6. DISCUSSION

6.1 Domestic Drainage Water

Streamflow data of urbanized catchments consist of stormwater runoff and also domestic discharges. The domestic flows are of greater concern during the drought periods. This is because the small size and the high impervious areas of urbanized watersheds do not generate sufficient base flow from groundwater.

The domestic component of drainage flow depends on the human usage pattern. This shows small temporal changes between each day of the week. In general the peak occurs around 6 a.m. of the day and another small peak is noted around 7.00 p.m. Domestic flow component for Torrington watershed has a peak of 0.17 m^3/s and Attidiya has a peak of 0.10. m^3/s. The daily volume of domestic flow for Torrington and Attidiya are about 1.8 &1.3.mm/day respectively. These values and distribution tally well with water release pattern of National Water Supply & Drainage Board records.

6.2 Watershed and Canal Gradients

Torrington and Attidiya watershed are close to the coast and have flat terrain. In the Torrington watershed, the minimum and maximum overland flow gradients are over 1.0 and 3.0 percent respectively. Same for Attidiya watershed were 0.5 and 3.0 percent respectively. This shows the flatness of the terrain. Drainage Canals of these watersheds consists of flat gradients. Canal bed slope at the end of main drainage in Torrington is nearly zero and in Attidiya at the end of main drainage the slope is around 0.0001.

The canal water surface slopes of the nearest to Heen Ela stretch (main stem) of Torrington during floods reach around 0.0001 and in Attidiya the water surface slopes reaches 0.00015 close to the Bolgoda canal.

6.3 Tidal Effect

Since the watersheds are close to the sea and has flat gradients the tidal effect on gauging stations are to be expected. This was checked for Torrington and Attidiya watersheds by modeling the canal network using the HEC RAS hydrodynamic model. The model after calibration and verification was utilized to check the tidal influence. In Torrington watershed tide levels greater than 0.3 m MSL at the D/S end of canal network was effecting the measurements at the gauge points. Similarly, in Panadura tide level greater than 0.3 m MSL was having significant effects on Attidiya gauge site as well as Badowita. Flood events, which occurred when the tide level was less than 0.3 m MSL was selected for generating rating curves for each catchment.

6.4 Hydrodynamic Modeling of Canal Network

Hydrodynamic model for Torrington network indicated on Mean Ratio of Absolute Error of water height in the estimation of peakflow of 8.65 % during calibration and 9.49% during verification. Canal network for Attidiya had a Mean Ratio of Absolute Error of waterheight in the estimation of peakflow of 4.0 % when calibrating the model. Verification data showed Mean Ratio of Absolute Error in the estimation of peakflow 8.9%. This shows that the model fitting was quite satisfactory. Therefore, the hydrodynamic models established for both watersheds could be used for computations of future watershed scenario.

6.5. Canal Network Roughness

Canal roughness coefficients in literature varies over a wide range. Properties for canal systems in both watersheds was established using field inspection and engineering survey. Due to the wide variation of roughness values available for the incorporation of the network, the canal modeling attempted to compute an effective canal roughness for both watersheds. In the Torrington system the effective roughness was 0.031. In the Attidiya catchment the effective roughness modeled is 0.032. These values indicate a good similarity.

6.6. Backwater Effect

Since the watersheds have mild or having near zero gradients the flow from other canal branches tend to create backwater effect. This was investigated through the hydrodynamic model by varying the discharges in canal branches while checking the gauge height readings. Torrington and Attidiya watersheds both indicated that the backwater effects are substantial. Due to lack of data to fully remove such effects from the gauge data, investigations were done to identify whether backwater effects are consistent and linear. Regression analysis done for both watersheds indicated the linear discharge at gauges with discharge at other branches.

Since the backwater effect could be taken as linearly increasing or decreasing and was not cyclically fluctuating as the tide, it was not necessary to separate backwater effect for this study. Such a consistent behavior is due to the similarity of land use in the adjacent catchments and also due to similar spatial rainfall. Therefore, thus justifies the use of a single rainfall station for analyzing each catchment.

6.7 Rating Curve

Removal of tide effected events from measurements showed the removal of the looped effect in the stage discharge curve. This enables the conversion of stage measurements at both watersheds to discharges. The rating curve for both watersheds are in Table B-3 & Figure B-7, Table B-4 & Figure B-8. The rating curve show an R^2 coefficient of 1.0 for Torrington and 0.9 for Attidiya. However, these rating curves need to be strengthened by taking more stage discharge measurements with minimum tidal influence.

6.8 Delineation of Sub-Catchments

Based on the drainage characteristics each basin understudy was divided into smaller drainage units. The catchment characteristics such as levels, landuse, drain by drainage directions, lengths etc., were filed surveyed and used for computations. Torrington watershed was divided into 10 sub watersheds while Attidiya was divided into 12. In urban watershed, modeling is necessary to clearly identify such sub catchments to compare the drainage detention/retention storage features to study its storm water releases at the identified outlets. Such storage details were incorporated into the system (sub basin no. 1, 2 & 4 in Torrington and E, C, J & D in Attidiya - Plan No. 1(a) & 1(b) respectively).

6.9 Land Cover of Watersheds

Land cover of each watershed is the key factor in stormwater generation. The study categorized land use in each sub catchment into 4 groups as roofs, roads, walkways and playgrounds & gardens. Sample areas were identified in each basin and land uses were computed using 1:4000 maps. Seven sample areas in Torrington watershed (290 ha), Ten sample areas in Attidiya watershed (270 ha) were selected and were tabulated. Roofs, roads and walkways were taken as the impervious faction. Gardens and playgrounds were taken as pervious faction.

Torrington and Attidiya watersheds sub catchments could be grouped into "urbanized" and "less urbanized". Out of 10 sub catchments in the Torrington basin 3 were less urbanized.

In Attidiya basin 7 out of 12 sub basins were less urbanized. Land use in urbanized and less urbanized sub basins in each watershed are given in Table 6.1.

Table : 6.1 Land use groups in Torrington and Attidiya.

Land Use		Torrington	Attidiya
Urbanized	Pervious	60%	65%
	Impervious	40%	35%
Less Urbanized	Pervious	78%	75%
	Impervious	22%	25%

6.10 Mathematical Model For Torrington

HEC-1 models developed for Torrington watershed using catchment and canal characteristics was calibrated and verified using 18 flood events measured during the study period. Mean Ratio of Absolute Error in the estimation of peak flow during calibration was 0.04 and during verification 0.032. This shows a very good model fitting. Therefore, peak flow estimation using this model could be done to Torrington basin quite satisfactorily. Optimized Curve Number values for Torrington for less urbanized and urbanized areas are in Table 6.2.

Table: 6.2 Curve Number Values for Torrington Watershed

	Urbanized	Less urbanized
Impervious	95	93
Pervious	70	65

6.11 Mathematical Model for Attidiya.

Rainfall runoff model for Attidiya was developed using 15 flood events. Model for Attidiya showed Mean Ratio of Absolute Error in the estimation of peak flow during calibration 0.043 and 0.039 during verification. This shows that the estimation of peak flow is quite good. The Curve Number values estimation is in Table 6.3.

Table: 6.3 Curve Number Values For Attidiya Watershed

	Urbanized	Less urbanized
Impervious	95	93
Pervious	66	63

The rainfall runoff model used the events experienced for one and half years. Therefore, it may be better to incorporate a few more data sets to strengthen the results.

6.12 Mathematical Models for Environmental Improvement

Mathematical models developed for the canal networks and for the surface flow showed very satisfactory results during calibration and verification. This permits the use of these models to study the behavior of basins with different design events. Also the models could be used with various Landuse scenario to identify peak flow variation.

A comparison of peakflow if the Torrington and Attidiya are uniformly urbanized to the present maximum levels in each catchment is in Table 6.4 & Table 6.5. These computations permit the forecast of flow to provide adequate drainage canals and structures for environmental improvement.

Table: 6.4 Prediction of Peak flow with increased urbanization - Torrington

Event	Observed Peak m^3/s	Uniformly Urbanized Increased flow Through Model	% increase
1	19.48	22.97	17.96
2	4.16	4.76	14.42
3	3.17	3.59	13.40
4	4.45	5.34	20.00
5	6.0	7.08	17.92

Table : 6.5 Prediction of Peak flow with increased urbanization - Attidiya

Event	Observed Peak m^3/s	Uniformly Urbanized Increased flow through Model	% increase
1	17.81	21.80	18.40
2	4.59	5.35	16.66
3	4.33	4.90	13.10
4	4.87	5.81	19.18
5	4.53	5.21	15.00

6.13 Comparison of Modeled Curve Number Values

i) The model computations showed that the weighted Curve Number values for impervious and pervious areas for Torrington watershed are 94.40 and 68.40 respectively. Same for Attidiya watershed are 94.1 and 64.75 respectively.

The design of Greater Colombo flood control project has used general Curve Number values of 81.38 for Torrington canal and 80.22 for Bolgoda canal.

ii) For watershed modeling by using Runoff Curve Numbers, it is recommended in literature that the range shown in Table 6.6 is to be used for urban watersheds.

Table: 6.6 Comparison of Curve Numbers for Urban Watershed

	Run-off Curve Numbers	
	Impervious area	Pervious area
Urban watersheds in literature	98 - 89	61 - 72
Torington	94.4	68.6
Badowita and Attidiya	94.1	64.7

The values obtained from the model show that the curve numbers obtained from the study are within the expected range of values and hence could be taken as reliable.

6.14 Comparison of results of AMC Class II & AMC Class III

Saturation of the ground due to previous rainfall is of major influence to the infiltration and absorption capacity of the ground. In view of the frequent rainfalls during the monsoon period and in particular of the long-term rainfalls over periods of several days identified to be responsible for occurrence of major floods. Out of the 18 rainfall events considered, 17 fall into the category of AMC class II, while one falls into AMC III. Therefore runoffs curve numbers for AMC class II were adapted to calculate peak runoff using input rainfall data. The error between the observed and calculated peak runoff values were very small for the 17 events in AMC class II (from 0.002 to 0 .071), while for the other event the error was 0.11. However, it is better to identify AMC III events if they occur in future and compare the results.