

Geomorphological Controls Over the Structural Growth of Chittagong City

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Abstract

The present paper exposes a clear relationship of geomorphological controls over urbanization process in the city of Chittagong. The role of topographical condition, hydrological situation, influences of drainage and other geological and tectonic effects on the urban growth, especially on the structural spreading out of Chittagong city have been examined in the light of both the historical and environmental perspectives in this research works. The present study facilitates to know the degree and magnitude of the physical controls over the process of urbanization of Chittagong city. The paper also includes the study of the position of the city under applied geomorphological outline i.e. Physiographical, topographical, tectonical and hydrological controls over the historical and existing urban growth of the city. Moreover, the Master Plans of Chittagong city (Viz. Structural Master Plans, Urban Development Plan) considering the geomorphological controls have been analyzed and discussed in the present study where once more the role of the geomorphic controls in the planning of Chittagong city is clearly been recognized.

Keywords: *Geomorphology, Physiography, Urbanization, Coastal flank, Topography*

I. Introduction

Chittagong, the premier port-city occupies the south-eastern coastal flank along with some hilly surfaces of the country.^{1, 2,3} It is one of the leading inland seaports of the South-Asia, stands about 10 to 20 km. interior from the mouth of the river Karnafuli.^{4,5} It started to take shape from the early 16th century A.C. and during the rule of Mughal Subeder Saistha Khan the city was named Islamabad.⁶ From the time immemorial, Arabia and other distant areas were familiar with this oriental port.^{7, 8} The process of urbanization got momentum in Chittagong city after the independence of Pakistan in 1947. At that time, it became the only seaport of the province of East Pakistan. After the liberation of Bangladesh in 1971, the city of Chittagong started to grow rapidly. Now, the greater city covers a total of about 1,000 sq. km. area accommodating about 40,00,000 inhabitants within urbanized territory.^{9, 10} However, the Metropolitan city is distributed over only 240 sq. km. area and it is incorporated some rugged hilly surfaces along the coastal flank of Chittagong district. The city is spread over some narrow strips of alluvial plains and valleys to the northern bank of the river Karnafuli.^{2, 3} The surface configuration of Chittagong city contains a complex and varied topography covers with higher elevated rolling surfaces of the tertiary period, low-lying marshes, flood plains of very recent period and coastal plains etc. Besides, numerous hydrological bodies like rivers, gullies, ponds and lakes (i.e. *Jheels* and swamps) have divided and dotted the city area at several places.^{3,11} All these varied geomorphological or topographical situations and differences have given the city of Chittagong a mixed structure seem to be with a suitably uneven distribution of urban profiles.^{3,6,11}

II. Some Theoretical Aspects Geomorphology

According to wikipedia, Geomorphology is the scientific study of landforms and the processes that shape them. It explains the landform history and dynamics, and predicts future changes through a combination of field observation, physical experiment, and numerical modeling.

Geomorphological Controls

Geomorphology is the study of the landforms. In other words, geomorphology refers to the study of the surface configurations with reference to the mechanism, features

and process of change of the space. Geomorphological controls mean the mechanism of the surface configurations or land form-features on the development or change of urban structures. For instance, one can see that the cities, particularly their size, shape and orientation of development are greatly dependent on the geomorphological situation of the place. In the case of Dhaka city, the city has been growing in a north-south orientation. In other words, Dhaka city occupies the elevated and elongated part of the city which runs from the northern part of the Buriganga river up to the Joydevpur and the process of growth are continuing. In the process of the city-growth first the higher lands are occupied by urban structural growth, then comes the secondary places like partially elevated lands and lastly comes the lowlands areas through earth filling and draining up of the low lying areas and the marshy lands are brought under the structural growth. Thus we see the growth and development of urban centres greatly depends upon the geomorphological situation. This role of the land form-features on the changing urban landscape may be attributed to the geomorphological controls on urbanization process. The presence and absence of rivers, land elevation, flood-ability and the soil condition etc. are geomorphological aspects that greatly influence the urban growth.

Physiographic Situation

Physiographic situation and the geomorphology of any space or land area are two synonymous terms. Physiography refers to the surface condition. Physiography covers the land surface along with the different geomorphological phenomena like high land, low land, marshy land, absence or presence of rivers, drainage situation of rivers and the other land forms situation, together form of physiographic situations. This includes the surface structure, landforms, fluvial sequences, fluvial processes, mass movement, slopes, hills lores and soil erosion. So, physiography also exerts significant role in the way of urban growth.

Aims and Objectives

The main objective of the present study is to determine and analyze the nature and characteristics of the geomorphological controls over the urbanization process in Chittagong city. The other specific objectives of the study are:

- i. to examine the cross-profile of the different parts of the city of Chittagong is for examine the multifarious relationship that exists between the urban structural growth and encroachments with the different geomorphological, hydrological and some other physiographical situations, and
- ii. to establish the hypothesis that the higher land levels of Chittagong have very effectively been influencing the structural growth of the city and its urban morphology.

Methods and Materials

Multiple cross profiles are drawn for the examination of the various physiographic situations and magnitudes of geographical controls over urbanization in Chittagong city. In order to achieve the objectives of the present study 8 east-west running horizontal cross-sections i.e., A-A', B-B', C-C', D-D', E-E', F-F', G-G', H-H', and 5 north-south running vertical cross-sections, i.e., I-I', J-J', K-K', L-L', M-M' have been drawn across the city boundary covering the whole area between the Bay of Bengal and the river Karnafuli in the west and east and north respectively. The length of the vertical lines of the profiles is 20 km. in north-south and the length of the horizontal lines of profile is 12 km. Each of these lines of cross-sections has been divided into intervals of 2.0 km in both the directions on both the horizontal and vertical lines. The starting point of the east-west running cross-profile (i.e. horizontal) is at the northern edge of Chittagong city along the hilly regions and the starting or base of the north-south running cross profiles (i.e. vertical) is at Chandgoan of Chittagong city.

These horizontal and vertical lines have created a grid by intersecting each other at a distance of 2.0 km in all the directions and have created number of squares of 4.0 sq. km. area. On the basis of these lines and grids of the city a total of 13 cross-profiles (viz. 5-north-south running vertical lines and 8-east-west running horizontal lines) of the city have been prepared. These cross-sections of the city

were selected from the six topographical maps i.e. contour map, survey of Bangladesh, Structural map of C.D.A. (1995), Geological map of Geological Survey of Bangladesh (1992). The urban boundary of the city has been drawn from the satellite images of the SPARRSO (SPOT-2004). At first, the cross profiles of different elevations is drawn; then the geological cross-section is drawn on the same cross-section. The flood-maps (Normal Flood and 1991) are drawn superimposing on the same cross-section of the lines. Besides, the urbanized and non-urbanized length for each of the profiles has drowned at the top of the cross-sections. Secondly, physiographic profiles have drawn under the urban cross-sections. Then in the larger box, the elevations, geological units and flood cross-profiles have been drawn in an ordinary way. Finally, in the columns showing the urbanized and non-urbanized areas the length (km.) and percentage are measured and calculated for each of the variables i.e. physiography, topography, geology and floods for the examination of the Geomorphological controls over urbanization of Chittagong.

III. Results and Discussions

Cross-Profiles of the different cross-sectional lines of Chittagong city clearly show that there is a apparent relationship between the urban morphological and geomorphological situations in the city. These multifarious relations of the geomorphological and hydrological controls over urbanization of Chittagong city have been expressed in the cross-profiles i.e. A-A', B-B' etc. which are drawn from the base map (i.e. grid-map). The various findings and relations that have been identified from the analysis of these 13 profiles are described below:

East-West Running Cross-Profiles

Under these horizontal cross-profiles A-A' signify Jalalabad, Gosail Danga, Chandgoan and Mohara and shows 0.90 km of urbanized area (length) where the higher land (above 10.1m) covers 11.1 percent very high land (6.1-10m), 22.22 percent and the high land (5.1-6m) occupies another 66.67

Figure 1 : Relationship Between Contour/Land Elevation and Urbanization of Chittagong city

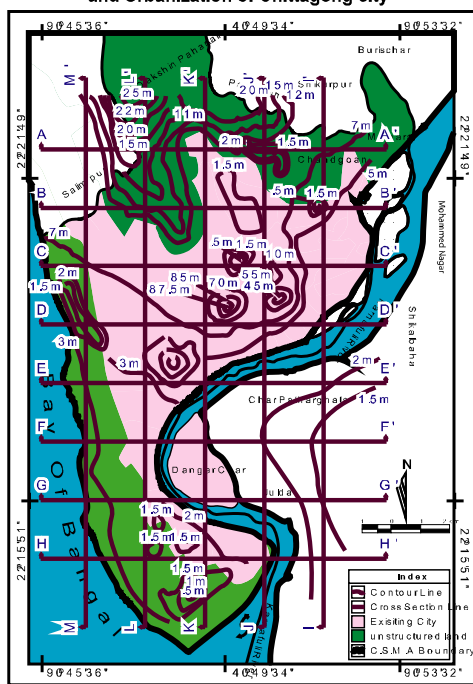
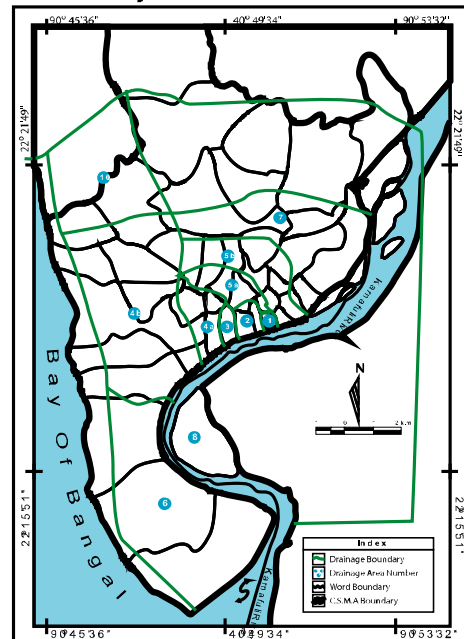


Figure-2 : Relationship between drainage system and urbanization of CSMA



Source : Survey of Bangladesh, 1997, CDA, 1995, SPARRSO, 2004.

Source : CDA 1995.

percent of the surface of the city. Within this length of the profile more than 77.78 percent of the surface falls in the Tertiary Hilly reigns and 22.22 percent covers the Abandoned Channel Fills. Geologically, about 100% percent of the length of the urbanized area under this cross-profile falls in the Tertiary Hilly reign (i.e. Jalalabad area). Regarding floodability along this profile, it is observed that this section of the structured area of the city is fully non-flooded (Fig.1 and Table 1, 2).

Cross section B-B' represents Uttar Pahartali, Sulok Bahar, Paschim Sholoshahar and Dakshin Bakulia area of the city. Here the urbanization occurs on above 5m elevation out of a total of 5.35 km of the total urbanized stretch of the cross-

section. It shows that along this line 24.23% in 5.1-6m, Medium alluvium land and 70.10 is low alluvium 1.5-5m. However, 24.30% covers Hills foot alluvium land, 9.34% covers old natural levee, 19.63 covers abandoned channel and depression and 46.73 covers active natural levees, flood plains, points bars and sands bars. With reference to floodability this is observed that 100% of the line 14.20% is along flooded area and 85.98% is non-flooded area, between this 49.99% was flooded in 1991 flood. This also exhibits a sound relation between the geomorphology and urbanization in Chittagong city along this cross profiles (Fig.1 and Table 1, 2).

Table 1. Examination of the Geomorphological controls (physiographic units) over urbanization with the help of multiple cross profiles of Chittagong (east-west cross- sections)

East-West Cross-Sections	Cross-Sections Length in Urbanized Area (km and %)	Elevation Zones (Km and %)				Physiographic Units (Km and %)							
		A	B	C	D	1	2	3	4	5	6	7	8
A-A'	0.90 100	-	.60 66.67	.20 22.20	0.10 11.10	.70 77.78			.20 22.22				
B-B'	5.35 100	3.75 70.10	1.35 25.23	0.25 4.76			1.30 24.30	.50 9.34	1.05 19.63	2.50 46.73			
C-C'	9.25 100	6.25 67.57	3.00 32.43				4.25 45.95	.50 5.40	.90 9.72	2.60 28.11			.60 6.49
D-D'	6.75 100	4.25 62.97	2.50 37.04				2.75 40.74	1.00 14.81	.50 7.41	3.5 51.85	.5 7.41		.50 7.41
E-E'	2.5 100	2.5 100						.50 20	1.50 20	60			
F-F'	1.00 100	1.00 100						.25 25	.75 75				
G-G'	0.80 100	0.80 100								.40 50			.40 50
H-H'	3.15 100	3.15 100							.50 15.87	2.00 63.49	.65 22.63		
A-H'	29.70	21.77 73.06	7.45 25.08	0.45 1.52	.10 0.34	.70 2.36	8.30 27.95	2.75 9.26	3.65 12.24	13.25 44.61	1.15 3.87		1.5 5.05

Note: Elevation Zones: (A) 1.5 to 05 m, (B) 5.1 to 6 m, (C) 6.1 to 10 m, (D) 10.1 m. and above; **Physiographic Units :** (1) Hilly Regions, (2) Hill's Foot Alluvium Land, (3) Old Natural Levee, (4) Abandoned Channel and Depression, (5) Active Natural Levees, Flood Plains, Point Bars and Sand Bars, (6) High Flood Plains and Gully Fills, (7) Low Lying Coastal Area, (8) Other Channel Area

Source: Field Study, 2008.

Cross section C-C' represents Saraipara, Pahartuli, Lal Khan Bazar, Baqmoniran, Chakbazar, Paschim and Dahshin Bakulia areas of the City. It is seen that about 67.57 of the length is urban which is supported by 6m. elevation. The central part of this line (i.e. cross-profile C-C') is elevated with a maximum height of about 7m. and the elevation gradually decreases towards east and west, where the lowest points are in the *Khals* (i.e. below 2.0m.).

Cross section D-D' represents Dakshin Kattali, Rampur, Uttar Agrabad, Uttar Pathantuly, Enayet Bazar, Anderkilla, Baksirhat, Dewan Bazar areas of the city. Here the urbanization occurs on above 5m. elevation out of a total of 6.75 km. of the total urbanized stretch of the cross-section. It shows that along this line 37.04% in 5-6m. Physiographically, 40.74% covers Hills foot alluvium land, 14.81% covers old natural levee, 7.41 covers abandoned channel and depression and 51.85 covers active natural

levees, flood plains, points bars and sands bars. With reference to floodability this is observed that 100% of the line 17.04% is along flooded area and 82.96% is non-flooded area, between this 29.63% was flooded in 1991 flood (Fig.1 and Table 1, 2).

Cross section E-E' represents Uttar-Madhya Hali Shahar, Gosail Danga areas of the city. Here the urbanization occurs on above 5m. elevation out of a total of 2.5 km. of the total urbanized stretch of the cross-section. It shows that along this line 100% is in low alluvium 1.5-5m. Physiographically, 20% covers old natural levee, 20% covers abandoned channel and depression and 60% covers active natural levees, flood plains, point bars and sands bars. With reference to floodability this is observed that 100% of the line 20 % is along flooded area and 80% is non flooded area, between this 100% was flooded in 1991 flood (Fig.1 and Table 1, 2).

Table. 2. Examination of the Geomorphological controls (different floods) over urbanization with the help of multiple cross-profiles of Chittagong (east-west cross sections)

East-West Cross-Sections	Cross-Sections Length in Urbanized Area (Km and %)	Geological Units (km and %)				Different Floods (Km and %)			
		I	II	III	IV	Normal Flood		1991 Flood	
						a	b	a	b
A-A'	0.90 100%	-	-	-	.90 100	-	.90 100	-	-
B-B'	5.35 100%	-	2.00 37.38	2.00 37.38	1.35 25.23	.75 14.02	4.60 85.98	2.30 42.99	2.75 51.40
C-C'	9.25 100%	-	5.00 54.05	4.25 45.95	-	.50 5.41	8.75 94.56	5.50 56.46	3.75 40.54
D-D'	6.75 100%	1.85 27.41	2.15 31.85	2.75 40.74	-	1.35 17.04	5.60 82.96	2.00 29.63	4.75 70.37
E-E'	2.5 100%	1.50 60	1.00 40.00	-	-	.50 20	2.00 80	2.50 100	-
F-F'	1.00 100%	.60 60	.40 40.00	-	-	.40 40	.60 60	1.00 100	-
G-G'	0.80 100%	.60 75	.20 25	-	-	.35 43.75	.45 56.25	0.80 100	-
H-H'	3.15 100%	3.15 100	-	-	-	2.75 87.35	1.00 31.75	3.15 100	-
A-H'	29.70 100%	7.7 25.93	10.75 36.20	9.00 30.30	2.25 8.42	6.40 21.55	23.90 80.47	17.25 58.08	11.25 37.88

Note: Geology: (I) Low Land Alluvium, (II) Medium Land Alluvium, (III) High Land Alluvium, (IV) Tertiary Hills and Hillocks; **Different Floods:** (a) Flooded Area, (b) Non-Flooded Area

Source: Field Study, 2008.

Cross section F-F' represents Dakshin Hali Shahar area of Chittagong city. Here the urbanization occurs on above 5m. elevation out of a total of 1.00 km. of the total urbanized stretch of the cross-section. It shows that along this line 100% is in low alluvium 1.5-5m. Physiographically 20% covers old natural levee, 20% covers abandoned channel and depression and 60% covers active natural levees, flood plains, point's bars and sands bars. With reference to floodability this is observed that 100% of the line 40% is along flooded area and 60% is non-flooded area, between this 100% was flooded in 1991 flood (Fig.1 and Table 1, 2).

Cross section G-G' represents Dakshin Hali Shahar and Uttar Potenga areas of the city. Here the urbanization occurs on above 5m. elevation out of a total of 0.80 km of the total urbanized stretch of the cross-section. It shows that along this line 100% is in low alluvium 1.5-5m. Physiographically 50% covers active natural levees, flood plains, point's bars and sands bars and 50% is in other channel areas. With reference to floodability this is observed that 100% of the line 43.75% is along flooded area and 56.25% is non flooded area, between this 100% was flooded in 1991 flood (Fig.1 and Table 1, 2).

Cross section H-H' represents Uttar and Dakshin Potanga area of the Chittagong city. Here the urbanization occurs on above 5m elevation out of a total of 3.15 km of the total urbanized stretch of the cross-section. It shows that along this line 100% is in low alluvium 1.5-5m. Physiographically 15.87% covers abandoned channel and depression and 63.49 covers active natural levees, flood plains, point bars and sands bars and 22.63% covers high flood plains. With reference to floodability this is observed that 100% of the line 87.35% is along flooded area and 31.75% is non flooded area, between this 100% was flooded in 1991 flood (Fig.1 and Table 1, 2). Along the lengths of cross-profiles

A-A' to H-H' within the total lengths of 8 lines, the urbanized areas cover a total length of 29.70 km. here the low land elevation (1-5m) covers 73.06% of the total lengths of all these 8 lines; 25.08% is over medium elevation, 1.52% comprises higher land elevation of lands. Physiographically, 36.20% occurs in old Natural levee; 12.29% in Abandoned Channels and Depressions, 44.61% in Active Natural Levee, Flood plains, Point Bars and Sand Bars; 3.87% in Flood plains and Gully fills; 5.05% in Other Channels Area (Fig.1 and Table 1, 2).

Geologically, about 5.42% of the total lengths of these lines, i.e. A-A' to H-H' comprises the 2.36% hilly region, .34% tertiary foot hills, 33.3% high land alluvium, 36.20% medium land alluvium and 25.93% low land alluvium. Again, as far the floodability of these profiles i.e. A-A' to H-H' is concerned that about 85% of the total length along these 8 lines represents flood free surfaces in normal floods while in the severe floods of 1991, 37.88 of the total surfaces along these lines remained flood free respectively. From the analysis of the cross- profiles A-A' to H-H' of Chittagong city, it is established that the most parts of Chittagong city occur on higher elevations of tertiary foot hills active natural levee, flood plains, abandoned channel and depression, old natural levee and in non-flooded areas (Fig.1 and Table 1, 2).

North-South Running Cross-Profiles

Under the north-south running cross-profiles of the city of Chittagong I'-I' line represents a cross-sectional lengths totalling 20 km. of the city running from Chadgoan, Purbashahar, Paschim and Dakshin Bakulia in the south the river Karnafuli and Shikarpur in the north. However, along this stretch about 3.00 km. urbanized area is located at Chadgoan, Purbashahar, Paschim and Dakshin Bakulia.

Table 3. Examination of the Geomorphological controls (physiographic units) over urbanization with the help of multiple cross profiles of Chittagong (north-south cross- sections)

North- South Cross-Sections	Cross-Sections Length in Urbanized Area (km and %)	Elevation Zones (Km and %)				Physiographic Units (Km and %)								
		A	B	C	D	1	2	3	4	5	6	7	8	
I-I'	3.00 100	3.00 100							1.00 3.47	1.50 5.20			.5 1.73	
J-J'	5.15 100	2.40 46.60	2.75 53.40				3.0 58.25	2.00 38.84	.40 7.77	.65 12.62				
K-K'	9.15 100	3.50 38.25	2.35 25.68	2.50 27.32	.75 8.20	1.75 19.13	4.35 47.54	.25 2.73	.95 10.38	1.5 16.39			.5 5.46	
L-L'	10.25 100	8.75 80.49	1.25 12.20	.25 2.44		.25 2.44	1.50 74.63	1.15 11.22	.60 5.85	7.00 68.29			.75 7.32	
M-M'	1.25 100	1.25 100					1.00 80					.25 20		
I-M'	28.86 100	17.65 61.16	6.35 22.00	2.75 9.53	.75 .60	2.00 6.93	9.85 34.13	3.40 11.78	2.95 10.22	10.00 34.65			.25 .87	.85 2.95

Note: Elevation Zones: (A) 1.5 to 05 m, (B) 6.1 to 10 m, (C) 6.1 to 10 m, (D) 10.1 m. and above; **Physiographic Units :** (1) Hilly Regions, (2) Hill's Foot Alluvium Land, (3) Old Natural Levee, (4) Abandoned Channel and Depression, (5) Active Natural Levees, Flood Plains, Point Bars & Sand Bars, (6) High Flood Plains and Gully Fills, (7) Low Lying Coastal Area, (8) Other Channel Area

Source: Field Study, 2008.

These structured (i.e. urban) areas belong to low-land mainly. Physiographically, these stretches are flood-plain of the areas belong to the tertiary foot hills. It is revealed that 31.67% is inundated by normal flood every year and the whole region was inundated in the flood of 1991. Naturally, these predominantly low-lying areas are not suitable for urbanization by normal way (Fig.1and Table 3, 4).

J'-J' line represents Gosail Danga, Paschim Shola Shahar, Chakbazar, Jamal Khan, Anderkill, Firingi Bazar. However, along this stretch about 5.15 km. urbanized area of the city is located at Paschim Shola Shahar, Chakbazar, Jamal Khan, Anderkill, Firingi Bazar. These structured (i.e. urban) areas belong to low-land mainly. Physiographically, these stretches are flood-plains of the areas belong to the

tertiary foot hills. It is revealed that 9.71% is inundated by normal flood every year and 41.75% was inundated in the flood of 1991 (Fig.1and Table 3, 4).

K'-K' line represents Jalalabad, Sulok Bahar, Lalkhan Bazar, Uttar Pathantuly, Pathantuly. However, along this stretch about 9.15 km urbanized area of the City is located at Sulok Bahar, Lalkhan Bazar, Uttar Pathantuly, Pathantuly. These structured (i.e., urban) areas belong to low-land mainly. Physiographically, these stretches are flood-plains of the areas belong to the Tertiary hills foot. It is revealed that 22.22% is inundated by normal flood every year and 21.86% was inundated in the flood of 1991 (Fig.1and Table 3, 4).

Table 4. Examination of the Geomorphological controls (different floods) over urbanization with the help of multiple cross profiles of Chittagong (north- south cross-sections)

North-South Cross-Sections	Cross-Sections Length in Urbanized Area (Km and %)	Geological Units (Km and %)				Different Floods (Km and %)			
		I	II	III	IV	Normal Flood		1991 Flood	
						a	b	a	b
I-I'	3.00 100	1.00 33.33	2.00 66.67	-	-	.95 31.67	2.05 68.33	-	-
J-J'	5.15 100	3.00 58.25	2.15 41.75	-	-	.50 9.71	4.55 88.35	2.15 41.75	3.00 58.25
K-K'	9.15 100	3.00 32.79	4.00 43.72	2.15 23.50	-	1.85 22.22	7.20 78.69	2.00 21.86	7.15 78.14
L-L'	10.25 100	7.00 68.29	2.00 19.51	1.25 12.20	-	3.25 31.71	7.00 68.29	2.25 21.95	8.00 78.05
M-M'	1.25 100	-	.25 20	1.00 80	-		1.25 100	.25 20	1.00 80
I-M'	28.86 100	14 48.68	10.40 36.61	4.40 15.28	-	6.55 22.74	22.05 76.56	9.65 33.50	19.15 66.49

Note: Geology: (I) Low Land Alluvium, (II) Medium Land Alluvium, (III) High Land Alluvium, (IV) Tertiary Hills and Hillocks; **Different Floods:** (a) Flooded Area, (b) Non-Flooded Area

Source: Field Study, 2008.

L'-L' line represents Uttar Pahartali, Sarai Para, Rampur, Uttar-Madhy Hali Shahar, Dakshin-Madhy Hali Shahar, Uttar Potenga. However, along this stretch about 3.00 km.

urbanized area is located at Uttar Pahartali, Sarai Para, Rampur, Uttar-Madhy Hali Shahar, Dakshin-Madhy Hali Shahar and Uttar Potenga of Chittagong city. These

structured (i.e. urban) areas belong to low-land mainly. Physiographically, these stretches are flood-plains of the areas belong to the tertiary hills' foot. It is revealed that 31.71% is inundated by normal flood every year and the whole region was inundated in the flood of 1991 (Fig.1 and Table 3, 4).

M'-M' line represents Uttar and Dakshin Kattali, Uttar Hali Shahar, Uttar-Madhya Hali Shahar and Dakshin-Madhya Hali Shahar. However, along this stretch about 1.25 km urbanized area is located at Uttar and Dakshin Kattali, Uttar Hali Shahar, Uttar Madhya Hali Shahar and Dakshin Madhya Hali Shahar of the city of Chittagong. These structured (i.e., urban) areas belong to low-land mainly. Physiographically, these stretches are flood-plains of the areas belong to the Tertiary hills foot. It is revealed that it is flood free areas but 20% was inundated in flood of 1991 (Fig.1 and Table 3, 4). The total length of cross profiles I-I' to M-M' in the urbanized area of Chittagong city is 28.6 km. Topographically, the higher land-formations cover 15.28%; 36.6% in medium land formations (5-6m.) and 48.61% occurs in low land formation.

Physiographically, 2.00% of the total land occurs in tertiary hills, 9.85% hills foot alluvium land, 3.40% in old natural levee, 2.95% in abandoned channels and depressions; 10.00% in active natural levees, flood plains, point bars and sand bars; 0% in high flood plains and gully fills; .25% low lying coastal area and 0.85% in Other Channel Areas. Geologically, most parts of Chittagong city is covered by the tertiary hills, foot hills and flood plains. In the total cross profiles length in urbanized area, 48.61% low land alluvium; 36.61% medium land alluvium and 15.28% high land alluvium. In normal flood about 22.74% of the city is flooded and 33.51% was flooded in 1991 flood. It reveals the total length in urbanized area of the all profile lengths of these north-souths running cross-sections of the city (Fig.1 and Table 3, 4). On the basis of this analysis of the cross-profiles along the different sections of Chittagong city, it is apparent that the city comprises a varied and complex geomorphological formation and the tertiary hills in the central part of the city is supporting the highest share of the structural growth of the city. Floodability, hydrology and geology of the city area have also been greatly influencing the urbanization particularly the structural growth of this city.

Findings

- i. There exists a clear relationship between various geomorphological features and process of urbanization in Chittagong city. Physiographic condition of the city, especially, the elevation of the surface of Chittagong significantly controls the structural growth of the city. For example the higher surfaces of the elevated tertiary hills in the north-eastern of Chittagong district shares more than 67% of the structured build up areas of the city. From historical past of the city, physiographical and topographical features have always been determining the urban growth of Chittagong.
- ii. The process of urbanization, particularly the structural expansion of Chittagong city is also greatly influenced by the hydrological and climatological situation of Chittagong

or occurrence of rivers, marshes (*jheels*) and other low-lying areas significantly controls and fluvio-geomorphological barriers the city is confined by the big river region of Chittagong. Besides, due to the lower elevation and flood vulnerability of the low-lying areas of the western, eastern and some other scattered areas of the central part of the city structural growth of the urban area in Chittagong is significantly restricted within the suitably higher surfaces in the central part of Chittagong.

- iii. The city is gaining its ultimate shape in the Chittagong urbanization process of its structural growth in a clear north-south running trend or orientation. However, during the initial period of urban development of Chittagong the trend was on east running orientation along the course of the Karnafuli. But in the course of time due to the normal process of urban growth the encroachment of newer land under the city has been following the suitable North-East running elevated the urban growth of Chittagong.

- iv. It can be visualized from the findings of the present study that the existing north-south running trend of urban expansion of Chittagong city will-be continued towards north until to the northern end of the elevated land of Sitakund regions.

- v. The present structural growth is taking place spontaneously over all the suitable lands of the city ignoring many geological and tectonical considerations. As a result of such indiscriminate encroachments, any tectonic adverse happenings like earthquakes; subsidence or land erosion may cause serious damages to the urban structures of Chittagong in future.

Recommendations

In order to improve the quality of structural facilities of the Chittagong city some apparent and scientific understanding about the various physical aspects, specially, the geomorphological situations and controls over the urbanization of the city is essential. In the light of the findings of the present study the following aspects are recommended for the urbanization of the city:

For the sustainable and healthy urban growth in Chittagong city particularly for its balanced structural development, emphasis should be given on the geomorphological condition of different areas of the City. Moreover, In-depth geological studies, soil testing and studies of the topographic situations should follow all the new site selection of structural growth activities. Moreover, elaborate hydrological studies and geomorphological tests like drainage characteristics tests, sedimentological test etc., can also be proved to be fruitful in this esteem.

Physiographic contour levels of the lands should be followed to construct the sewerage canals and storms culverts of the City. Besides, extensive greening of the open surfaces through plantation and grass carpeting can be immensely helped to protect the erosion of soil in the city. However, Topographic diversities of Chittagong city should be maintained in order to give the city more attractive landscape. The vivid and varied relief with elevated high lands, low-lying marshes and water-bodies and mid-level flood plains will definitely give the city more picturesque scenery.

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