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Chapter Thirteen

NATURAL CALAMITIES DUE TO FLOODING AND CYCLONIC STORMS: BANGLADESH

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INTRODUCTION

Bangladesh, meaning land of Bangladeshis, is a small country with an area of 88,000 square kilometers and home for 110 million people. Bangladesh, formerly known as East Pakistan, became an independent and sovereign country on December 16, 1971. It is surrounded by India to the east, north, and west. Burma fringes a narrow tip of the southeast border while the south is open to the Bay of Bengal (Figure 1). Bangladesh is located between 20° 35′ N to 26° 40′ N latitudes and forms a part of the subtropical Asia with semihumid climate. The annual rainfall ranges from 130 cm to 575 cm; however it can reach up to 800 cm in the northeastern region of the country. Most of the precipitation occurs during the monsoon season, May to October.

Bangladesh is a riverine country and forms a major portion of the Bengal Delta, one of the largest deltaic complexes in the world. The mighty Ganges-Brahmaputra drainage system, one of the largest in the world, is responsible for the delta-building activity. It is one of the most-densely populated countries in the world and, similar to other developing nations in southeast Asia, is overburdened with complex socioeconomic problems. In addition, Bangladesh is particularly frequently subjected to natural calamities due to flooding and cyclonic storms.

Currently, the country is constantly experiencing frequent catastrophic and high-magnitude flooding and cyclonic storm events. Warm, moist, maritime, airmasses associated with excessive precipitation cause severe local flooding. Sometimes daily precipitation can reach up to 50 cm and make it impossible for adequate drainage in an otherwise flat terrain. The total inability of the large rivers to contain very rapid and extremely high discharge from the upstream region causes severe flooding in this region. *Besides the rapidly growing demographic trend (almost 2 percent every year since 1970) and food shortage, these floods and cyclonic storms constitute the major national problem.* Nowadays, flood and cyclonic storm-induced disasters are becoming international crises since the country is unable to effective-

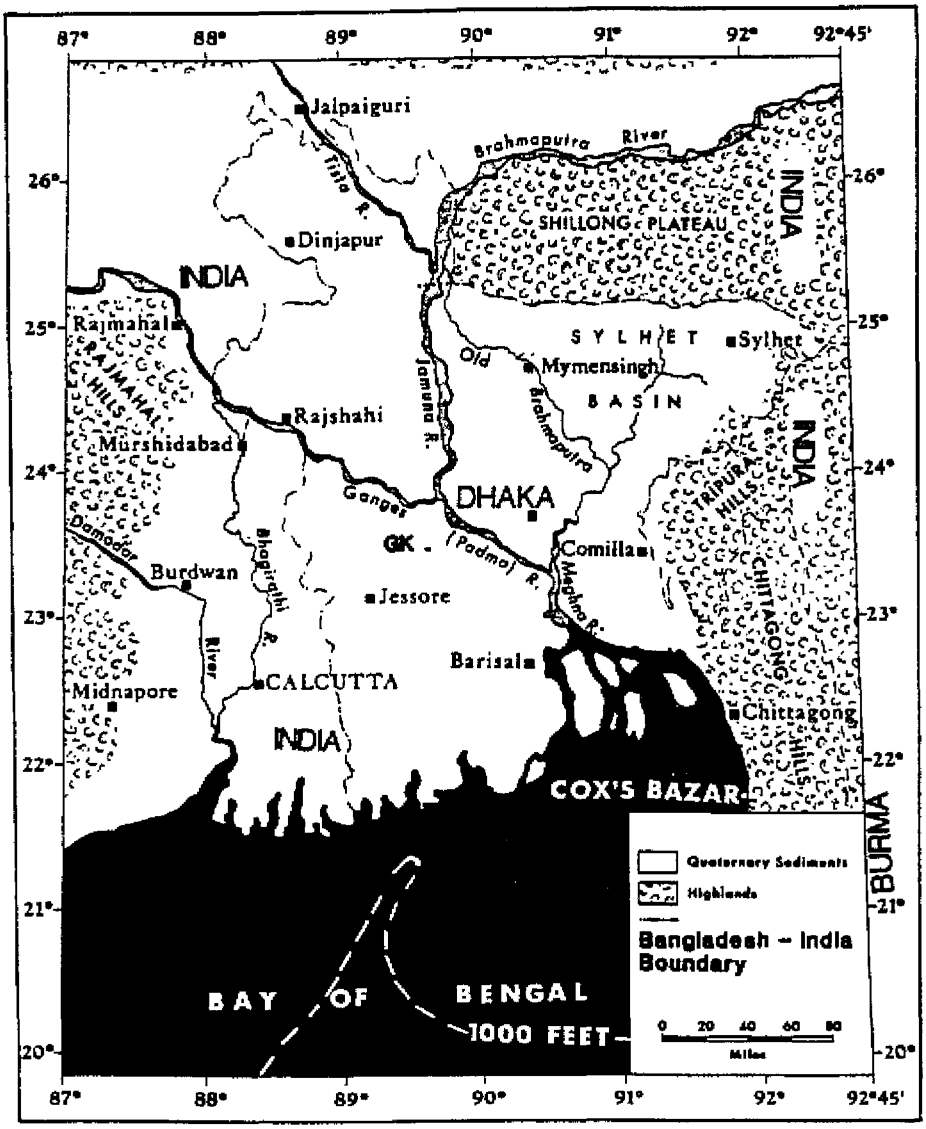

FIGURE 1. Physiographic map of Bangladesh and adjacent countries. Quaternary Sediments: mostly deltaic-floodplain sediments (younger than 1.5 million years); Highlands. composed of pre-Quaternary and older rocks GK: Ganges-Kobadak Project. (With permission from Morgan & McIntire, 1959)

ly respond to these natural calamities alone. About 1/3 of the total country is annually flooded. Excessive and long-term flooding events, sometimes lasting for several weeks, inundate almost 3/4 of the country (1973 and 1988). Similar flooding happens in several regions in South Asia, but the effects are not always disastrous. Ironically, without the annual deposition of organic-rich silts from the Ganges and Brahmaputra Rivers, intensive rice and jute cultivation characteristic of the country would be impossible.

CAUSES

The primary causes for excessive flooding and cyclonic storms in Bangladesh can be attributed to several factors including, *climatic, geological, geomorphological, deforestation in the high Himalayas, and global warming trends.*

CLIMATOLOGICAL

The unique geographic situation of Bangladesh with respect to warm ocean water of the Bay of Bengal in the south and Himalayan Mountain belt in the north provides a critical control on the monsoonal precipitation in the country. This monsoonal precipitation is largely due to the effect of excessive heating over the higher Himalayas and inland deserts which force a strong onshore monsoon flow during the summer. The fundamental driving mechanism of this circulation is differential heating. The inland temperature attains a maximum compared to the surface ocean, which is relatively cooler and denser. The heated continental airmass having a lower density than cool ocean airmass results in an ascending current over the land and an onshore flow in which denser ocean airmass pushes against the lighter air inland. The magnitude of the ascending and onshore circulation of airmass is determined by the degree of heating of the higher Himalayas and inland deserts. In addition, the close proximity of the region to the very warm surface waters of the Bay of Bengal contributes very high moisture content to the onshore airmass. As the warm moist air rushes inland it is forced to rise where it encounters the topographic barrier posed by the mountains. The rising air mass cools, which results in condensation, cloud development, and heavy rainfall. Orographic lifting coupled with the development of cyclonic storms, produces tremendous rainfall intensity which ultimately leads to flash flooding. Hence, flooding is an integral part of the climate of Bangladesh largely because of its characteristic geography and topography[2,3,4]

GEOLOGICAL

Geologically, Bangladesh is a very recent landform, emergent since Holocene (10,000 years ago) time. Bangladesh constitutes about 80 percent of the Ganges-Brahmaputra delta. It is generally a featureless plain with elevation ranging from near sea-level to 10 m for most of the country. The southeastern and northern part is dominated by an elevated region (175 m above mean sea-level). An enormous accumulation of deltaic to floodplain sediments, mostly less than 3.5 million years old, and on the order of 15,000 to 17,000 m thick, constitutes the basin-fill.

Geologically, most of the northwestern and southeastern regions of Bangladesh are neotectonically active (indicating current tectonic activity). Recent structural modification of these deltaic and floodplain sediments are expressed in the form of raised stream terraces, shifting stream courses, unique drainage patterns, and seismic activity (Figure 1). Two meters of Holocene uplift over an extent of more than 2000 km^2 in the northcentral region of Bangladesh has been documented by recent study.[5,6] This northcentral region is situated within the previously documented geologically active zone (Figure 1) which roughly follows the trend of the Jamuna-Padma-Meghna river system. This evidence points either to a subsiding basin or to a single major fault at depth.[5]

GEOMORPHOLOGICAL CONSTRAINTS

Drainage patterns and behavior

The present Brahmaputra River, west of the Madhupur Tract (Figure 1), now known as the Jamuna River, has shifted course dramatically during the recent history. During 1792 and about 1830, the Brahmaputra River, now known as the old Brahmaputra River, shifted westward about 100 km from the east of the Madhupur Tract. During higher flood events, overflow is still diverted into the old Brahmaputra and enables the two rivers to flow at the same level. Changes in the courses of the Ganges and Brahmaputra rivers across the northcentral region of Bangladesh during the last few hundred years can be attributed to faulting and resultant tilting of fault blocks. This remarkable channel shifting is accentuated by lateral migration with some minor channel switching and a prominent avulsion in the last 200 years.[5,7] Coleman (1969) concluded that the change in course took place gradually due to increased flood discharge, faulting, or a combination of both.[8] The avulsion (shifting) resulted in a maximum channel displacement of 100 km westward.

The unique nature of drainage patterns, especially complex braiding (characterized by extremely variable discharge, high width-depth ratio, easily erodible banks, and formation of sandbars within or across the main channel which results in the development of a network of interlacing channels separated by bars or islands) associated with most of the rivers in northcentral Bangladesh directly influence the flooding phenomenon. The characteristic channel pattern in the Brahmaputra River reflects the interaction of the hydrologic regime, sediment supply, grain size, and slope.[9]

Variable discharge

The Brahmaputra River is 2840 km long and drains an area of some 380,000 km^2

from Tibet to the Bay of Bengal. The maximum discharge recorded in 1984 (September 18) was 75,700 m^3/sec; the minimum discharge also in 1984 (February 20) was 3,950 m^3/sec.[9] The large variability in discharge results from the variable seasonal monsoon rains. High discharge condition may last for six to eight weeks and could cause prolonged overbank flooding. The overbank flood in 1973 had lasted for eight weeks. The Ganges-Brahmaputra river systems carry about 2 billion tons of sediments denuded from the higher Himalayas over Bangladesh.[9,10] Very high suspended sediment loads (4,544 ppm) characterize the Brahmaputra River[11,12] High-sediment yield coupled with shifting courses and frequent bank collapse also trigger major flooding.

Formation of sandbars

Formation of sandbars, the large width and depth of the channel, and higher rate of bottom siltation exacerbates to the flood event during the monsoon periods. The unique development of sand bars due to high sediment-load and bank collapse along and within the channel provide an additional constraint on the flow-path. Morphologically, these sandbars constitute around 53 percent of all deposition within the main river.[9] Development of sandbars within the main channel drastically reduces the depth of the main channel, decreases the stream velocity, and promotes overbank flooding.

In addition, bottom siltation and clogging of city sewage or underground drainage networks by plastic bags or nondecomposible garbage were one of the reasons the city of Dhaka (Figure 1) was severely flooded in 1988.

DEFORESTATION

Extensive deforestation in the upstream areas is considered to be an integral factor in increasing the frequency and magnitude of flood events in Bangladesh.[13] Deforestation decreases infiltration and increases the runoff generated by any precipitation event, and therefore may lead to unprecedented flooding. Deforestation enhances loss of topsoil which in turn promotes siltation in riverbeds. Large-scale deforestation in Nepal (source of the Ganges) and Assam (upstream Brahmaputra) has been going on for several decades. In addition, within the territorial limit of Bangladesh, total forest area rapidly declined from 25 percent to a mere six percent in the last several decades.

Rapid urbanization, demand for more ploughable land, and reliance on wood as a convenient source for energy, all pose a dangerous threat on the rapidly perishing forest resources of the country. The adverse effect of deforestation on the ecology, particularly the declining population of the Royal Bengal Tiger in the Sunderban mangrove forest is well-known, and has been cited as one of the primary causes for the diminishing population of this royal beast.

GLOBAL WARMING

A very significant factor pertaining to frequent flooding in Bangladesh may be attributed to the global-warming connected with the greenhouse effect. A gradual warming trend is believed to be global in character, based on the average temperature records from 1800 to the present.[3] This warming trend, seems to be compatible with greenhouse scenarios predicted by computer simulations. The effect of global warming on the existing air-circulation and precipitation patterns, and characteristic vegetation zones could be far-reaching and can easily disrupt a wide range of human and natural systems. Other effects, especially rise in sealevel due to increased melting rates of glaciers in the mountainous region, can inundate a large portion of the low-lying areas. This would definitely be devastating for coastal regions of Bangladesh and Maldives[13].

A sea-level rise of ten meters would leave three quarters of Bangladesh permanently under water[1]. Furthermore, its effect could be devastating on crops and human settlement on low-lying coastal regions. Melting of glaciers in the high Himalayas coupled with unusual precipitation and rapid deforestation rates are believed to be the primary causes of unprecedented flooding in Bangladesh during late monsoon of 1988. This late monsoonal flood inundated almost the entire country for six weeks, caused loss of human lives (officially 2000 people died), and heavy damage to roads and highways, houses, autumn crops, and livestock. It is quite apparent that the recurrence interval of higher magnitude flood events is being shortened considering eight of the world's ten worst floods severely affected Bangladesh in the last century.[14]

CYCLONIC STORMS AND CAUSES

The most dramatic natural disasters in South Asia have been associated with cyclonic storms.[1] These cyclonic storms originate in the late summer over the oceans of southeast Asia when water temperatures considerably exceed 27°C, the critical minimum for tropical cyclones to form. Once formed, the storms travel across the Bay of Bengal, guided by the Upper Air Easterlies. The Bay of Bengal acts as a funnel, and if the curved path of the storm brings it across the coast of Bangladesh, the most populated parts of the flat islands, large-scale catastrophic disaster can occur.[1] Some of the flooding in Bangladesh owes its origin to the sea. Bangladesh is particularly susceptible to such floods because much of the terrain is less than 10 m in elevation above sea level.

Storm surges, associated with cyclones, are capable of raising sea level temporarily by three meters or more[1]. In 1970, 1988 and 1991, for example, this led to the inundation of coastal regions. This effect, known locally as *Gorki* or tidal bore, caused not only loss of life on a colossal scale but also long-term damage to agricultural land through salinization, The recent cyclonic storm happened on April 30, 1991, severely destroyed the seaside town of Cox's Bazar and nearby islands, where 95% of the houses were completely destroyed (Figure 1). These islands and cyclone-affected continental region, are home to ten million people. The cyclone had struck during a full moon and high tide. 100,000 fishermen had been out in the sea and became the victims of the voracious tidal bore. Official estimates put the death toll around 125,000. Ten million people remain homeless. Of the ten million people, four million are classified as "in immediate risk".[14]

Fishermen lost their precious and hard-earned fishing fleets. Nearly one-tenth of the country's population live in the area and helplessly experienced the merciless effects of the storm. Cyclonic winds reaching up to 230 km/hour levelled most of the mud and straw huts. Prior warning systems in the form of megaphones and beating drums were sounded. Fortunately, hours before the cyclone hit, several thousand people took shelter in some of the sophisticated cyclone shelters built on three-story-high columns.

Similar tidal-storm surges have also wreaked havoc in other parts of South Asia. Some of the atolls of the Maldives, situated in the southern Indian Ocean, have been completely inundated, resulting in total loss of life and destruction of the island habitat.[14] This recent crisis compares closely with the 1970 cyclone in Bangladesh that claimed 0.5 million lives. The catastrophic disaster of November 12, 1970 will long be remembered. Sea level rose by over two meters in close proximity to the low pressure zone and where onshore winds pile up water against the shore. The sea surge coincided with very heavy rain and hurricane winds. Cyclonic storm-induced wind speeds reaching up to 240 km/hour triggered a tidal wave of up to nine meters in height. This tidal wave approached the nearby densely populated, low-lying, coastal islands situated near the mouth of the Ganges delta. The early warning system for cyclones was largely ineffective, and, without the protection of a sea wall or shelter, tens of thousands of people had nowhere to flee. Official estimates put the death toll as high as half a million.[1]

CONSEQUENCES OF FLOODING

The disastrous effects of flooding on the country's economy, human lives, agriculture, communications, livestock, and properties are numerous. Encroachment of salt water associated with the 1970 and 1991 cyclonic storms into the coastal surface and subsurface water ruined drinking supplies and thousands of acres of rice crops which were almost ready for harvest. These coastal areas are well known for their shrimp farms, seafish, and salt industry. Contamination due to seabrine on these coastal sites is long-ranging and it might take several years before these areas can be profitably utilized again. Frequent failures to harvest or raise crops due to flood damage place the country on a tremendous hardship when there is not enough food to support the entire population in the first place. Very often, food grains stored in private sectors are damaged due to excessive flooding. Disruption of communications further worsens the situation. Most of the roads especially semi-paved or unpaved village roads which are the major link to the nearby towns or markets, are washed away and even make it extremely difficult to distribute relief goods to the outlying areas of the country. Diseases such as cholera, typhoid, and dysentery spread as epidemics and take a heavy toll on human lives. Extreme shortages of safe drinking water during flood stages also add to the epidemics.

LONG TERM SOLUTION

Flooding and cyclonic events and their resultant consequences in Bangladesh are clearly connected to several factors including *climatic, physiographic, geologic, demographic, global climatic change, and international situations.* Any long-range planning to address these natural hazards requires complete understanding of each of these critical components. Educating people about the havoc of cyclonic and flooding events, building sophisticated shelters, creating emergency food storage to circumvent any catastrophic situation, establishing a well-organized relief force, and implementing effective warning systems through radio and television, will perhaps, substantially reduce the loss of human life and livestock. Damage to drinking water, crops, shrimp cultivation, and salt pan are more difficult to overcome.

Currently, large-scale flood-prevention measures include the Ganges-Kobadak project (see Figure 1) situated in the north-central part of the country. The project is designed for flood control, irrigation, and drainage.[15,16] This project, built in the 1960's in the Kushtia District, is fed by the water drawn from the Ganges River, the second largest river flowing into Bangladesh (the Brahmaputra being the largest). An intake channel receives pumped water from the Ganges River.

The Ganges-Kobadak project is also designed to partially help irrigate land during the drier months of February and March when the discharge through the Brahmaputra-Ganges system is the lowest (3,950 m^3/sec compared to 75,700 m^3/sec in September).[9] During the months of February - April, the north-central portion of Bangladesh faces a near drought condition when the surface runoff as well as precipitation is the lowest. Without adequate precipitation, aquifers in this region are not properly recharged. Groundwater pumping to meet the demand for water results in excessive drawdown and further worsens the situation. Eventually the underground water table drops deeper into the aquifer.

The initiation of this project has greatly improved the agricultural practices in the project area. Rice production, especially from high yield varieties (HYV) of rice, developed in the early 1960s, has been extremely fruitful. Other cash crops such as sugar cane, tobacco, wheat, and dal (lentils) also showed similar improved yields.[17]

A successful implementation of this project will have a tremendous impact on the socioeconomic situation of the country. However, like some other waterprojects in Bangladesh, the Ganges-Kobadak project has its engineering as well as bottom-siltation problems. Nedeco (1983) estimated a net 30 percent water loss since its initiation and ascribed this to infiltration and ineffective operational procedures.[15] Other significant geotechnical problems related to the projects are uneven distribution of water to the adjacent agricultural plots and rapid siltation within the intake channel. Creation of several secondary intake channels and building of earth dams along the channels have been recommended to overcome these geotechnical problems.[18] In addition, the expensive year round dredging will be a necessity for the successful implementation of this project.

Regional Water and Forestry Management Policy

Regional problems pertaining to waterpolicy and deforestation require effective participation of Bangladesh, Bhutan, China, India, and Nepal. This could be augmented by setting up a *multinational commission* to impose forestry management and water-flow regulations.[13, 19] Bangladesh is trying to establish a regional water policy involving India, China, and Nepal. Complete participation and establishment of a multinational commission has yet to take place. So far, China has expressed its willingness for bilateral cooperation. In the interim, frequent dialogues between Bangladesh and India during the past several years have helped to ease the situation and a more congeniel water-treaty between the two countries seems very likely in the near future.

According to World Watch Paper 89, "an estimated 40 percent of the world's population depends for drinking water, irrigation, or hydropower on the 214 major river systems shared by two or more countries; 12 of these waterways are shared by five or more nations".[13] Since the Ganges-Brahmaputra waterways are primarily shared by India, Nepal, and Bangladesh, the downstream users, particularly Bangladesh, have no effective means to solve flood problems alone and have to depend on cooperation of the upstream countries. Political disputes pertaining to water use rights have long been a traditional problem and exist in virtually all parts of the world. Some of the critical components of these water disputes involve reduced water flow through dams constructed by upstream countries, water diversion, siltation of rivers, and flooding aggravated by deforestation and soil erosion.[13]

Any long-term measures directed towards preventing flood-induced calamities require utmost cooperation among the neighboring countries within a particular drainage basin. Equitable distribution of this precious water resource is extremely crucial in terms of developing agricultural products, and in the transporting and proper marketing of these goods.

Local preventive measures

Local preventive measures include detailed morphometric analyses of the major and tributary river systems draining the entire country. Channel shifting, intricate braiding patterns, high sediment load, rapid growth of sandbars along or within the channels, and easily erodible banks contribute much to the flood problem. Understanding the river evolutionary pattern and providing a long-term solution to this problem requires close interaction between disciplines such as geology, meteorology, and water engineering.

Currently, the first phase of a detailed *Quaternary Geology Project* on Bangladesh has been completed under the joint sponsorship of the United States Geological Survey and Bangladesh Geological Survey. Preliminary published data strongly indicate neotectonic activity along the north-central part of Bangladesh where the major river systems enter the country.[6] Incorporation of this geological data into the climatological and water engineering data will improve efforts to predict flash floods and to cope with the incoming flood situation. However, an absolute solution to this problem has to be of *bilateral or multilateral nature considering the unique geographic entities of Bangladesh.*

Rapid population growth, often cited as one of the primary causes in excessive loss of human lives, must also be considered in this context. In the last two decades, the population of Bangladesh has increased from 75 million in 1970 to 110 million in 1990. An increase of 35 million people over a period of 20 years has not only exerted tremendous pressure on the national economy, it has forced the farmers to utilize all the available land for rice production, irrespective of soil condition. Farmers lacking the knowledge regarding *crop patterns* and still using traditional agricultural practices are rendering some of the farmland *less productive.* This trend will be detrimental for the future food production in the country. Farmers need to be educated and made aware of this situation.

Increased rice production has not been able to keep up with rapidly changing demographic patterns. Current birth-control measures are semi-effective and a very strong birth-control campaign must be undertaken as a positive step towards minimizing untold human suffering.

Discouraging people from living on recent floodplains will be a *futile exercise* considering the present agro- and-socio-political system in Bangladesh. Building houses above the maximum flood event, construction of several reservoirs in the north-central part of Bangladesh, year round dredging of the major river systems and erecting earthen dams along the frequently threatened flood-prone regions will minimize the impact of flooding on the people. However, acquisition of land and availability of substantial amount of resources for the purpose of building reservoirs in the north-central part of Bangladesh remains a critical factor. External funding might improve the situation, yet relocation of thousands of people from the reservoir site to another locality will be an extremely difficult task to accomplish since there is hardly any uninhabited land in the country.

CONCLUSIONS

Any long-term efforts towards solving the present flooding problem in Bangladesh will certainly be a *monumental task* for the people and the government. Domestic steps including birth control, building several reservoirs in the north-central part of the country, creating earthen dams adjacent to potential flood-prone areas, establishing emergency food and medical supply, building temporary shelter on concrete structures, and implementing an effective flash flood warning system will certainly minimize the colossal effect of this critical national problem on the economy and social-infrastructure of the country. However, any effective long-term policy to cope with the flooding problem in Bangladesh has to be of *bilateral or multilateral dimension.*

Creating a *Flood Data Bank* and allowing free exchange of climatological, geological, and Landsat data among India, Bhutan, Bangladesh, Nepal, and China will help these countries to formulate a multilateral water policy, and understand individual problems and needs. With the current change in attitude toward and ease in initiating frequent political dialogues between these countries, especially China and India, Bangladesh should be highly optimistic for close participation of the neighboring countries in establishing a coherent and long-term water policy to prevent the negative outcome of the recurrent flooding situation. Finally, a sustainable long-term solution to this traditional national problem in Bangladesh will depend on the sincerity of the government, continued and amiable co-existence with the neighboring countries, and a stable political system.

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