# REGIONAL TRAINING PROGRAMME ON EROSION AND SEDIMENTATION FOR ASIA (RTPESA)

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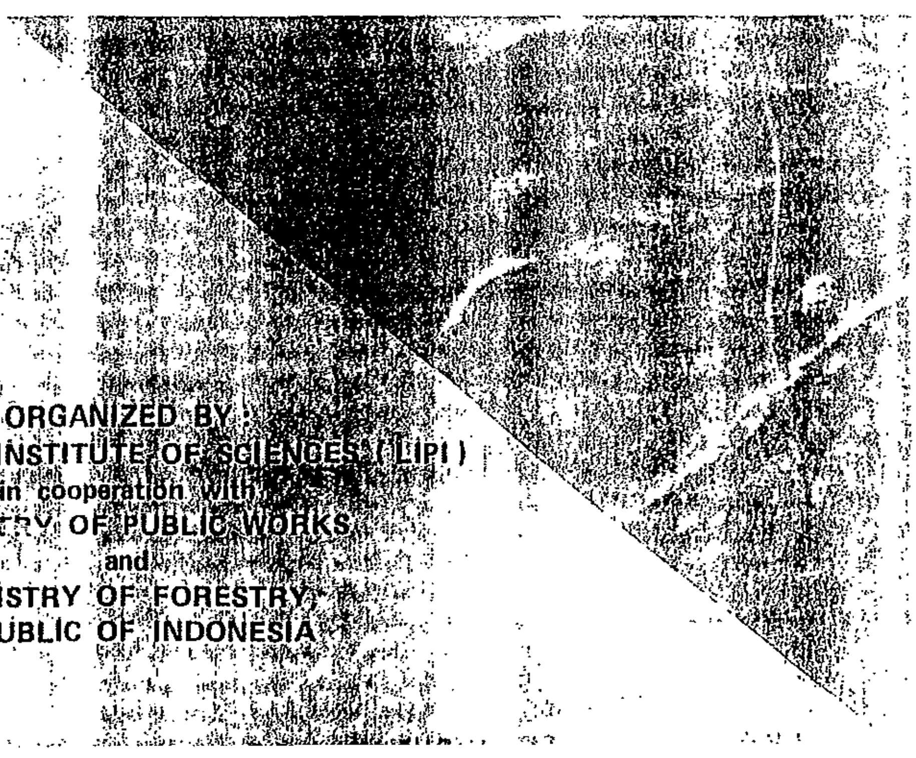
## PROCEEDINGS OF RTPESA 5: WORKSHOP ON SOIL EROSION AND DEBRIS FLOW CONTROL

VSTC, YOGYAKARTA, INDONESIA, 5 – 8 NOVEMBER 1991



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# EROSIONAL HAZARDS IN CHITTAGONG CITY, BANGLADESH.

MIR FAZLUL KARIM* & MOHAMMED JAMAL HAIDER**

## ABSTRACT

The port city of Chittagong is situated at a junction of sea, hill range and plainland and subject to heavy rainfall along with a number of natural hazards like cyclones, tidal surges and flash floods.

Due to a complex geological environment it has been potentially susceptible to erosion. During the last two decades, an increase in human interference like deforestation and cutting of slope, has triggered massive erosion. The erosion, in the city area, is graded into severe, moderate and low. It has also resulted in various types of landslides in the dipping and fractured strata.

Proper management is imperative to control this erosion. A model is proposed on which a management plan may be developed.

## INTRODUCTION

The port city of Chittagong is located in the south-eastern part of Bangladesh at a junction of the sea, hill range, flood and tidal plain and experiences heavy rainfall. The mapped area lies between latitudes $22^0 14'$ - $22^0 24'$N and longitudes $91^0 45'$ - $91^0 54'$E. Chittagong, the second largest city of the country, shows a continuously increasing industrial development.

The climate is tropical characterized by cool winter, hot summer and rainy monsoon. The major climatic parameters are given in

* Deputy Director, Geological Survey of Bangladesh, Segun Bagicha, Dhaka, Bangladesh.
** Deputy Director, Geological Survey of Bangladesh, Segun Bagicha, Dhaka, Bangladesh.

figure 1. The city experiences different types of natural hazards including cyclonic storms, coastal surges and flash floods.The cyclonic storms occur during the transitional period of monsoon and flash floods during the months of May to August.

The area has two distinct topographical divisions. (a) The hill range and (b) the fluvio-tidal complex. In general, these two divisions are divided into ten engineering geologic units (Fig. 2 and Table 1). Most of the urban and industrial zones have been developed in the hilly region. The general geomorphology of the city area has been described as structural denudational hills and slopes (Karim et.al.1990).

**EROSIONAL HAZARDS**

The two distinct geological environments of the region are controlled by different erosional processes. The hilly area of the city is affected by soil erosion together with mass movement phenomena like landslides,slope-failures, flash flood and debris flow. The hazards in the plainland are flood, saline water intrusion and soil collapse.

As indicated by Holy (1980) kinetic energy of torrential rainfall in the tropics is greater than 32 $J/m^2$ for 1mm of rain where the intensity may reach upto 100 mm/h. The monthly rainfall co-efficient and erosivity index of Chittagong city were derived using Fournier equation (Moldenhauer, 1980). Ten years rainfall data was used in determining the indices (Table 2).

The high kinetic energy and erosivity of rain have made the study area severely susceptible to erosion. Due to natural growth of dense tropical vegetation, erosion was considerably less. But during the last two decades severe erosion has been triggered by human

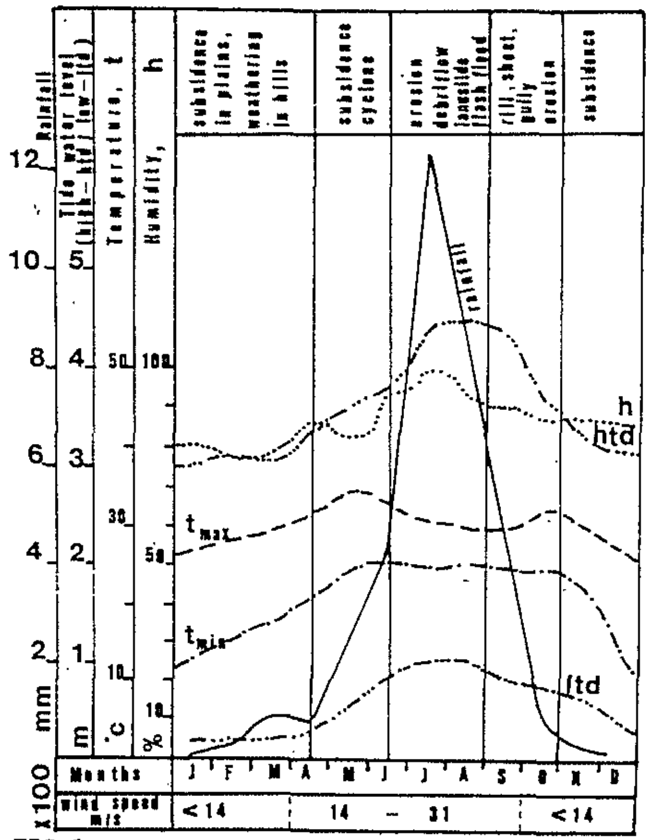



FIG.1: RELATION BETWEEN CLIMATIC CHANGES AND POSSIBLE GEOLOGICAL HAZARDS.

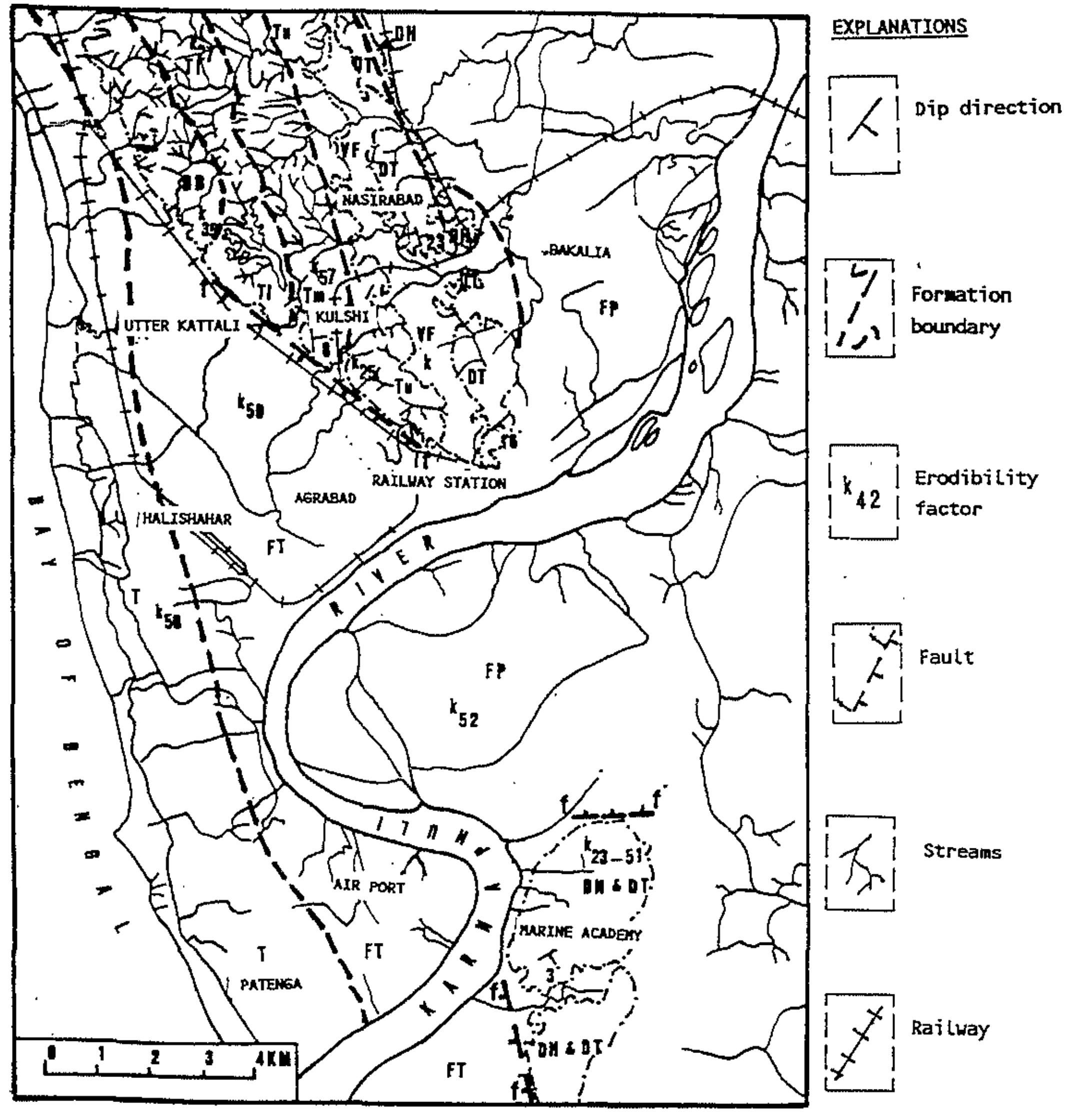
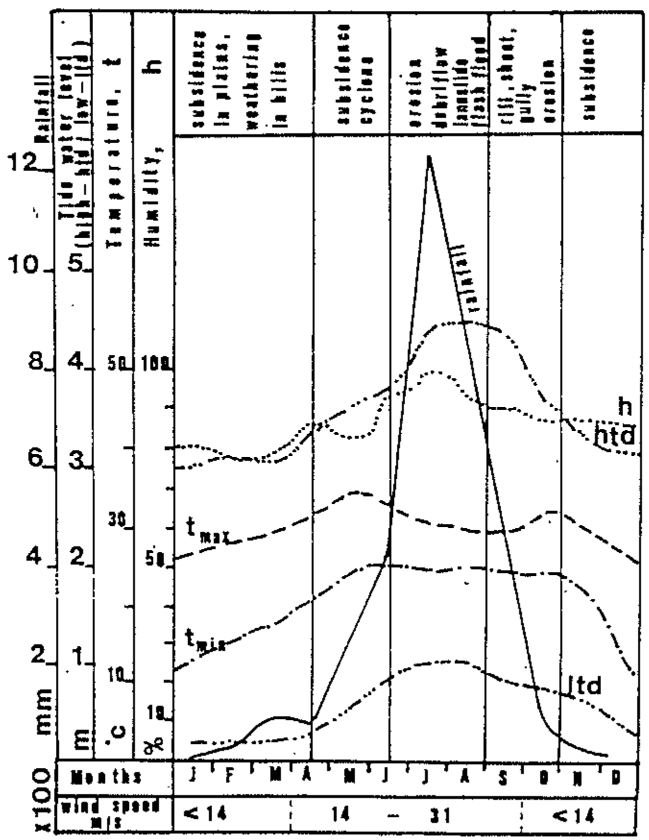



Fig. 2. ENGINEERING GEOLOGICAL MAP OF CHITTAGONG CITY

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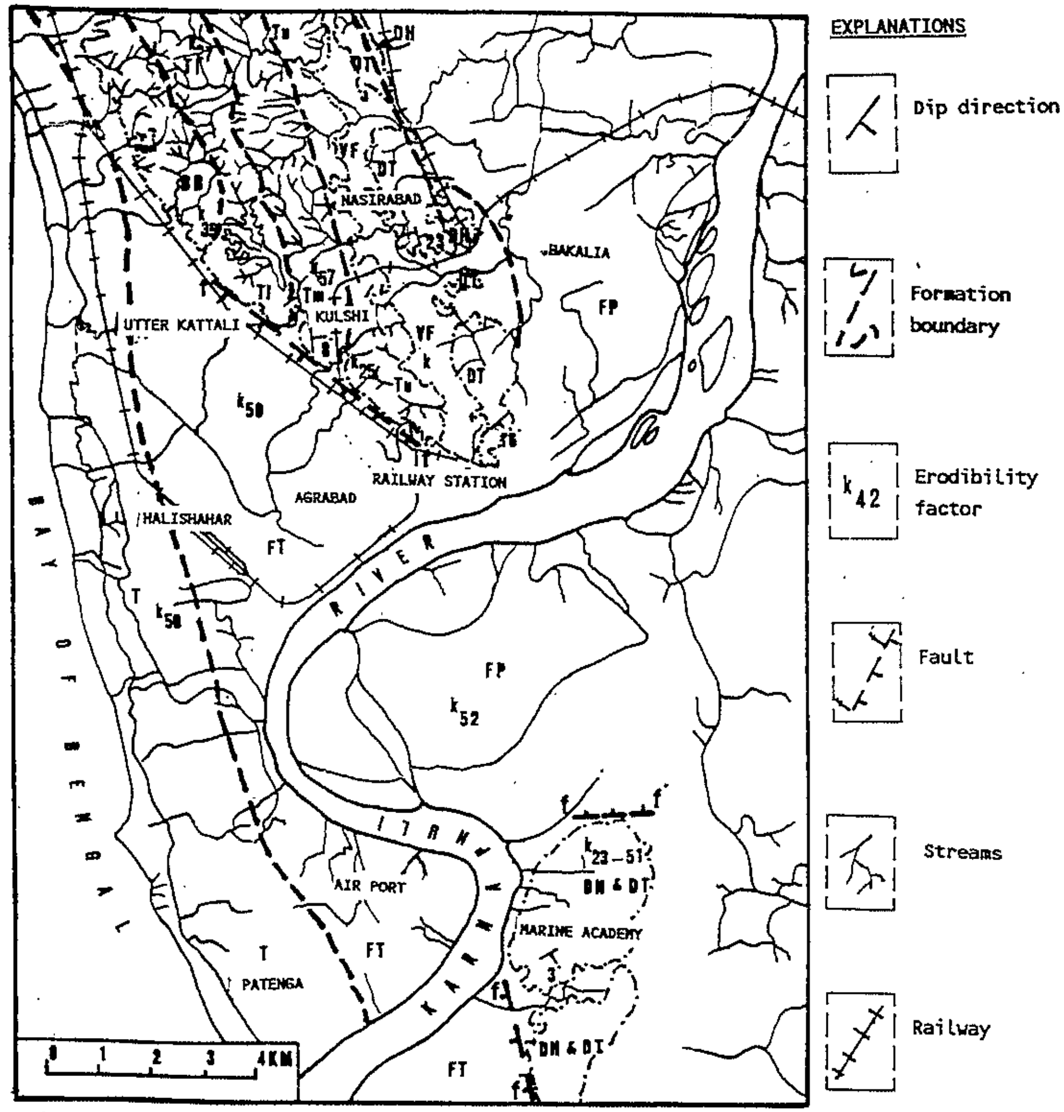


Fig. 2. ENGINEERING GEOLOGICAL MAP OF CHITTAGONG CITY

Table 1. ENGINEERING GEOLOGICAL CHARACTERISTICS OF THE MAP UNITS

| INDEX | UNIT | LITHOLOGY | AGE | GRAIN SIZE % | | | UNI. COPM. STRENGTH kg/cm$^2$ | ERODIBILITY FACTOR, k |
|---|---|---|---|---|---|---|---|---|
| | | | | SAND | SILT | CLAY | | |
| T | Tidal deposit | Grey fine sand, silt and clay. | H O | 4 to 13 | 66 to 67 | 10 to 29 | 0.44-0.88 | 50 |
| FT | Fluvio-tidal deposit | Brownish grey silty, sand, clayey silt. | L O C | 7 to 77 | 20 to 92 | 08 to 26 | 0.37-0.83 | 50 |
| FP | Flood plain deposit | Gray silty sand, sandy silt. | E N | 3 to 77 | 23 to 92 | 0 to 08 | 0.60-0.73 | 52 |
| VF | Valley fill deposit | Brownish gray clayey silt and sand. | E | 24 to 60 | 14 to 56 | 0 to 20 | 0.39 | 42 |
| DH | Dihing Formation | Reddish brown pebbly sand and clay silt. | PL-EI-ST. | 14 to 95 | 5 to 63 | 0 to 23 | 1 - 2<br>10 - 100 (intact) | 32-47 |
| DT | Dupi Tila Format-ion | Brown sand-stone, silt-stone silty shale. | P L I | 18 to 90 | 10 to 62 | 0 to 20 | 1.8<br>10-30 (intact) | 23-51 |
| Tu | Tipam Fm. (Upper) | Sandstone and silt stone. | O / | 89 to 92 | 08 to 13 | – | >550 (intact) | 25 |
| Tm | Tipam Fm. (Middle) | Siltstone and shale. | M I O | 10 to 36 | 60 to 76 | 04 to 15 | 550-1100 (intact) | 57 |
| Tl | Tipam Fm. (Lower) | Sandstone with inter-bedded shale | C E | 77 to 88 | 12 to 23 | --- | 275 - 750 (intact) | 27 |
| BB | Bokabil Fm. | Sandstone, siltstone, shale. | N E | 3 to 95 | 5 to 74 | 0 to 24 | 250 -750 (intact) | 35 -50 |

Table 2. Values for rainfall coefficient,C and erosivity index,EI.

| Months / Index | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | .003 | .138 | 2.204 | 30.38 | 1.37 | 53.56 | 552.82 | 155.98 | 58.17 | 0.45 | 0.83 | 0.10 |
| EI | 0.05 | 1.28 | 6.58 | 125.01 | 8.00 | 202.24 | 1473.2 | 502.54 | 217.24 | 3.5 | 5.8 | 0.97 |

activity in the hills formed of soft rocks.

## Soil erosion

A soil erosion map (Fig. 3) has been made following intensive engineering geology field work. In the map, erosion is graded into severe, moderate and low by on-the-spot checking of visible erosional features (concentration of rills, gullies, loss of soil cover, density of vegetation and type of mass movement) and potential erosional hazards.

Severe erosion

Severe erosion is taking place in the hilly region, mostly in the eastern part of the city and in the hillocks located in the southern bank of the Karnaphuli river near the Marine Academy. Severe erosion in this area was triggered about two decades back when development work caused the removal of vegetation. In some places the severe erosion is active (Sa), where the area has turned to badland. At places like Sholoshahar, North Nasirabad, etc. erosion has been recently initiated (Si) by cutting of hills. The valleys near Kulshi, Foy's Lake and Nasirabad are being filled with uncompacted sand creating a seat of potential catastrophe. Besides, erosion by rills and gullies, landslide, slope failure and mass movement of

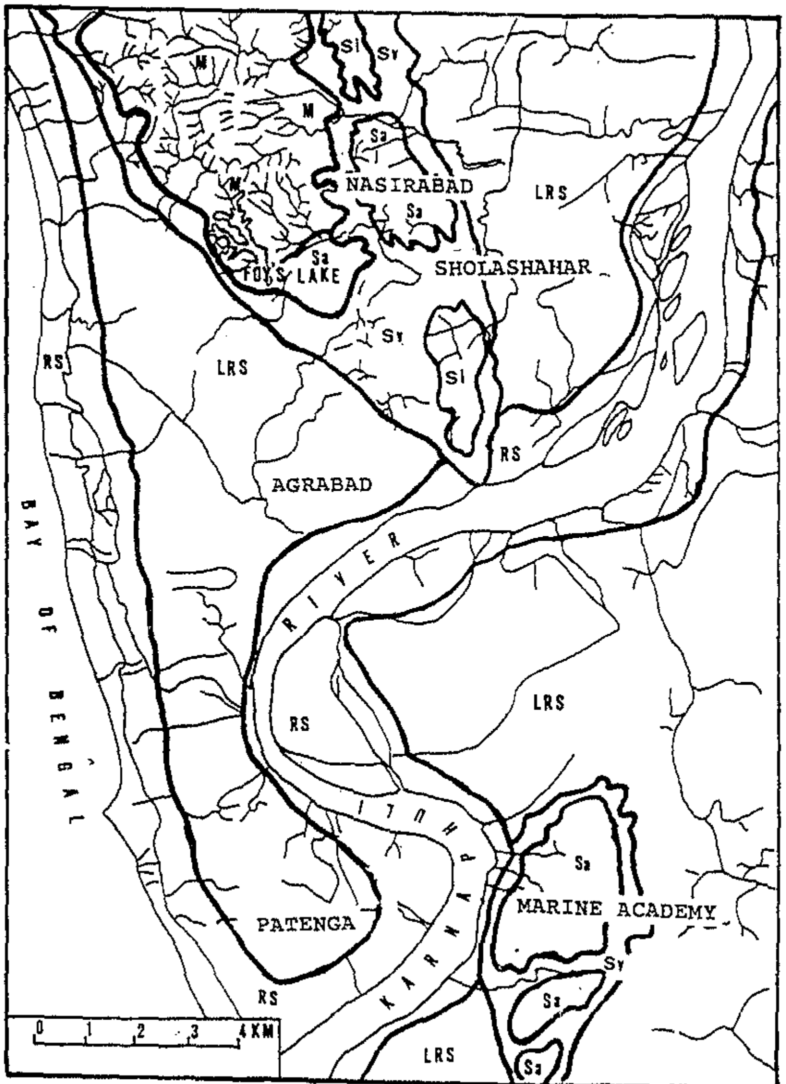


Fig. 3. EROSION MAP OF CHITTAGONG CITY

**EXPLANATION**

A. Severe erosional area subject to deforestation.

| | |
|---|---|
| Sa | Active, severe erosion. |
| Si | Severe erosion, initiated by human interaction. |
| Sv | Valley fill under potent erosional threat. |

B. Moderate to low erosional area subject to flash flood and steady water flow.

| | |
|---|---|
| M | Moderate erosion initiated by mass movement along the valleys, and slope surface. |
| LRS | Low erosion by steady water flow, reel and sheet type erosion. |
| RS | Low erosion mainly reel and sheet type along the coastal plain and river banks. |

rocks are taking place.

Precipitation, slope and human interference are among the primary factors eliciting erosion. During a heavy rainfall, a sloping area, in north Nasirabad, of about 2 sq.km was monitored. The slope angle ranges from $15^0$-$45^0$. The vegetation and part of the soil cover had been removed earlier due to human activity. It was found that sediments upto a depth of 0.5m was removed at places by gully scouring in 2 hours of rainfall . This phenomenon probably occurs seldom, but it gives an idea of the severity of the erosion.

Moderate erosion

Moderate erosion is taking place in the west of the city area and in the hills in the north and south of the river. Rills and gullies have been initiated with relatively lesser amount of mass movement.Presently, this part of the area is covered with shrub, reed and grass type vegetation but once it was covered with dense forest.

Low erosion

The plainland including river banks and coastal area is affected by low erosion. Exceptionally, during cyclones, the coastal area may suffer severe erosion. The coastal plain and river bank are being eroded due to rill, sheet,bank and marine erosion. Rest of the plainland is affected by rill and sheet erosion.

Some parts of the plainland are acting as pockets of deposition including alluvial fan deposits along the foot of the hills. Aerial photographs of 1960 show that a large number of ponds/depressions were present in and around the city areas. The result of the field investigation indicates that a number of these have been filled up by natural sedimentation in the last 30 years. Most of the existing ponds are about 3.5 metre deep.

Cyclones and tidal surges cause spectacular erosion. During the cyclone of April 29, 1991, tidal surges washed away the 3 metre high earth embankment, near the port in Patenga and at numerous other places. The coastal relief was changed to a considerable extent. Besides devastation to life and property, the entire plainland was flooded by saline water which was very harmful to crops.

Area covering Dupi Tila Formation is being severely eroded (Fig. 2 & 3). But when correlated with erodibility factor it is found that, theoretically, the constituent materials of Dupi Tila are less likely to be eroded. Human interference, like removal of vegetation cover and cutting of slope, is the main catalytic factor causing this discrepancy.

**Landslide and slope failure**

Slope failure is one of the major geologic constraint in the hilly area which is causing recurring landslides. If management is not planned it is liable to aggravate further. It may be noted that the inclined, interbedded nature of the rock strata and heavy precipitation are all potent for landslide. In this situation, human interference acts as the triggering device by interrupting the natural equilibrium. Three types of landslide and slope failure were identified in the area.

a. Lateral spreading failure,

b. Rotational and translational failure,

c. Planer or block failure.

Landslides due to lateral spreading failure occur in the hill formed of Dupi Tila Formation. The sites of such failure are located south of the Marine Academy (Hasan,1981) and north of Sholashahar Railway Station. It also causes initiation of translational and rotational movement affecting structures at long distances. Landslides by spreading failure are also found in the areas occupied by Tipam Sandstone. The height of hills in which such landslides have occurred varies from 20m to 25m where the width at the toes is around 30m.

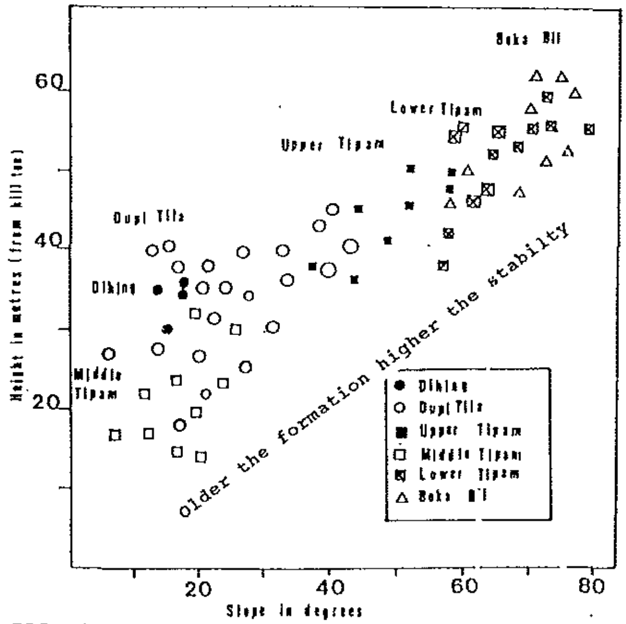

FIG. 4. PLOT OF HEIGHTS VERSUS SLOPE ANGLES OF NATURAL HILL SLOPES FOR THE DIHING, DUPI TILA, TIPAM AND BOKABIL FORMATIONS.

The rotational and translational failures are found mostly around Foy's Lake in Tipam Sandstone unit. During the rainy seasons the failures mostly take place along the dip directions of the beds consisting of massive sandstone alternating with fissile shale. Rotational slides also take place in the hills formed of Dupi Tila Formation in the south of the river Karnaphuli. The height of these hills is about 45m and the slope is around $20^0$.

Planer slide or block failure occurs in Tipam and Bokabil Formations in hills having a height of more than 20m. In the Bokabil Formation the landslides are composite of slump and block failures. The formation is composed of thinly laminated silty shale interlayered with very hard calcareous lenticular bands of siltstone. The beds are fractured predominantly in the vertical direction, which sliced the hills into large blocky segments. Though the bands have unconfined compressive strength upto 350 kg/cm$^2$, the breakdown of the formation into blocky segments and the fissility of silty shale have reduced its overall shearing strength. The increase in slope inclination and decrease of shearing resistance due to weathering or removal of cementing material are among the causes (Terzaghi,1950) of these landslides.

The correlation between the height and slope of the hills shows a positive correlation of slope stability (Fig. 4). Except for the Middle Tipum hills, the older the formation the higher the stability.

**CONTROL MODEL**

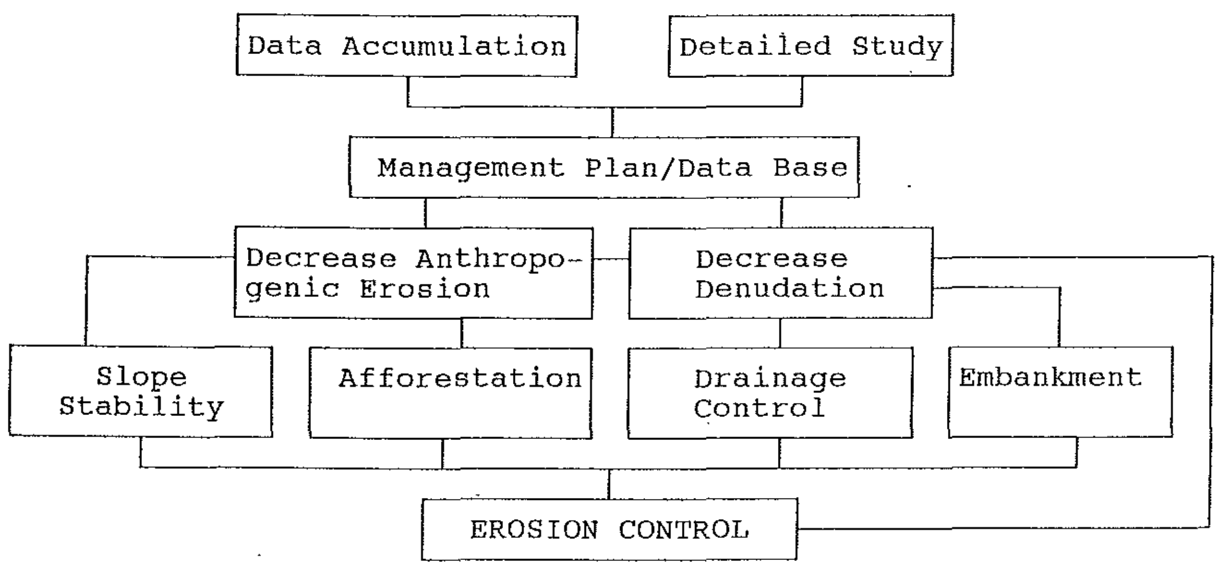


Fig. 5. Model for erosion control in Chittagong City area.

For any control programme to be effective, the input data have to be sufficient in quality and quantity. For Chittagong city there is a dearth of data needed for estimation of erosion. There is a great need for a systematic accumulation of data. This together with detailed engineering geological work will create a data system with which a management plan against erosion may be initiated. The first priority of the control would be to stop the spectacular anthropogenic erosion and then to limit denudation.

As Chittagong is expanding as a port city, the following four factors are to be considered important and be incorporated in the master plan.

i) Further municipal drainage and road communication network may be set up so that it would also act as a countermeasure for erosion. The first step would be to establish the pattern and quantity of runoff. Then the drainage system should be made or suitably reinforced so that it would intercept the runoff causing it to run through municipal\trained channels and making erosion significantly ineffective. As cuts in the slopes also reduces erosion, required roads be should cut across the slopes taking the mentioned factor into account.

ii) Construction work may be integrated with a form of local terracing which would reduce slope. For selecting the site for constructions, the dip of the local beds and fractures are to be taken in the design factors.

iii) Afforestation and agricultural locations in and around the city should influence the surface runoff and soil existence.

iv) The badland areas are drained by dense rills and gullies. These gullies are prone to intensive scouring and require gradual treatment and checking by stabilization of slope and plantation of fast growing vegetation or using proper geo-textile.

## CONCLUSION

Due to the geographical location and the tropical erosional factors, Chittagong city has always been a potentially erosive zone. With the expansion of urban development work, human interference has triggered spectacular erosion.

Detailed study and systematic data accumulation are needed to make a management plan of the city. This would first act as counter measure to the anthropogenic erosion and next take on denudation in general.

Due to geographic and geologic factors, various forms and types of erosion are taking place in and around the Chittagong city. The authors would like to propose this erosively dynamic zone as a type area to be studied for various types of tropical erosion.

## REFERENCES

Hasan, A. K. M. S. 1981. Slope Instability and Construction Damages at Mercantile Marine Academy, Chittagong District, Bangladesh. Records of The Geological Survey of Bangladesh, Vol. 3, Part 1, pp. 1-21.

Holy, M. 1980. Erosion and Environment. Pergamon Press, Oxford.

Karim, M. F., Ahmed, S. and Olsen, H.O. 1990. Engineering Geology of Chittagong City. Report of Geological Survey of Bangladesh. 158 pp.

Moldenhauer, W.C. 1980. Developing erosion research programs in areas where limited data are available.In: Assesment of erosion. Boodt,M.De and Gabriels,D. Eds. John Wiley and Sons. New York. pp. 271-276.

Terzaghi, K. 1950. Mechanics of Landslide. In: Application of Geology to Engineering Practice ( Berkley Volume ), Geol. Soc. Amer. pp. 83-123.