ENVIRONMENTAL HAZARDS IN THE COASTAL AREAS OF BANGLADESH: GEOLOGIC APPROACH (SUMMARY)

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(In, Ferraras, S. F., and Pararas-Carayannis, G. (eds.), Natural and Man-made Coastal Hazards, Proceedings of the 3rd International Conference on Natural and Man-made Coastal Hazards held in August 15-20, 1988, Ensenada, Baja California, Mexico, p. 37-42.)

Introduction:

Bangladesh is a south asian country with an area of 142,000 sq.km, about the size of Wisconsin. Bangladesh borders India on three sides, north, east, and west. The population of Bangladesh is about 100 million, of which 20 million live in the coastal districts. The density of population in the coastal districts is higher than that of the rest of the country. The density of population has increased as much as four times during this century. The high rate of population growth pushes millions of people to live in the low lying coastal areas which are highly vulnerable to various types of environmental hazards.

This paper is based primarily on my field work in the coastal areas between 1983-85. I have also used some published data and maps on the area by other authors, but the interpretations are essentially my own. This paper addresses various natural and man-made coastal hazards that have lead to the death of thousands of people and significant property damage in the past. The evolution of the coastal areas and relationship between coastal hazards and geologic processes is also discussed. Finally, the necessity of understanding these problems from the view point of geologists and the need for geologic studies to mitigate these hazards are shown.

Natural and man-made coastal hazards:

The Bangladesh coast is the most hazardous coast in the world in terms of the number of people who suffer from various types of environmental hazards every year. The coastal cyclonic surges are the most dangerous hazards in the coastal areas of Bangladesh. When the annual cyclones roar in, hundreds and sometimes thousands of people are swept away. Counter-clockwise cyclonic surges are created offshore due to low atmospheric pressure, which pushes a wall of water with a height of up to 10 m and a wind velocity of about 150-200 km/hour to the land causing both death and property damage. The "great cyclone" of 1970 killed a half million people and left another million homeless. Since 1963, 600,000 people have been killed in Bangladesh by cyclonic surges. The most frequent surges return every 2-10 years with a surge height of 2-10 m and wind velocity of 50-200 km/ hour. A total of 145 surges struck the coast of Bangladesh, Burma, and India during the period of 1877-1987, giving an average rate of 1.3/ year.

Tornadoes are another type of coastal hazard. They are capable of causing both casualties of human lives and extensive property damage. More tornadoic events occur in Bangladesh than elsewhere on the Indian subcontinent. During the period of 1877-1987 a total of 19 severe tornadoes were reported in Bangladesh. Estimates of wind speed within the tornadoes have ranged up to 150-200 m/sec. One tornado in 1963 reportedly scoured the ground and deposited scraps of metal 50 km from the source.

Flooding has become a common annual hazard during the rainy season in recent years. There are about 300 large rivers, creeks, and channels in Bangladesh forming a network together with the three major rivers, the Ganges, Bramhaputra, and Meghna. The dimensions of these rivers and their drainage basins are disproportionately large compared to the small area of Bangladesh. Seasonal variation in precipitation, and in the intensity and amount of discharge cause the flood flow in Bangladesh. Changes in the base level of the rivers due to sea level rise has added another dimension to the flooding problem. Now, compared to past, the same amount of water can cause intensive flooding in the country. The annual flood situation, especially in the low lying coastal districts, has further deteriorated following the damming, Farakka barrage, of the Ganges inside India. The drainage capability of the Ganges and its distributaries has been reduced due to the increase in aggradation of river beds since the diversion of the upstream flow of the Ganges. Now, less water flows from India into Bangladesh during times of drought, in summer months, and more is released during flood season which causes severe flooding, such as in 1974, 1987, and 1988. The government has taken many flood control project, such as building up of embankments along the river banks to reduce the intensity and amount of discharge cause the flood flow in Bangladesh. A regional plan would be necessary to mitigate the flooding problem.

The upstream diversion of the Ganges water and consequent reduction of sediment influx to the coastal areas have triggered many other secondary environmental hazards: shoreline erosion, submergence of coastal areas (especially the western parts of the delta which are drained by the Ganges and its distributaries), salinity intrusion, erosion of the riverbanks of other rivers (such as the Bramhaputra, Meghna, and Tista) due to disequilibrium in the hydrodynamic system, interruption of the navigation system in the coastal areas, drawdown in the groundwater levels, and many others.

Some of these hazards, namely the coastal cyclonic surges, and tornadoes are caused by natural processes. Others, like coastline and river banks erosion, coastal submergence, floods, drawdown in groundwater levels, salinity intrusion, and gradual fall in water levels of the rivers are caused by a combination of natural processes and human interference with nature.

Most of the man-made coastal hazards in Bangladesh have been triggered or accelerated by the upstream diversion of the Ganges inside India. The fluvial sediment supply to the coastal areas is a prerequisite to and a primary cause of any delta building process. The Ganges contributes about 67% of the total suspended sediment load in Bangladesh. The upstream diversion of the Ganges has reduced the sediment contribution by 30% . As a result, the once prograding delta is now experiencing coastal submergence due to transgression caused by a reduction in sediment supply combined with the eustatic sea level rise and local subsidence.

Geologic approach:

The Ganges-Bramhaputra delta has been growing both upward and seaward since its creation. Historical, archeological, and geological evidence shows an average progradation rate of about 80-100 m /year until the recent past. Radiocarbon dates on peat deposits collected from the delta area show a sedimentation rate of 0.5-0.6 cm/year.

The seaward growth of the delta has been reduced drastically during last two hundred years, probably due to severe erosion of the coastal land surface caused by extensive agriculture and deforestation by the settlers in the coastal districts. The coastal embankments along river banks, tidal creeks, and islands also accelerated this erosional process as they protected tidal flats from tidal inundations. As a consequence, the vertical sedimentation rate was insufficient for the delta to prograde seaward for the last two hundred years, or since extensive settlement in these areas. Instead, the delta has rather striven to keep pace with sea level rise. This situation has further deteriorated due to the reduction of sediment supply to the coastal areas following the 1974 damming of the Ganges in India. Now, most of the western parts of the delta do not have any fluvial sediment supply and are undergoing coastal submergence.

The diversion of the Ganges flow by the damming of the upstream region and consequent reduction in the annual sediment supply from 2.4 billion tons/year to 1.8 billion tons/year, have not only retarded delta progradation but also have threatened the existence of the delta, the homeland for about 30 million people of the coastal districts of Bangladesh. The entire world is about to enter in a period of rapid sea level rise due a global warming up of the atmosphere caused by man's activities, the "greenhouse effect". Bangladesh is the most vulnerable to the further rise in sea level projected by the scientists for the next century. The Ganges-Bramhaputra delta in Bangladesh would be especially susceptible to an increase in sea level rise in the future, because it has already started to experience coastal submergence due to sediment starvation, and because the present elevation of the entire coastal region does not exceed 2 m AMSL. Further removal of fluvial sediment supply, as through upstream damming projects, would reduce the ability of the delta to build itself seaward or to stabilize itself against the forces of subsidence and erosion. More drastic would be the combined effect of decreased sediment supply to the coastal areas and the predicted sea level rise of 1-2 cm/year in the next few decades. An increase of sea level by only 1 m will cause submergence of an area of about 20,000 sq. km, and encroachment of the present shoreline into the upland areas by 100 km inundating many major cities and localities such as Khulna, Barisal, Bagerhat, Patuakhali, Barguna, and many others. The relative increase in sea level with respect to the land will proportionately increase the area of violent inundation by deadly storm surges further inland.

All of the coastal hazards are related to the geologic processes and have an profound impact on coastal landforms. Thus, better understanding of their nature is necessary to plan the land and water resources wisely while safeguarding the quality of the environment. Even though not all coastal hazards, like tornadoes,and coastal cyclonic surges, can directly be mitigated by a geologic approach, many others, such as shoreline and river bank erosion, coastal submergence, river bed aggradation due to siltation which causes problem to navigation, and salinity intrusion, can be solved if a better geologic understanding of the environmental hazards and the geology of the coastal area itself can be coupled with the knowledge and efforts of engineers, meteorologists, and planners.

Geologic Solutions:

The primary and basic geologic solution of these coastal hazards is to permit the delta to grow both vertically and horizontally, seaward at a rate that would keep pace with the predicted sea level rise in the next century. A detailed study of geologic processes, namely the geometry and hydrodynamics of the rivers and channels in the coastal areas, dynamics of sedimentation, amount and rate of sediment accumulation, rate of coastal erosion and subsidence, rate of local sea level rise, nature of dynamic coastal processes like wave, tide, and wind, are necessary in order for any development plans or preventive measures to mitigate the coastal hazards to be successful.

Human modification and control of geologic and other dynamic processes has become a very common practice for better management of the world's coastal zones. Physical control on hydrodynamic processes, such as velocity and direction of the river flow in the coastal areas, geometry of river basins, amount of terrigenuous sediment influx to the coastal areas, sediment dispersion, and sediment accumulation would be necessary in order to accelerate the delta growth, and consequently to mitigate the hazards in the coastal zones. If the location of the coastal zones is displaced seaward from their present location, the intensity and severity of the coastal hazards will migrate seaward as well.

Sediment availability, supply, dispersion, and accumulation are the primary needs for such accelerated, physically controlled, growth of the delta. The average suspended sediment load of the Ganges-Bramhaputra river system has declined from 2.4 billion tons/ year (67% delivered by the Ganges) to 1.8 billion tons/year since the diversion of the Ganges through the Farakka-Barrage damming project. This reduction in sediment influx has definitely decreased the growth of the delta, especially in the western parts of the delta which are drained by the Ganges and its distributaries. If this reduction continues for a long time, it will preclude delta growth against the holocene transgression due both to eustatic sea level rise and local coastal subsidence.

The calculation of a sediment budget using the amount of annual suspended load, area of deposition, and rate of sedimentation in the coastal zones shows that merely 10% of the annual suspended sediment load, 2.4 billion tons, is required to aggrade the delta at the present rate of sediment accumulation, 0.5-0.6 cm/year. Most of the accumulation of suspended sediment takes place in the coastal areas by tidal inundations. Other parts of the country, fluvial delta plains, get a little fluvial sediment only during rainy seasons by flood inundations. For the rest of the year, fluvial delta plains undergo erosion due to extensive agricultural use and tillings, resulting in a net rate of sedimentation on the fluvial delta plains that is very low to negligible. Probably, not more than 5% of suspended load is deposited on the fluvial delta plains. Thus it can be calculated that net sediment accumulation from suspended load does not exceed 10-15% of the total load. Apparently, many factors are responsible for the low rate of sediment accumulation in the coastal areas: local subsidence; narrow continental shelf (30-90 km); erosion of the tidal flats and other areas due to human activities (mainly through tilling); bypassing of the suspended sediment coastal embankments along the tidal creeks and channels; channeling of suspended sediment to the offshore submarine canyon- "Swatch of no ground"; and the high velocity of tidal currents.

The present suspended sediment load, 1.8 billion tons/ year, is still sufficient for the delta to keep pace with rising sea level, provided the rate of sediment accumulation can be increased. Calculations of sediment budget and accumulations show that 30% of the present suspended sediment influx to the coastal areas is capable of aggrading an area of 30,000 sq. km, the area of the entire coastal districts of Bangladesh, when sea level rises at a rate of 1 cm/year, the EPA (Environmental Protection Agency of the U.S.A.) predicted rate for the next century. The same amount of sediment is capable of aggrading an area of 150,000 sq. km (an area greater than the size of Bangladesh) at a vertical rate of 0.3 cm/year, which would keep pace with the present rate of local sea level rise.

The primary cause of the present and predicted coastal submergence is the deficit in the rate of sediment accumulation in the coastal zones compared to that of sea level rise. Physical control on the velocity and direction of the rivers (through construction of sluice-gates and other control structures), on the amount of sediment supply to the coastal zones, and on sediment dispersion and accumulation at desired rates, would be necessary in order to increase the amount and rate of sediment accumulation in the coastal areas. Diversion and increase in the amount of fluvial sediment on the tidal flats, especially in the western and central parts of the delta, can come from several sources: increase the amount of suspended load by excavating the already abandoned tributaries and distributaries of the Ganges; annual dredging of the Ganges and its distributaries namely, the Madhumati, Bhairab, Chitra, Kalia, Nabaganga, Kaliganga, Mongla, Passur, and others; controlling the diversion of the suspended load from the Bramhaputra, Meghna, and their distributaries to the submerging parts of the delta; increasing the frequency and duration of tidal inundation of the tidal flats by puncturing the embankments to allow suspended sediment to reenter the low lying tidal flats. Most of the tidal flats are segmented and surrounded by dikes and embankments built to protect the crops from floods, and for aquaculture developments. Thus, they are undergoing erosion, and suffering from lack of sediment supply.

The rate of sediment accumulation can also be increased by building up an artificial headland or offshore design structure. The design structure can be built further offshore, where depth of water does not exceed 2-3 m. The details, economic aspects, feasibility, construction materials, study of the nature, and behavior of the coastal dynamic processes, exact location, etc., would need to be worked out before the actual project were started. The artificial barrier would not only increase the rate of sediment accumulation in the coastal zones but also decrease the severity of the cyclonic surges, and erosion of sea face tidal scarps caused by waves and tidal currents. If such an artificial headland could withstand the forces of coastal dynamic processes including cyclonic surges for about 50 years or so, a huge sub-aqueous delta front could emerge rapidly above sea level. Beside the formation of an artificial barrier, reforestation of the reclaimed coastal zones and sea face strips of present tidal flats could also increase sediment accumulation.

Reoccupation of formerly active distributaries of the Ganges through dredging would reestablish the already disrupted equilibrium of the hydrodynamic system due to upstream diversion of the Ganges. Agriculture, irrigation, and navigation would benefit from planned and homogeneous distribution of water and sediment load. Also, the annual flood situation and river bank erosion would be minimized as well.

Conclusions:

All of the coastal hazards described earlier are related to geologic processes, and have a profound effect on coastal landforms. Therefore, a better understanding of their nature, frequency, intensity, magnitude, and effects are necessary from the geologic point of view.

It is not too late to investigate these problems and to attempt to mitigate them in order to save millions of lives. The entire scientific community, especially the geoscientists, should come forward to face this challenge.

However, mutual cooperation and understanding among the coriparian nations is a prerequisite for implementing any extensive interbasin development program. Moreover, for Bangladesh, a developing country, it is important to get the assistance of the international community, without whose cooperation more casualties of human lives are expected in the future. The U. N. resolution for establishment of the International Decade for Natural Disaster Reduction (IDNDR) is definitely a lighthouse of hope for millions of people living in the regions vulnerable to natural disasters, such as Bangladesh.

Reference: Presented at 3rd International Conference on Natural and Man-made Coastal Hazards held in Ensenada, Mexico in 15-20, 1988. This summary is published in Ferreras, S. and Pararas-Caryannis, G. edited Natural and Man-made Coastal Hazards: Ensenada, Mexico and San Diego, USA, 1989, p. 37-42.