41-50	1.75	5.50	5.50	8.00	7.00	7.50	8.50	12.00	18.00	20.00	20.00	25.00	40.00	45.00
Over 50	1.75	5.50	11.00	19.50	19.50	20.00	25.00	25.00	32.00	35.00	35.00	38.00	45.00	45.00

Source - NWS&DB (2002)

www.lib.mrt.ac.lk

Table - 3.1.1(a)

Water Tariff - National Water Supply & Drainage Board - Rs. / Unit (m³)**Non Domestic**

Water Consumption (m ³)	81/83	1984	1990	1991	1991	1992	1993	1994	1997	1997	1998	1999	2001	2002
		Jan	Apr	Jan	Aug	Jan	Jan	Jan	Jan	Jan	Oct	Mar	Aug	Jan
Govt. Institutions and Commercial	2.75	5.50	11.00	19.50	19.50	20.00	21.00	22.00	25.00	25.00	27.50	30.00	35.00	42.00
Tourist Hotels	9.00	9.00	16.50	25.00	25.00	27.00	27.00	27.00	27.00	27.00	30.00	30.00	35.00	42.00
Industries	5.50	9.00	16.50	25.00	25.00	25.00	25.00	25.00	25.00	25.00	27.50	30.00	35.00	42.00
Shipping	9.00	15.00	50.00	75.00	75.00	80.00	80.00	80.00	80.00	100.00	110.00	120.00	125.00	140.00

Source - NWS&DB (2002)

Table - 3.1.1b

Tariff Increase - According to the Water Consumption**Domestic**

Water Consumption (m ³)	81/83	1984	1990	1991	1991	1992	1993	1994	1997	1997	1998	1999	2001	2002	
		Jan	Apr	Jan	Aug	Jan	Jan	Jan	Jan	Jan	Oct	Mar	Aug	Jan	Jan
15 - 20															
Rs / Unit (1m ³)	0.75	1.00	1.00	1.50	1.00	1.10	1.20	1.30	1.50	1.80	2.50	2.75	5.00	6.50	
% of tariff increase between 20 m ³ to 21 m ³ of water consumption	33	200	200	200	250	290	275	269	230	230	200	245	160	208	
21 - 25															
Rs / Unit (1m ³)	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	5.00	6.00	7.50	9.50	13.00	20.00	
% of tariff increase between 21 m ³ to 25 m ³ of water consumption	0	0	0	0	0	0	0	0	92	100	100	87	84	125	
26 - 30															
Rs / Unit (1m ³)	1.00	3.00	3.00	4.50	3.50	4.00	4.50	4.80	9.60	12.00	15.00	18.00	24.00	45.00	
% of tariff increase between 26 m ³ to 31 m ³ of water consumption	75	83	83	78	100	88	89	96	30	25	20	11	25	0	
31 - 40															
Rs / Unit (1m ³)	1.75	5.50	5.50	8.00	7.00	7.50	8.50	9.40	12.50	15.00	18.00	20.00	30.00	45.00	

Source:- NWS&DB- Commercial Unit (2003)

Table - 3.1.2

Disconnection due to non payment of water bills

Area Engineers' Divisions	No. Identified to be Disconnected due to non payment of bills											
	1998	Total No. of connections	% of disconnections from the total connections	1999	Total No. of connections	% of disconnections from the total connections	2000	Total No. of connections	% of disconnections from the total connections	2001	Total No. of connections	% of disconnections from the total connections
Colombo North (CB I)	874	23652	3.7	970	25526	3.8	-	29921	4.9	2436	32240	7.6
Colombo Central (CB II)	489	18589	2.7	590	21020	2.8	1279	22784	5.6	2231	23489	9.5
Colombo South (CB III)	749	21391	3.5	518	25395	2	1160	27842	4.2	2007	29222	6.9
Dehiwala	833	28073	3	1503	30752	4.9	1795	34412	5.2	1806	36832	4.9
Panadura	121	5896	2	104	6285	1.7	79	6599	1.2	649	6969	9.3

Source : NWS&DB - Disconnection Unit (2002)

Table - 4.5

Water Tariff excluding service charge - Monthly consumption greater than 25m³

Unit	Cost in Rs.	Unit	Cost in Rs.	Unit	Cost in Rs.
1	1.25	34	623.75	67	2,257.25
2	2.50	35	673.25	68	2,306.75
3	3.75	36	722.75	69	2,356.25
4	5.00	37	772.25	70	2,405.75
5	6.25	38	821.75	71	2,455.25
6	7.50	39	871.25	72	2,504.75
7	8.75	40	920.75	73	2,554.25
8	10.00	41	970.25	74	2,603.75
9	11.25	42	1,019.75	75	2,653.25
10	12.50	43	1,069.25	76	2,702.75
11	15.00	44	1,118.75	77	2,752.25
12	17.50	45	1,168.25	78	2,801.75
13	20.00	46	1,217.75	79	2,851.25
14	22.60	47	1,267.25	80	2,900.75
15	25.00	48	1,316.75	81	2,950.25
16	31.50	49	1,366.25	82	2,999.75
17	38.00	50	1,415.75	83	3,049.25
18	44.50	51	1,465.25	84	3,098.75
19	51.00	52	1,514.75	85	3,148.25
20	57.50	53	1,564.25	86	3,197.75
21	77.50	54	1,613.75	87	3,247.25
22	97.50	55	1,663.25	88	3,296.75
23	117.50	56	1,712.75	89	3,346.25
24	137.50	57	1,762.25	90	3,395.75
25	157.50	58	1,811.75	91	3,445.25
26	227.75	59	1,861.25	92	3,494.75
27	277.25	60	1,910.75	93	3,544.25
28	326.75	61	1,960.25	94	3,593.75
29	376.25	62	2,009.75	95	3,643.25
30	425.75	63	2,059.25	96	3,692.75
31	475.25	64	2,108.75	97	3,742.25
32	524.75	65	2,158.25	98	3,791.75
33	574.25	66	2,207.75	99	3,841.25
				100	3,890.75

Source: NWS&DB Commercial Section (2003)

Table 4.5a

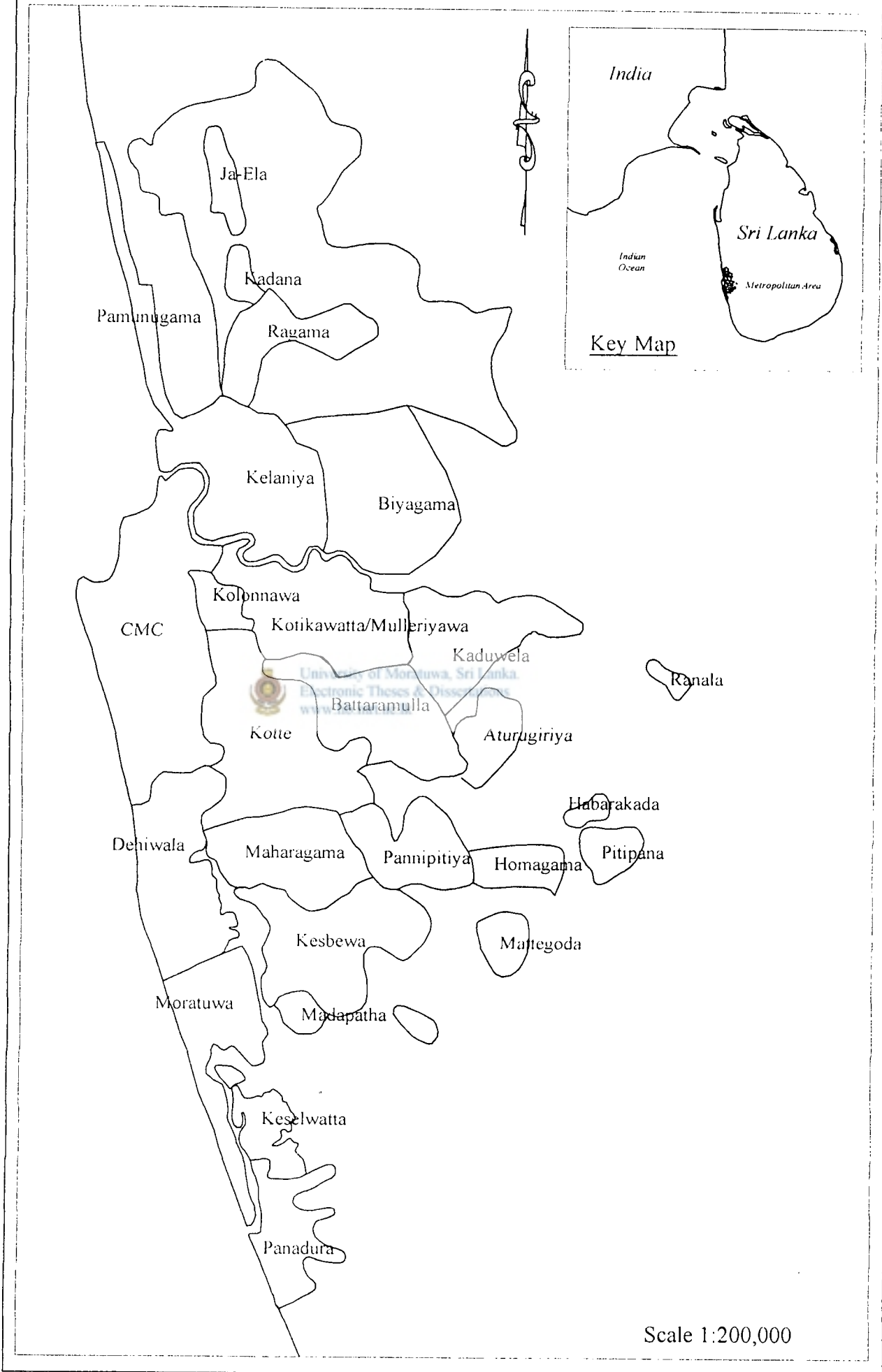
Water Tariff excluding service charge - Monthly consumption equal or less than 25m³

Units	Cost	Units	Cost	Units	Cost
1	1.25	9	11.25	17	38.00
2	2.50	10	12.50	18	44.50
3	3.75	11	15.00	19	51.00
4	5.00	12	17.50	20	57.50
5	6.25	13	20.00	21	77.50
6	7.50	14	22.50	22	97.50
7	8.75	15	25.00	23	117.50
8	10.00	16	31.50	24	137.50
				25	157.50

Source: NWS&DB Commercial Section (2003)

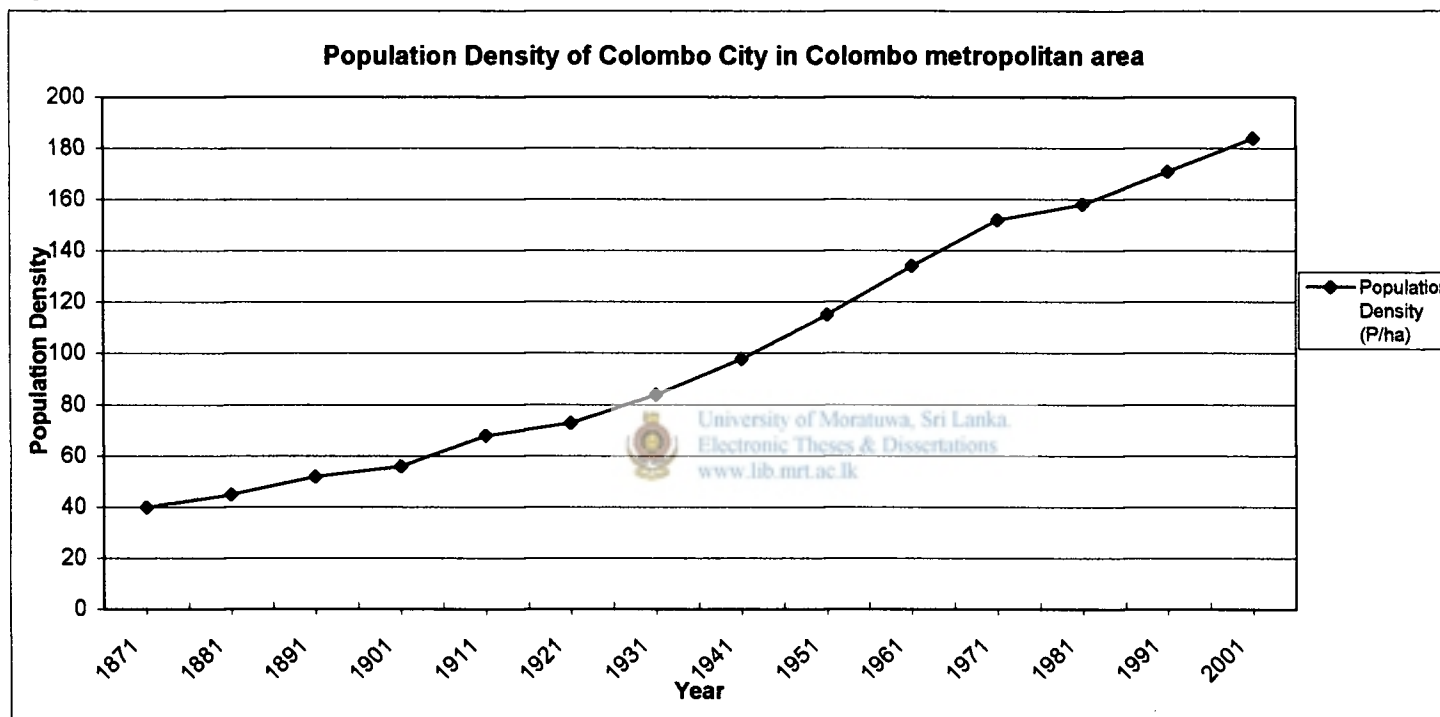
Fig 1.1

BOUNDARY OF COLOMBO METROPOLITAN AREA



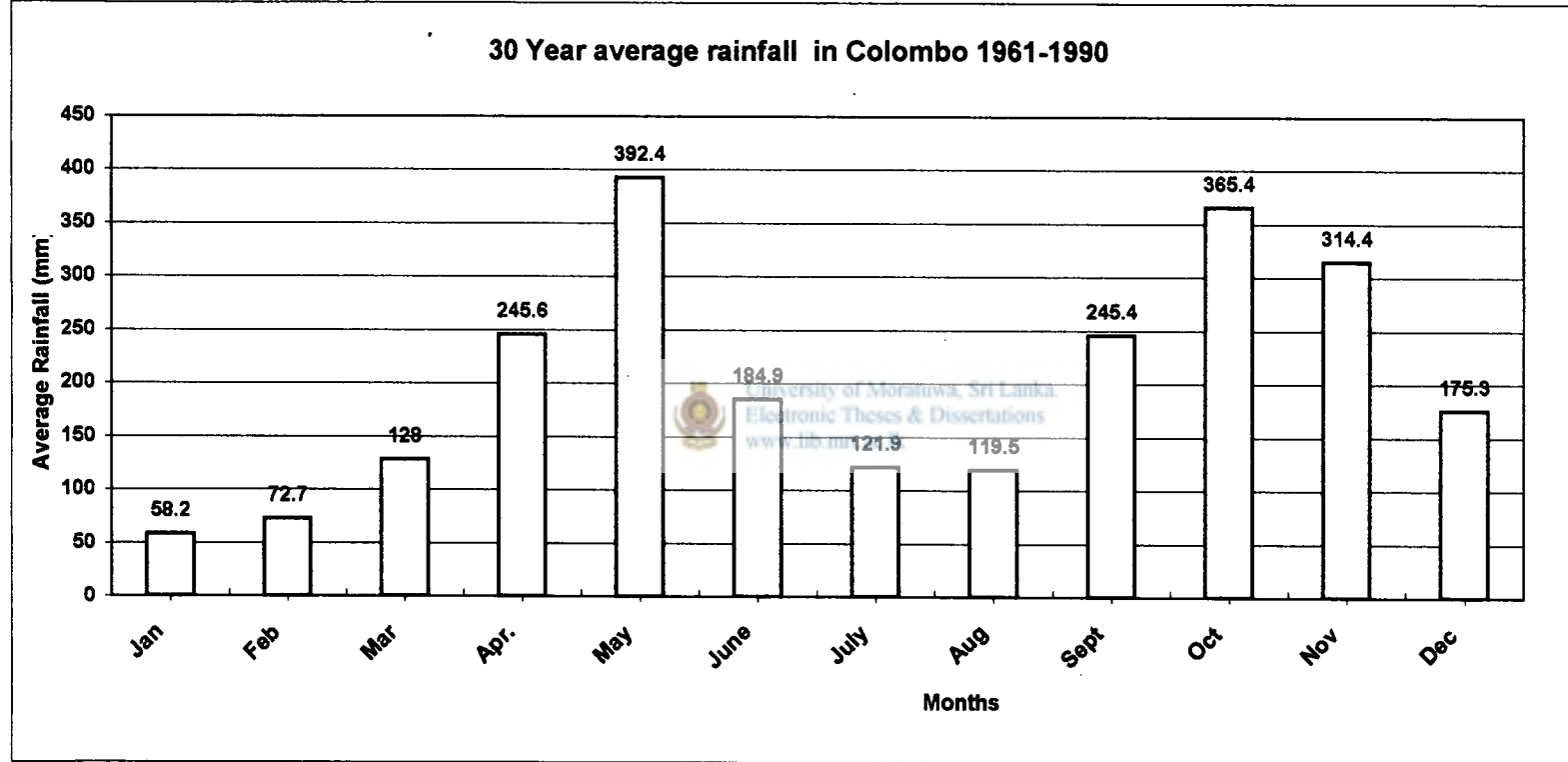
Scale 1:200,000

Fig - 2.1.1



Source :- Centenary Volume , CMC 1983
Urban Development Authority 1996

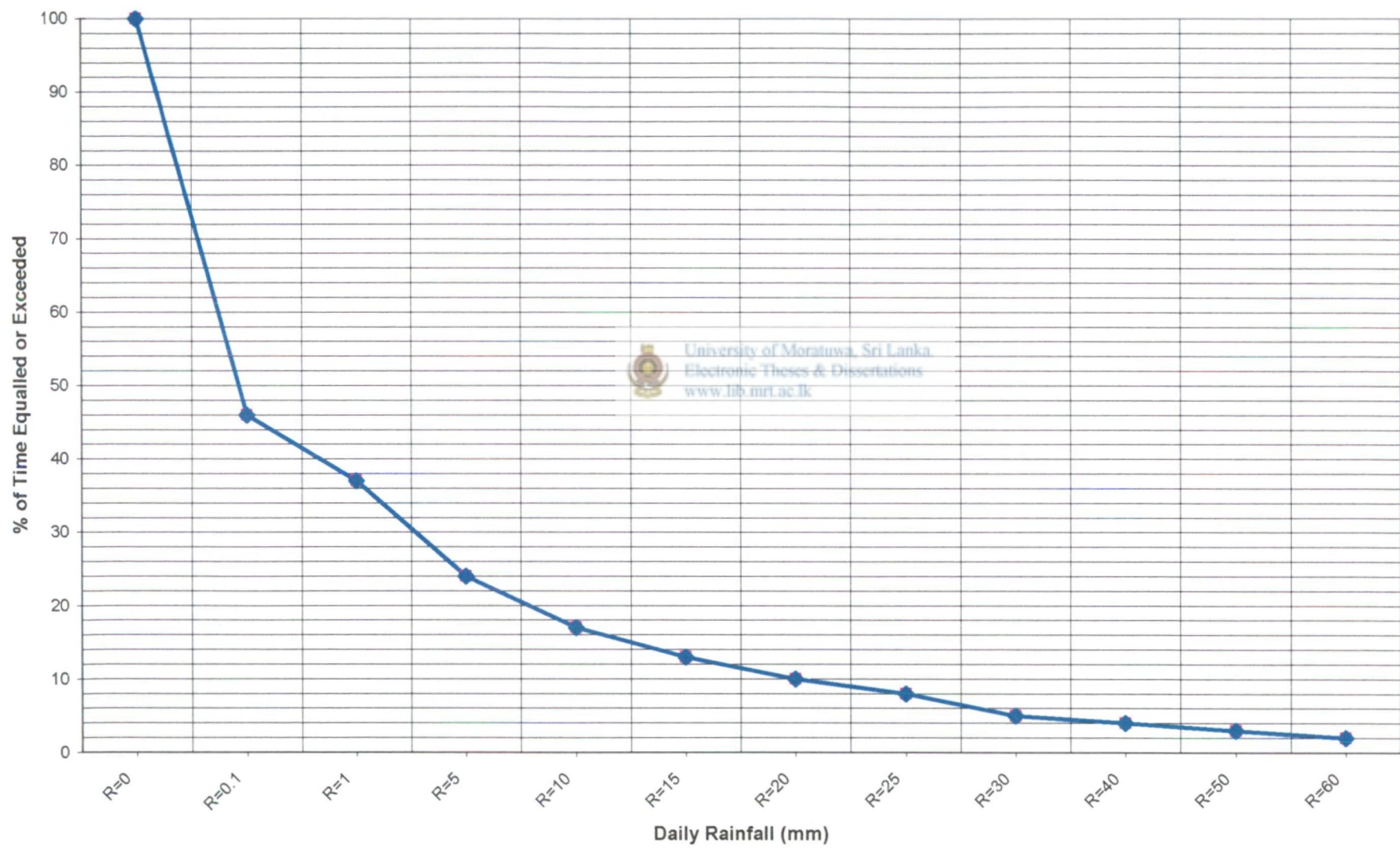
Fig - 4.3



Source :- Meteorology Department -SriLanka

Fig - 4.3a

Probability Curve of Rainfall Frequency



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Fig -5.1

No of Successful Days during the months of the year for Different Roof Areas Harvested & Storage Capacity

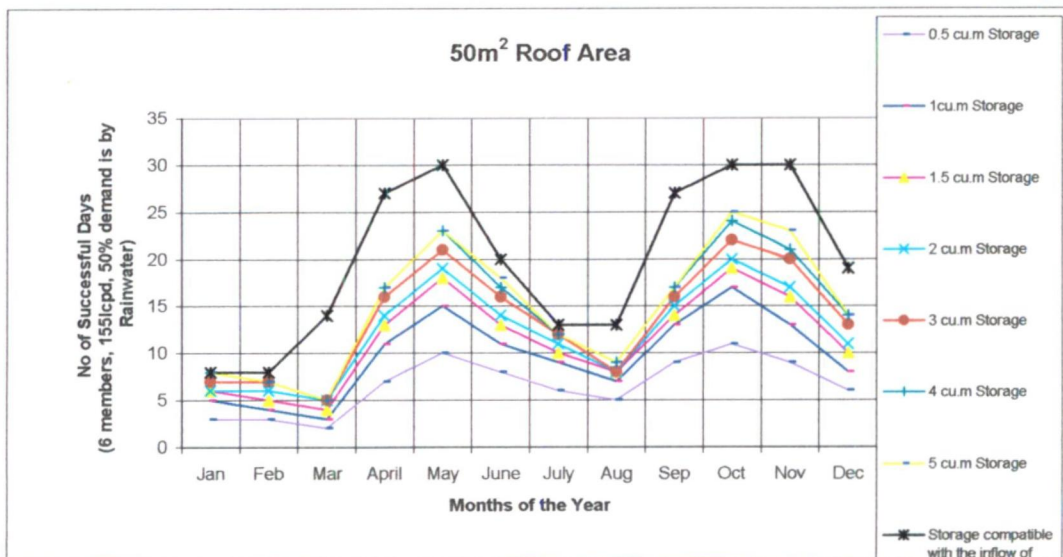
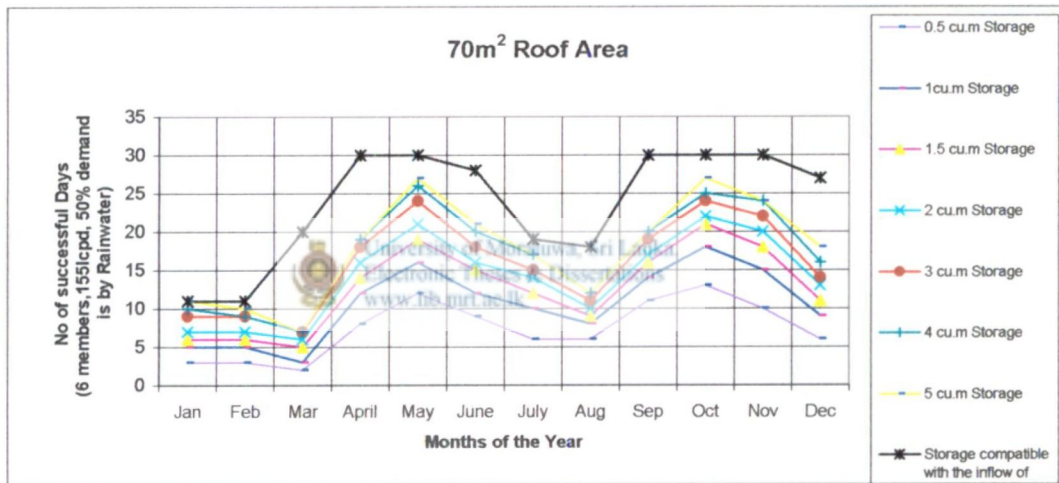
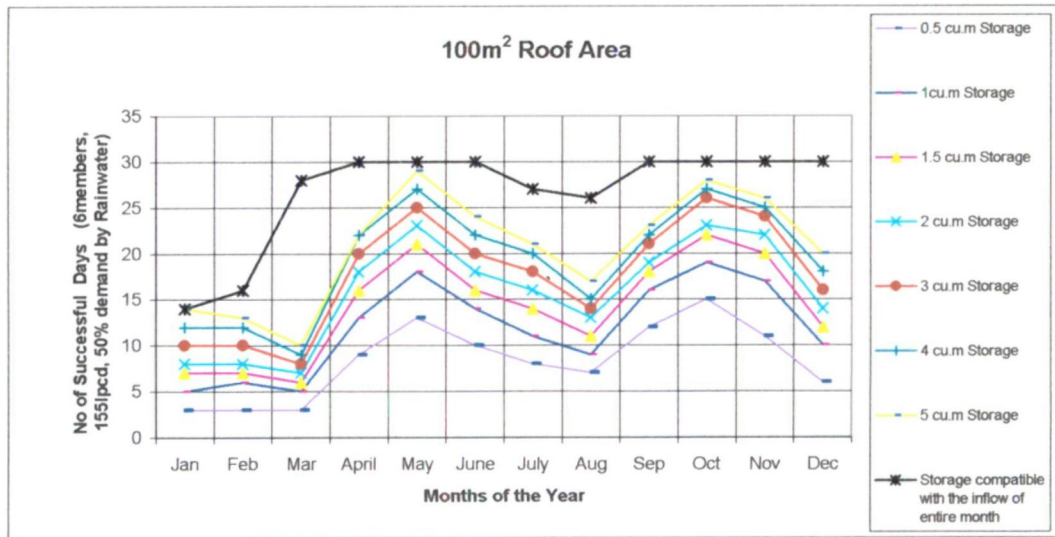
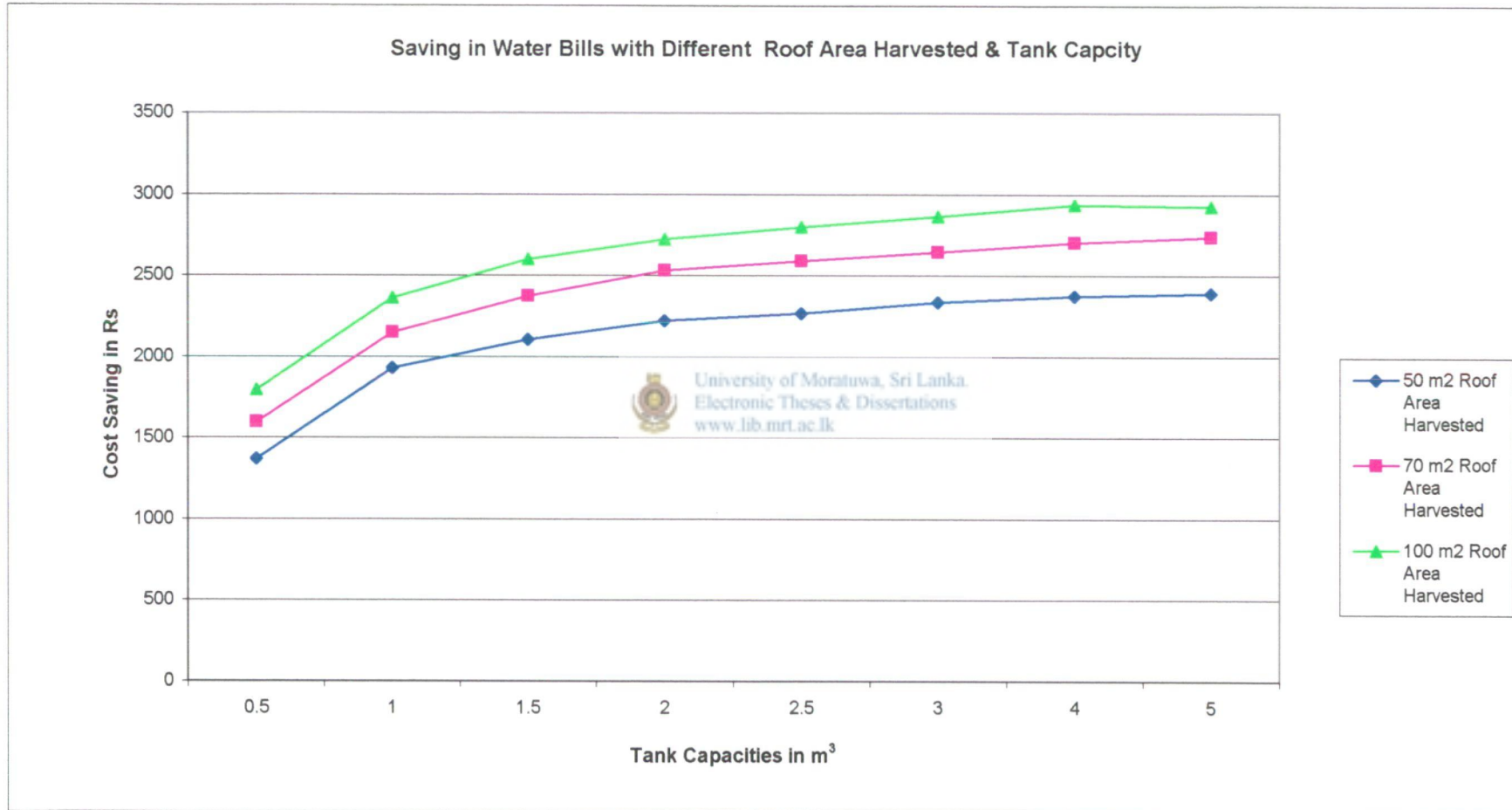


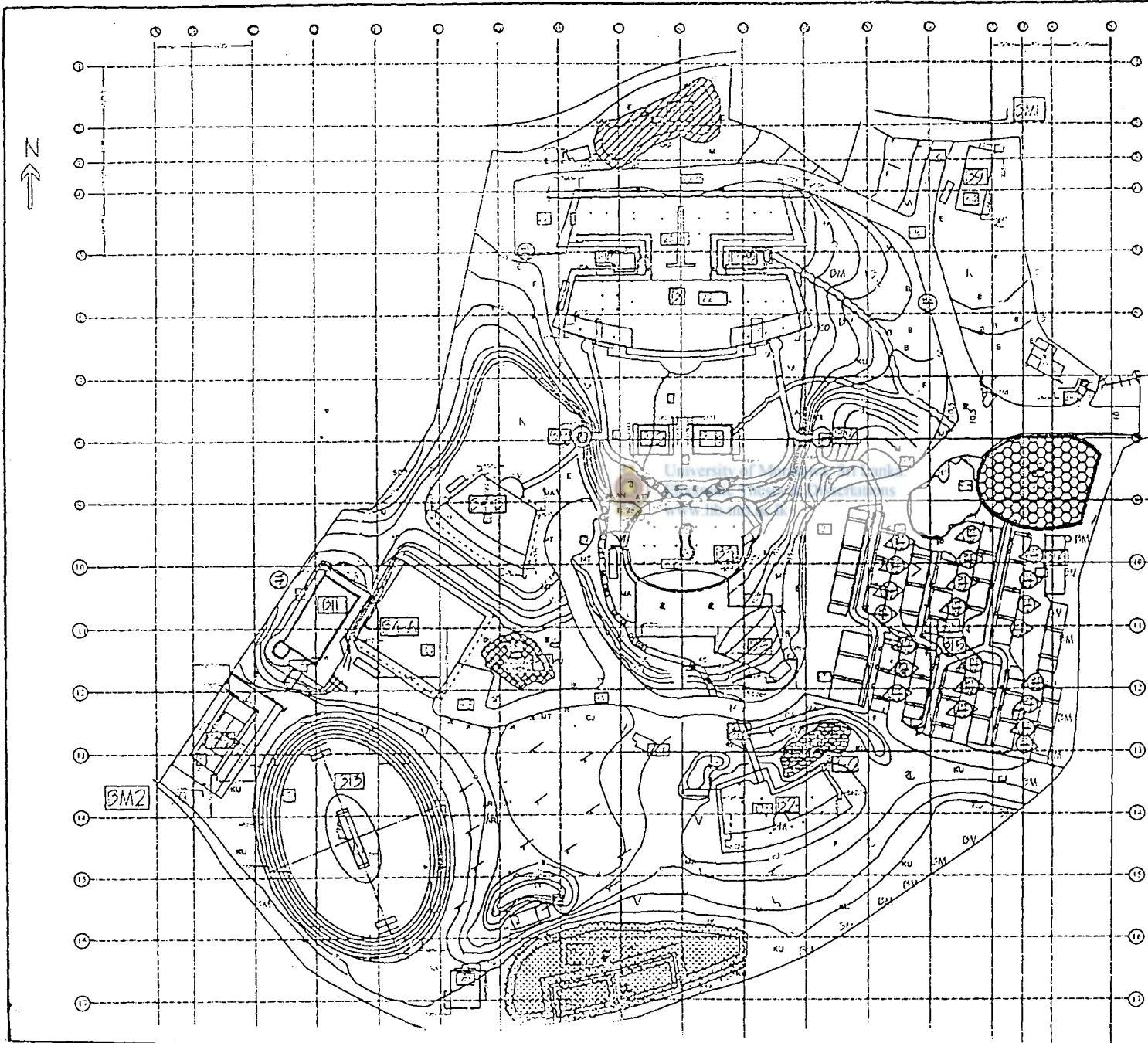
Fig - 5.1a



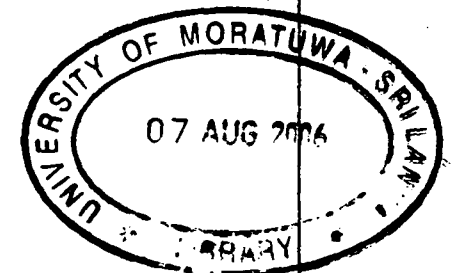
Note : Analysis is done for a six member family unit and half of the per capita demand is fulfilled by Rainwater Harvesting.

FIG. - 61

LAYOUT OF RAIN WATER HARVESTING PONDS AT MILLENNIUM INFORMATION TECHNOLOGY CENTRE



	1008 m ²
	340 m ²
	280 m ²
	1425 m ²
	2250 m ²



LANDSCAPE LAYOUT PLAN
MILLENNIUM T COMPLEX
FOR MIT AT MALABE

DATE: 01/10/2002
SCALE: 1:500
PROJECT: LANDSCAPE LAYOUT PLAN FOR MIT AT MALABE
DESIGNER: [Name]
CHECKER: [Name]