Chapter 9

Flood Management and Vulnerability of Dhaka City

Saleemul Huq and Mozaharul Alam

Dhaka, the capital and largest city in Bangladesh, was established by the Mughal Emperor Jahangir in 1608 on the banks of the river Buriganga. The city is surrounded by the distributaries of the two major rivers, the Brahmaputra and the Meghna. The surrounding rivers are Buriganga to the south, Turag to the west, Tongi khal to the north, and Balu to the east. The city and adjoining areas are composed of alluvial terraces of the southern part of the Madhupur tract and low-lying areas of the doab of the river Meghna and Lakkha. The combined area of Dhaka East and Dhaka West known as Greater Dhaka covers an area of approximately 275 square kilometers (JICA 1991). The elevation of Greater Dhaka is 2 to 13 meters above the mean sea level, and most of the urbanized areas are at elevation of 6 to 8 meters above the mean sea level. The land area above 8 meters above mean sea level covers about 20 square kilometers. The land ranging from 6 to 8 meters above mean sea level covers 75 square kilometers, while 170 square kilometers of Greater Dhaka is below 6 meters above mean sea level (JICA 1987). The highest lands are located at Mirpur.

The present population of the Dhaka Statistical Metropolitan Area is more than 10 million. The last decadal growth rate was about 70 percent, though the population growth rate was even higher, more than 100 percent in the previous decade (1981 to 1991). Population statistics of Dhaka city show that the annual growth rate was 2.9 percent from 1951 to 1961, 10.2 percent from 1961 to 1974, and 8.1 percent from 1974 to 1981.

By virtue of being surrounded by the distributaries of several major rivers, the city has been subjected to periodic flooding since its early days. Major floods in the Greater Dhaka area have occurred in 1954, 1955, 1970, 1974, 1980, 1987, 1988, and 1998 due to spillover from surrounding rivers. Among these, the 1988 and 1998 floods were catastrophic. In the 1988 flood, it was estimated that about 85 percent of the city was inundated at depths ranging from 0.3 to over 4.5 meters, and about 60 percent of city dwellers were affected. It also disrupted city life, air travel, and communication from the capital city to the outside world. The 1998 flood was most severe in terms of extent and duration. It was estimated that about 56 percent of the city was inundated, including most of the eastern and 23 percent of the western parts of the city. The flood protection embankment and floodwalls along the Turag and the Buriganga rivers protect the western part of the city from river flooding.

The Buckland Flood Protection Embankment along the river Buriganga was the first attempt to mitigate flood damage in Dhaka City. Flood protection plans for Greater Dhaka have been under study and consideration for many years, but the catastrophic flooding that occurred in 1987 and 1988 brought into focus the urgent need to proceed with immediate action. In 1989, construction activities commenced on a "crash program" defined as Phase I work to embank the western part of the city. This has been completed. Flood protection infrastructure for the eastern zone is under active consideration by the government of Bangladesh.

This report on the flood vulnerability of Dhaka city and flood management is organized into five main sections. An introductory section briefly explains the origin, population, flood proneness, and mitigation measures of Dhaka City. The second section provides historical development, emphasizing physical growth of the city and demographic features. The third section of the report highlights flood proneness of the city, including detailed impact assessments from the 1988 and 1998 floods. The fourth section provides information on various measures completed and ongoing to mitigate flood hazards. The concluding section of the report attempts to conduct

an analysis of integrated flood management plans for Dhaka city, to protect it from natural disasters with minimum environmental disruption.

Physical and Demographic Development

The physical features, topography, and demographic features of Dhaka City have always influenced its expansion. Political importance and trade played significant roles in the city's expansion during the Mughal and British regime. This section briefly describes the growth and expansion of the city in the scale of time under five major periods: pre-Mughal (before 1604), Mughal (1604–1764), British (1764–1947), Pakistan (1947–1971), and Bangladesh (after 1971).

Pre-Mughal Period (before 1604)

Growth and expansion of Dhaka city in the pre-Mughal period is obscure. The near capital city of Vikrampur was in the limelight from the 10th to 13th centuries. The Muslim occupation of southeastern Bengal can be placed in the late 13th and early 14th centuries, when Sonargaon rose to prominence. This was first as a mint town and an administrative headquarters and subsequently for a short time as the capital under the early Iliyas Shahi Sultans. Sonargaon enjoyed the position of a metropolis in the region in the pre-Mughal period.

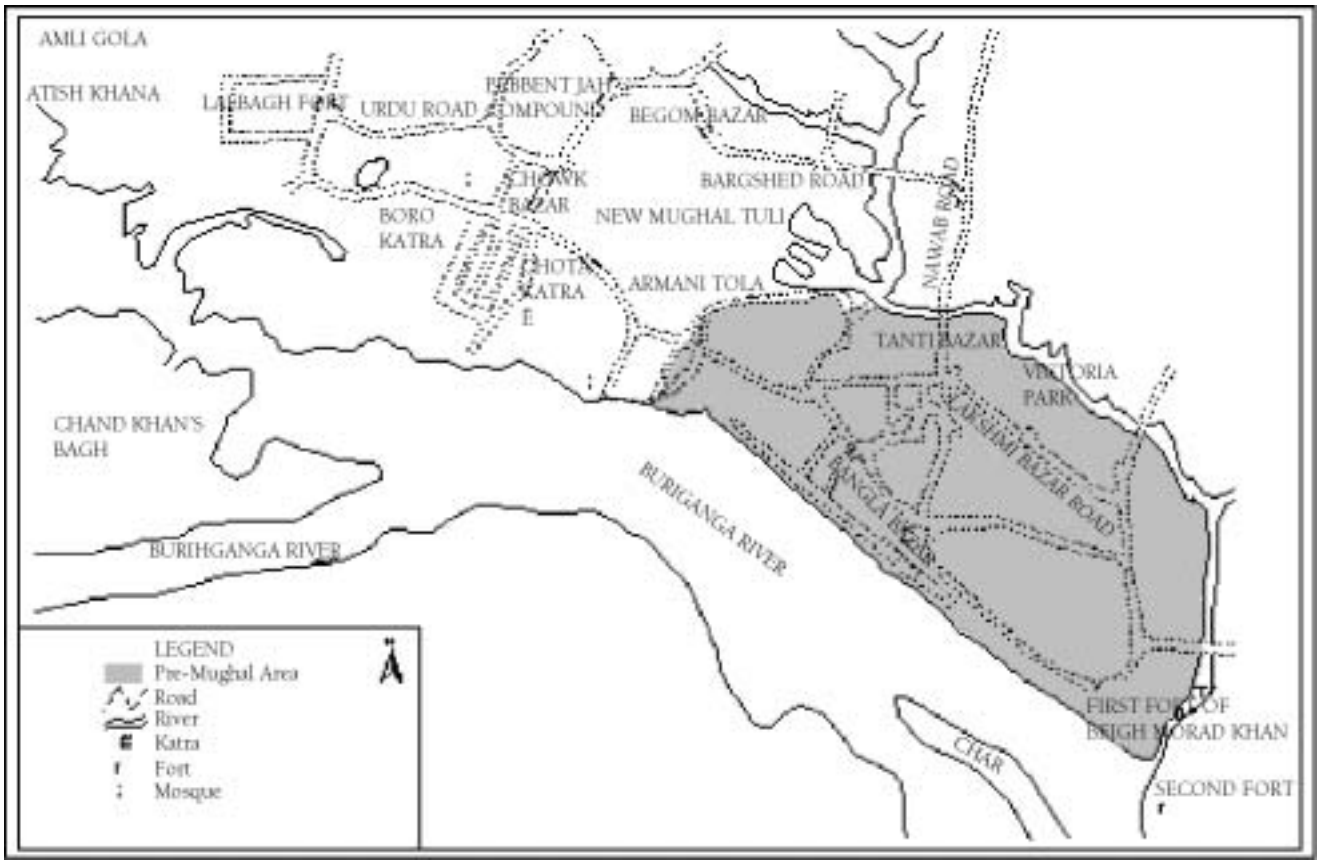
It is evident from the various writings on Dhaka that the areas to the east, northeast, and southeast of Babur Bazar up to the Dulai river on the left bank (northern bank) of the Buriganga formed the old town. The conglomeration of Hindu-named localities in this part of the city bears testimony to the predominance of Hindu craftsmen and professionals in the population of old Dhaka city at that time. The Dulai River possibly formed the northeastern boundary of the old city, though it is difficult to determine the western limit of the pre-Mughal "old city." Considering testimony to the existence of a mosque at that time, however, it can be assumed the city limits went beyond Babur Bazar on the western side (figure 9.1). It is quite likely that, following the course of the Buriganga, settlements grew on the southern, western, and northwestern parts of the city. These, of course, were sporadic growths with the riverbank determining the basis for settlements. The population of Dhaka city at that time is unknown.

Mughal Period (1604–1764)

The "new Dhaka" inaugurated by Islam Khan through the establishment of a fort, Chandnighat and the Chauk, experienced growth under the subsequent Mughal Subahdars until 1717, when the provincial capital was officially shifted to Murshidabad. Dhaka enjoyed status as a provincial capital for slightly more than a century. During this period, administrative and defense needs, coupled with flourishing commercial activities, led to Dhaka's growth from a town to a metropolis. The accounts left by foreign travelers, the extant of the Mughal ruins, and the names of the localities that still survive show the extent of Mughal Dhaka (Karim 1964). It appears from various documents and Muslim sculptures that Mughal Dhaka encompassed the "old Dhaka" within itself. The noteworthy feature of the city was its growth to the northern Phulbaria area. In this period, the expansion to the west and the north was significant. With the fort in the center, the expansion to the west followed the riverbank, and the city spread northward to Phulbaria on the fringe of the Ramna area. The peelkhana (elephant stable) was established at the western end. Residential quarters for officials, government functionaries, and merchants grew in the area between the fort and the peelkhana to the west and the fort and Phulbaria to the north. In this growth of Mughal Dhaka, the general characteristics of a Mughal city were noticeable. The areas to the south and southwest of the fort up to the riverbank grew mainly as commercial areas, while to the north and northeast, residential areas sprouted.

The northern limit of the city extended to the gateway built by Mir Jumla (1660–63), near the present-day mausoleum of three leaders, at the southeastern corner of the Suhrawardy Udyan. Mir Jumla's name is also associated with the construction of two roads connecting Dhaka with a network of forts built for the defense of the capital city. A road headed north to a fort at Tongi-Jamalpur and another toward the east connected Dhaka with Fatullah, where two other defensive forts were constructed. These two roads influenced the growth of the city in these directions.

Figure 9.1 Demarcation between Pre-Mughal and Mughal Dhaka



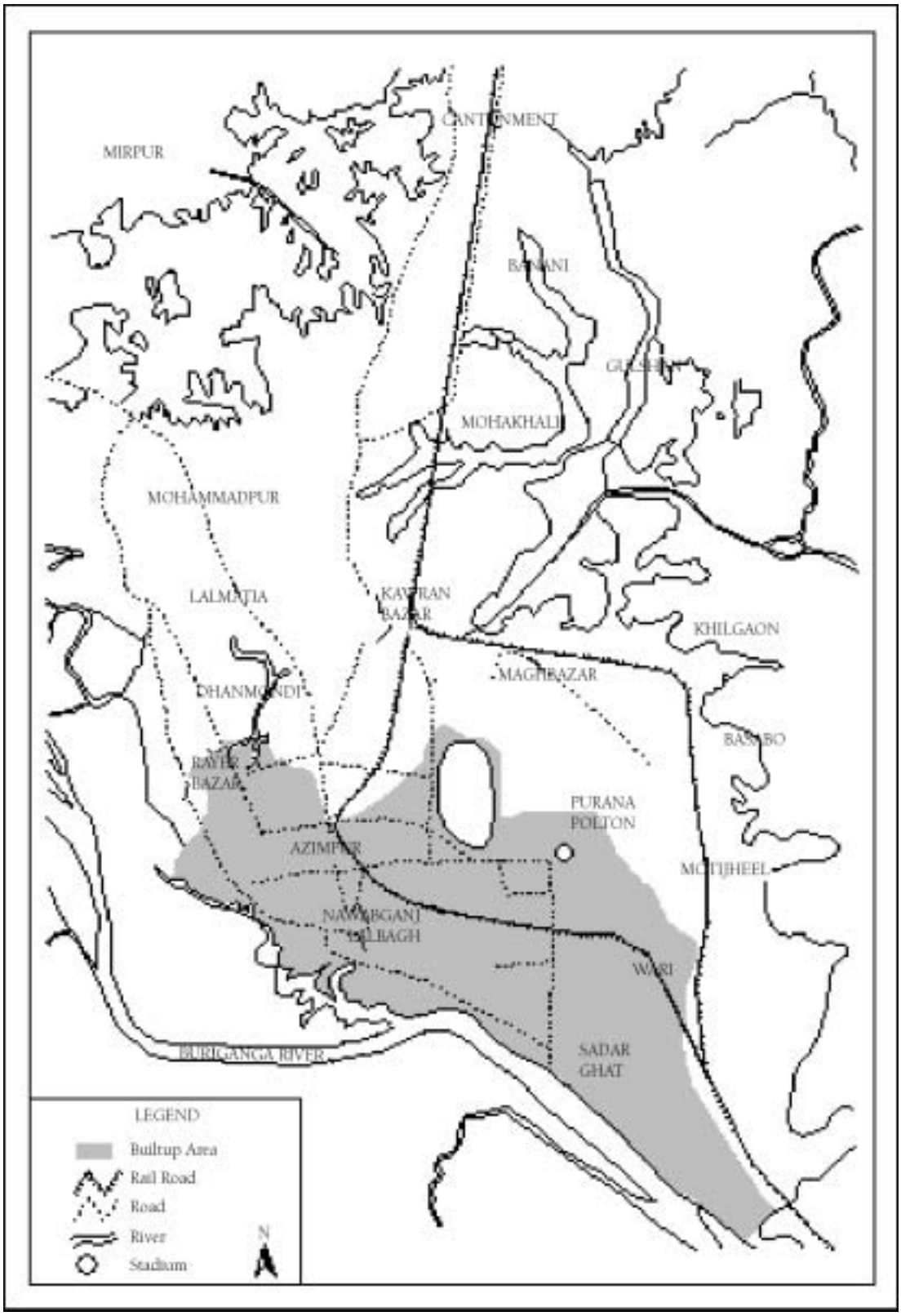
In the available early records of the East India Company (1786 and 1800), the boundary of the city is mentioned as: Buriganga in the south, Tongi in the north, Jafarabad-Mirpur in the west, and Postogola in the east. The expansion of the city in the Mughal period was dictated by nature due to the highlands.

With the establishment of the Mughal provincial capital at Dhaka, the city entered a glorious era and became the chief emporium for products from eastern Bengal. The commercial headquarters was established in the Mirpur area, Shah Bandar. Due to its commercial importance, Dhaka attracted numerous traders—Portuguese, Dutch, English, French, and Armenians—who established trading houses in Dhaka in the 17th century. Factories were also established in the Tejgaon area, which continued to enjoy commercial importance during the next century (figure 9.2). The road built by Mir Jumla formed an axis with European settlements on either side, north of the Kawran Bazar and Amber Bridege (Karim 1964). The physical size of Dhaka was about 50 square kilometers; the population about 0.9 million.

British Period (1764–1947)

After the acquisition of the Diwani in 1765 by the East India Company and the shift of Bengal's capital to Calcutta, Dhaka lost its political importance. Gradually the administrative and commercial importance of the city dwindled, and by 1828 the city was reduced to a mere district headquarters, though it retained its position as a provincial Circuit Court of Appeal. By 1840, this decline had reached its nadir, and most of the former Mughal city had been deserted or fallen victim to the encroaching jungle (Ahmed 1986). The decline affected Dhaka seriously, and during this period Dhaka also suffered physical shrinkage. The jungle-beset city was shown in a topographical map prepared in 1859 as covering an area only a little over three square miles (figure 9.2).

Figure 9.2 The buildup area of the Mughal capital



The second half of the 19th century marked the beginning of the physical renewal of the city. In 1857, India came under the direct rule of the British crown and saw some development of utility services. In 1905, Dhaka became the capital of the new province of East Bengal and Assam. Building the new town started beyond the railroad in Ramna. The only locality developed as a fully planned residential area was Wari. In 1885, Frederick Wyer, the Collector of Dhaka, began developing the area with "broad roads and proper drains." Wari became an upper-middle class area considered "the sanatorium of Dacca."

The Siddheswari area to the northeast of the Race Course was cleared by the government in the early 20th century and the former jungle was developed as a residential area. At the same time, the wasteland around the Dhakeswari shrine was cleared by the local people who felt encouraged to occupy the areas around the newly developed area of Ramna. Thus the "new Dhaka" of the present century had its birth at the hands of the British rulers.

The impetus for growth created by the 1905 partition of Bengal was seriously jolted by the annulment of the partition in 1911, when Dhaka reverted back to the status of a district town. The establishment of the University of Dhaka, which came to occupy many of the buildings of the Ramna area, was the only important event in Dhaka's history until 1947, when Dhaka again attained the status of the provincial capital of the eastern part of Pakistan, initially called East Bengal and later named East Pakistan.

Pakistan (1947–1971)

In 1947, India become independent of British rule and Pakistan was created. Dhaka restarted its life as the capital of East Pakistan. The needs of the officials engaged in administration, the business community, and the residents grew out of the sudden onrush of people to Dhaka. This contributed to the growth of the city in its new role as the provincial capital.

In 1954, the Motijheel area, once desolate and lying on the fringe of marshes and swamps where the Nawabs had built a garden house, was earmarked as a commercial area. By that time, the area north of Nawabpur Railway crossing to the Purana Paltan was developed as the open area of the city with the stadium forming the nerve center of sporting activities. Jinnah Avenue (now Bangabandhu Avenue) was laid to form the main thoroughfare along the western side of this expansive open area.

To cater to the ever-increasing residential needs of the new capital, the Dhanmondi area, adorned with paddy fields in the early 1950s, was developed as a residential area after 1955. The Mirpur Road formed an axis, and the highlands on both sides of the road came to be occupied, right up to Mohammadpur and Mirpur. In the mid-1960s these two areas were developed by the government, mainly to accommodate the migrant Muslim population. The Tejgaon Airport and the Tejgaon Industrial area came under governmental schemes in the early 1950s. In the second half of the 1960s, the decision to have a capital for East Pakistan at Dhaka led to the development of the area to the west of Tejgaon farm and the airport (now known as Sher-e-Bangla Nagar).

With the creation of the Dhaka Improvement Trust (DIT) in 1956 (transformed into the Rajdhani Unnayan Kartripakkha in 1987), greater interest and care were undertaken in road construction and city planning. The DIT developed the Gulshan Model Town in 1961, Banani in 1964, Uttara in 1965, and Baridhara in 1972 (though first conceived in 1962). The Dilkusha Gardens adjacent to Motijheel were eventually engulfed by the ever-growing commercial needs.

In the mid-1960s the main railway line was shifted and directed eastward, after Tejgaon and before Kawranbazar, before rejoining the old track near Swamibagh-Zatrabari cutting through Rajarbagh, Basabo and Kamalapur. The Dhaka Railway Station was moved from Phulbaria to Kamalapur. This eliminated the landmark that had long stood between the "old Dhaka" of the Mughals and the "new Dhaka" of the English. The rapid growth and development of the area between the old railway track and Kawranbazar necessitated this change. The loop through the heart of Ramna had to be abandoned. Since then, the old track has been developed into a broad road connecting Kawranbazar with Phulbaria through Plassey and Nilkhet to the northwest and Swamibagh-Zatrabari through Wari to the north and Narinda to the southeast.

Table 9.1 Area and population of Dhaka City, 1600–2001

Period and year	Approximate area (sq. km.)	Source	Population	Source
1600 Pre-Mughal Period	1	Islam, 1974	Unknown	
1700 Mughal Capital	50	Taylor, 1840	900,00	Taylor, 1840
1800 British Town	8	Islam, 1974	200,000	Taylor, 1840
1867 British Town	8	Islam, 1974	51,000	Census of Bengal, 1901
1911 British Town	—	—	125,733	Census of Bengal, 1911
1947 Capital of East Pakistan	12	Islam, 1974	250,000	Census of Pakistan, 1951
1951 Pakistan Period	—	—	335,928	Census of Pakistan, 1951
1961 Pakistan Period	28	Census of Pakistan	550,143	Census of Pakistan, 1961
1971 Capital of Bangladesh	40	Census of Bangladesh, 1974	1,500,000	Census of Bangladesh, 1974
1974 Capital of Bangladesh	40	Census of Bangladesh, 1974	1,600,000	Census of Bangladesh, 1974
1981 Dhaka Municipality	62.4	Census of Bangladesh, 1981	2,475,710	Census of Bangladesh, 1981
1981 Dhaka SMA	155.4	Census of Bangladesh, 1981	3,440,147	Census of Bangladesh, 1981
1991 Dhaka SMA	—		6,950,920	Census of Bangladesh, 1991
2001 Dhaka SMA	—		9,912,908	Census of Bangladesh, 2001

Bangladesh (1971 onward)

The creation of the independent state of Bangladesh in 1971 bestowed glory and prestige on Dhaka, now capital of a sovereign country. This additional factor led to Dhaka's phenomenal growth since 1971. The low-lying areas on the eastern side, such as Jurain, Goran, Badda, Khilgaon, Rampura, and Kamrangir Char, Shyamali, Kalayanapur on the western side came under occupation. Dhaka's growth picked up at a tremendous pace and private initiatives played the dominant role.

The growth of the city followed the pattern set by the Mughal founders. The city was delineated the maximum limit to Tongi in the north and Mirpur in the northwest. The southeastern limit reached Postogola. The riverine surroundings with water-channels, marshes, and lowlands form the western, southern, and eastern boundaries of the city. With increased population pressure, the highlands spreading northward were occupied and built up. The intervening ditches, swamps, and marshes were filled in, not in any planned manner, but as exigencies arose and private initiatives dominated the process. Development under the aegis of the Dhaka Improvement Trust dictated nature, rather than allowing it to direct planned growth. In selecting the sites for the Model Towns of Gulshan, Banani, Baridhara, and Uttara, the method of selecting the highlands on the main Dhaka-Tongi axis road is clearly discernible. No serious effort at reclaiming land under a well-planned scheme to give the city homogenous and cohesive growth is visible. Dhaka has grown on its own in a haphazard manner, and the topography of the area dictated the terms and direction of the growth. Since Dhaka became the capital of an independent country, the pressure on it has been enormous. The permanent inhabitants of the city have registered a steady growth. In addition to this growth, there was a very large floating population, the pressure of which has resulted in the growth of slums on any available vacant land. The recently built high-rise buildings, both in the commercial and residential sectors, occupy the city's highlands and demonstrate ever-increasing pressure on Dhaka as it builds upward, an inevitable and common phenomenon in all modern cities facing population growth. Since the 1990s, Dhaka has been on the verge of change in its urban character, with vertical growth replacing horizontal expansion (Chowdhury and Faruqui 1989). Over the years, most of the low-lying areas of western Dhaka have been filled in to meet the city's residential and commercial demands. The eastern side of the city is being filled in by private intervention. Table 9.1 provides built-up areas and populations from the pre-Mughal period to 2001.

Major Floods in Dhaka

A number of severe floods have struck Dhaka since its early days, and its vulnerability is reflected in the Buriganga River's flood embankments, first built in 1864. Severe floods in Greater Dhaka City are mainly caused by spillover from surrounding rivers flowing to and from

the major rivers of the country, as well as internal water logging. In recent history, Greater Dhaka city experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, and 1998 due to the overflow of surrounding rivers. Among these, the 1988 and 1998 floods were catastrophic.

Flooding due to rainfall is also a severe problem for certain city areas that may be inundated for several days, mainly due to drainage congestion. The water depth in some areas may be as high as 40–60 centimeters, which creates large infrastructure problems for the city, economic losses in production, and damage to existing property and goods. Impacts of the riverine floods are more severe and disrupt economic activities and livelihoods of people dependent upon urban activities. This section provides causes and characteristics of floods with brief descriptions of their impact from the last two major floods, in 1998 and 1988.

1998 Flood

The main reason for the 1998 flood was excessive rainfall over the catchments area of the Ganges-Brahmaputra-Meghna (GBM) river basin. Three different flood waves passed through the GBM river basin, and the last one was synchronized with the peak flow of the Ganges and the Brahmaputra. In addition, the impact of the lunar cycle and its resulting high tide caused floodwaters to recede slowly, prolonging flooding in the country and the city for two months.

The main causes of flooding inside the protected area were hydraulic leakage, failure to operate the regulators, and lack of timely pumping of accumulated water upstream from the Rampura Regulator. Due to completion of 75 percent of Phase I work of the Dhaka Integrated Flood Protection Project (DIFPP), it was assumed that the Gulshan, Banani, Baridhara, and Tejgaon areas would not be flooded. However, near the Cantonment Railway Station, there are 4 or more drainage pipes of about 4 feet in diameter that connect the Nikunga area with the floodplain on the eastern side. An apparent lack of coordination between the Bangladesh Water Development Board (BWDB) and Dhaka Water Supply and Sewerage Authority (DWASA) to prevent flooding was found. Although DWASA has responsibility for ensuring proper drainage, BWDB is in charge of operating the regulators and gates. In fact, there was neither an operating policy nor person assigned to operate the Rampura Regulator that controls the drainage of 40 percent of the protected area under Phase I of DIFPP.

Balu River Flood in Dhaka East

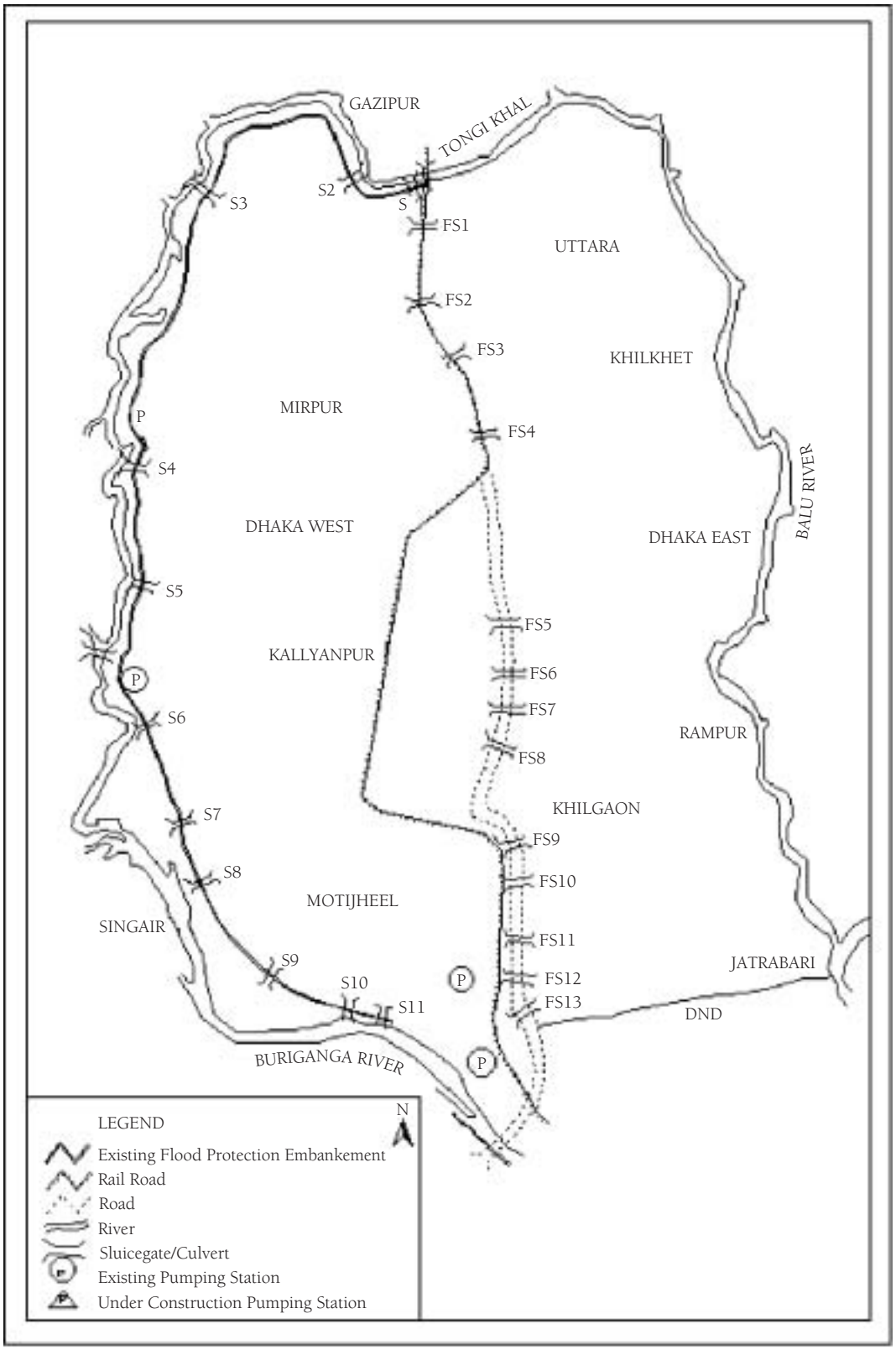
In the 1998 flood, almost all of Dhaka East was flooded by spillover from the Balu River. The flood started around July 22 and continued for some 65 days. The waters peaked on September 12. Residential areas such as Basabo, Mugdapara, Uttar Badda, and Joar Sahara were the worst affected. The ground floors of most buildings were inundated.

Balu River Flood in Dhaka West

As it is protected by the flood control project, it was expected that Dhaka West would remain flood-free, even though the areas adjacent to Mymensingh Road, Progati Sarani, DIT Road, and Biswa Road were submerged during the flood. Mahakhali, Gulshan, Banani, Badda, Baridhara, etc., faced worse flooding problems. The floodwaters remained in the western areas for about 30 days.

The intrusion of floodwater from Balu River to Dhaka East through unblocked culverts and open regulators was considered to be the general cause for river flooding in Dhaka West. It was revealed that three drainage structures, FS8 (Begunbari Khal Rgulator), FS5 (Shajadpur bridge on Pragati Sarani), and FS4 (Khilkhet pipe culvert at Nijunja), served as a flood-carrying channel (figure 9.3). Structure FS4 remained open during the entire flood and caused flooding in Nijunja adjacent to the airport and cantonment areas. Structure FS8 and FS5 were closed after the intrusion of substantial floodwater from the Balu River in Begunbari khal, Gulshan-Banani-Mohakhali Khal, and areas adjacent to the DIT road were submerged. The channel at structure FS5 was closed by an earthen bund. Structures FS9, FS10, and FS11 on Biswa road were responsible for partial flooding in Rajarbag, Gopibag, and Fakirapul before they were closed. Floodwaters in those areas were pumped out by 30 pumps installed at FS12 on Segunbagicha khal at a crossing with Biswa road.

Figure 9.3 Flood and drainage infrastructure of Dhaka



Buriganga River Flood in Dhaka West

The western part of the Dhaka Flood Protection Embankment ends in Lalbag Kellarmore at Swasan Ghat. It has a 2.2-kilometer embankment under construction from Kellermore to the Buriganga Bridge, and it was not closed during flooding, which allowed floodwater to flow into the western part of the city. Flood fighting by local people creating sandbag barriers saved Old Dhaka from flooding, especially in Lalbag Kellarmore. The difference in water levels between the outside and inside at Kellamore point was about 1.5 meters. It was found that the flood protection work started immediately after the flood recession.

Flooding Due to Excessive Rainfall

During the 1998 flood, excessive rainfall in Dhaka caused short-duration flooding in the areas of Shantinagar, Nayapaltan, Rajarbag, Dhanmodi, Azimpur, and Green Road. The runoff generated by rainfall could not flow to the surrounding rivers since the river stage was higher than the inside flow; therefore, the accumulated runoff in low-lying areas remained stagnant until the river stage receded. Extensive water logging occurred in Dhaka West during the flood due to a higher river water stage in the surrounding rivers.

Impacts

It is evident from various studies that damage to infrastructure including roads, water supply, and housing was severe. It was estimated that 384 kilometers of paved roads went under floodwaters, of which Gulshan Thana accounted for a significant amount. Severe damage occurred in Sabujbag Thana, followed by Demra. Severe disruption of water supplies from deep tube wells (DTW) and suspended production occurred in the Cantonment Thana followed by Gulshan and Uttara. Considering the major impacts of floodwaters, it appears that Sabujbag and Gulshan Thanas were worst affected, followed by Demra, Uttara, and Cantonment Thana.

Affected Population: Prof. S. A. Hye (1999) carried out a rapid appraisal of flood-affected people during the flood, dividing the flood-affected area into three categories: most severely affected area, severely affected area, and moderately affected area. It was found that the flood displaced or dislocated 94 percent of families in the most severely affected areas, 52 percent of families in severely affected areas, and 50 percent in moderately affected areas. It was also estimated that the total flood-affected population would likely be 4.55 million. Table 9.2 provides details of affected households and populations.

Effect on Water Supply and Production: It was found that 44 deep tube wells were affected by floodwater; production of 13 of these was suspended. The estimated loss in water production due to suspension was 45 million liters per day.

The remaining tube wells were kept operational by adopting protection measures including the erection of a protection wall around the pump house and raising housing pipes and electrical appliances above floodwater. It was also found that 5 of the 13 suspended tube wells were badly damaged and required replacement. The estimated cost to rehabilitate the water supply system is about 127 million taka, detailed in table 9.3.

Table 9.2 Flood-affected people in Dhaka City by severity of the flood, 1998

Severity of flood	*Affected wards (no.)*	*Total affected households*	*Total affected population (millions)*
Most severe	22	203,000	1.20
Severe	15	150,000	0.90
Moderate	43	409,000	2.45
Total affected	80	762,000	4.55

Source: Hye 1999.

Table 9.3 Cost of rehabilitation and replacement of Dhaka Water Supply System (DWASA), March 1999

Item	*Rehabilitation and replacement needs*	*Estimated cost (million taka)*
1	Repair and cleaning of 600 kilometer water distribution mains	15
2	Replacement of 5 deep tube wells	20
3	Rehabilitation of pump and electrical sub-station of 42 flood-affected DTWs	42
4	Raising level of reconstruction of walls of 42 pump houses	10
5	Installation of 3 low-lift pumps	15
6	Reconstruction of 20 kilometer water mains	25
		127

Source: Ahmed 1999.

Housing Damage: The 1998 flood caused damage to more than 262,000 shelter units, or 30 percent of the 860,552 units in the Dhaka Metropolitan Area; the cost of damage was Tk. 2,311 million. Of these, 32 percent were permanent and semipermanent structures belonging to wealthy or well-to-do households not dependent on assistance for repair and rehabilitation. About 36 percent of shelter units in the katcha-1 type, belonging to lower-middle and poorer classes, suffered damage of Tk. 283 million. Their owners had the ability to cope with repairs but would face hardship. Nearly 32 percent of units of Katch-2 and Jupri types, belonging to the poor and hard-core poor, suffered severe damage and required Tk. 195 million in repairs. The owners were too poor to mobilize funds on their own (Islam and Ali, 1999).

1988 Floods

In 1988, one of the most severe floods in recent history hit Dhaka and inundated 85 percent of the city. Floods of this intensity hit the country approximately once in 70 years. Depths of inundation ranged from 0.3 to more than 4.5 meters, and 60 percent of city dwellers were affected (JICA 1991, 1992). This unprecedented level of flooding disrupted city life and air travel. Communication with Dhaka to the outside world was cut off for about two weeks. Impacts and damage from the 1988 flood were compiled and analyzed according to component 8 of the Flood Action Plan (FAP8).

The entire eastern part of Dhaka and the entire low-lying area of the western part of Dhaka were under floodwater. Parts of Mirpur, Tejgaon, Banani, Sher-e-Banglanagar, Azimpur, and the Old Town were not flooded.

Impacts

Affected Population: According to available information on impacts of the 1988 flood on Dhaka, it was found that 2.2 million people were affected and the death toll was about 150. The figure for "affected population" was found to be lower than that of the detailed analysis that was carried out by FAP8 based on data collected through the flood damage sample survey (FAP8A).

Affected Houses and Institutions: It is estimated that the number of institutions and houses affected in the 1988 flood was 14,000 and 400,000, respectively. The damage was about Tk. 4 billion for residential buildings and more than Tk. 400 million for institutions.

Comparison of Flood Characteristics of 1988 and 1998

An analysis of water level hydrographs at gauging stations in surrounding rivers and at Noonkhawa on the Brahmaputra River revealed that in 1998, the first flood waves took approximately 6 days to reach Dhaka City from the India-Bangladesh border, while the flood peak required approximately 4 days to reach Dhaka. Due to hydraulic reasons, the flood peak moves faster than the flood trough. Figures 9.4 and 9.5 present hydrographs of surrounding rivers and rainfall in Dhaka City during 1988 and 1998. Table 9.4 presents flood characteristics of the 1988 and 1998 floods in rivers surrounding Dhaka.

Flood Mitigation Measures

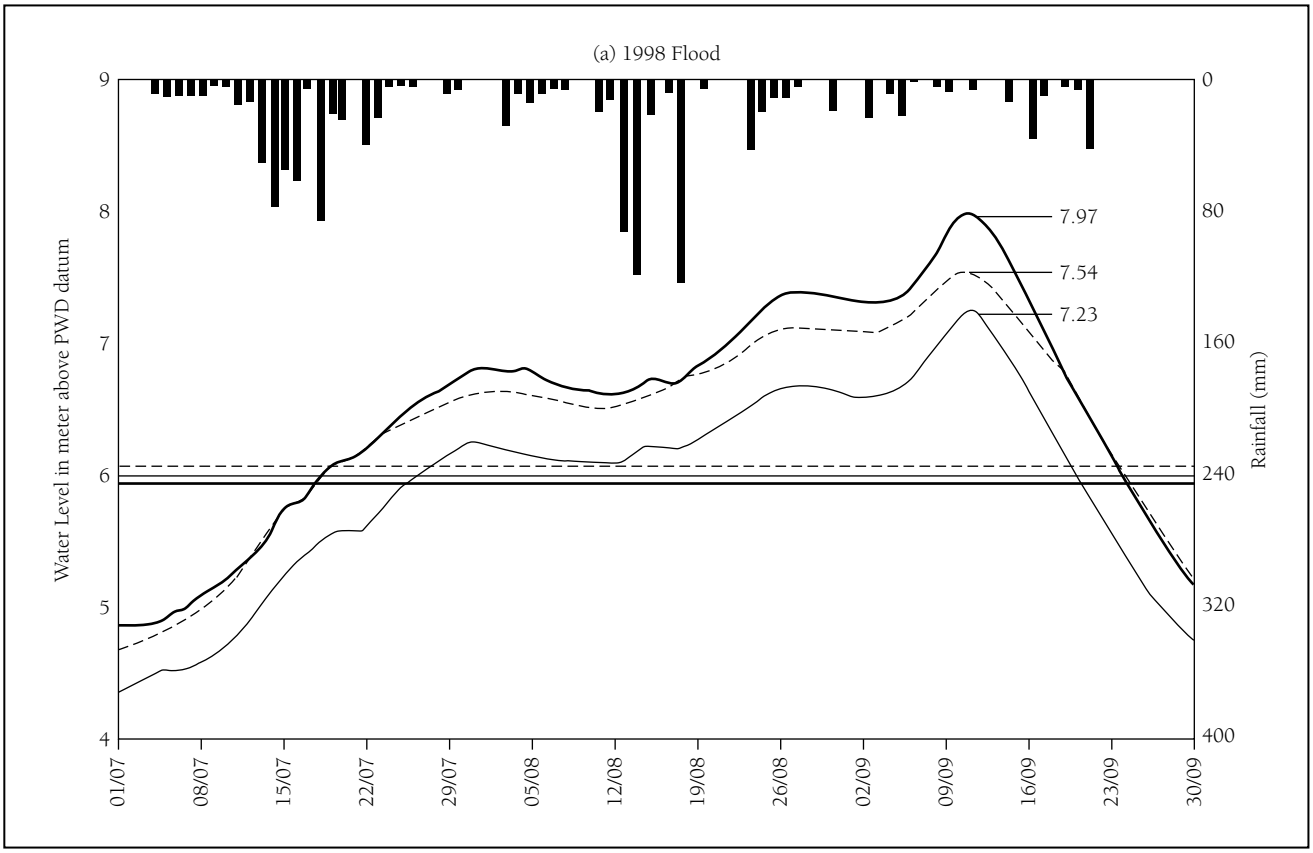
The first flood protection embankment along the Buriganga River was constructed in 1864 to protect the riverbank from flooding and erosion and give a facelift to the riverside. C.T. Buckland, the Commissioner of Dhaka, launched a scheme to construct an embankment (known as the Buckland Bound), which was completed in three phases in the 1880s.

Plans for flood protection for Greater Dhaka have been under study and consideration for many years, but the extreme flooding that occurred in 1987 and 1988 brought into focus the urgent need to proceed with immediate action. Subsequently, the Government of Bangladesh prepared an urgent flood protection and drainage plan, which included enclosing the greater Dhaka area with flood embankments, reinforced concrete walls, and drainage/flood regulation structures such as sluices and pumping stations.

Construction of Flood Protection Embankment

Construction activities commenced with a "crash program" in 1989, and most of the work defined as Phase I has been completed. It provides flood protection facilities to the western half of Dhaka and includes the most highly urbanized areas, covering about 87 percent

Figure 9.4 Water level hydrographs for Turag, Tongi, Buriganga, and Balu Rivers and rainfall in Dhaka during 1998



of the population. Important components of the flood protection measures are:

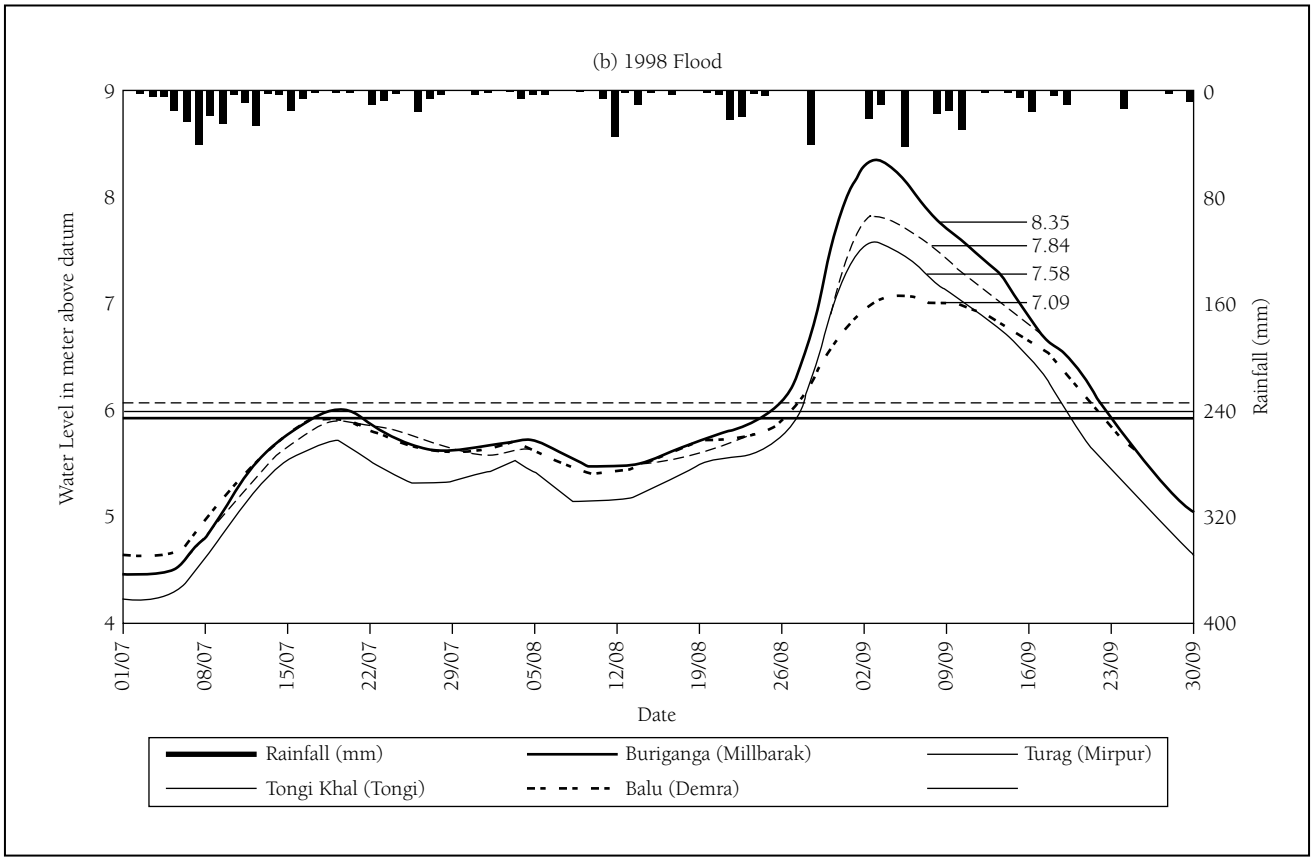
- Approximately 30 kilometers of earthen embankment along Tongi khal, Turag River, and Buriganga River.
- Approximately 37 kilometers of raised road and floodwall.
- A total of 11 regulators at the outfall of khals to the surrounding rivers along the embankment.
- One regulator and 12 sluice gates on the khals at the crossings with Biswa Road, DIT Road, Pragati Sarani, Mymensingh Road, and railway line at Uttar Khan.
- One pumping station at the outfall of Kallyanpur khal to the Turag River, and another one at the outfall of Dholai khal to the Buriganga River. These pump stations are for draining rainwater from parts of Dhaka West.
- A special 10.53-kilometer embankment to surround the Zia International Airport.

A rail-cum-road-embankment that will run along the Balu River for a total length of 29 kilometers is proposed for the eastern part of the city. This will be constructed under Phase II of the Dhaka Integrated Flood Protection Project (DIFPP) to protect the area between Biswa Road and the Balu River. The locations of regulators, sluice gates, pump stations, embankments, and raised roads are shown in figure 9.6. These flood control and drainage works have brought major changes in the flood regime of Dhaka West, including major changes in land use.

Construction of Storm Sewer and Pump Station

To alleviate the internal drainage problems of Dhaka, a storm-water drainage improvement plan was undertaken by Dhaka WASA (JICA 1991). As a part of the plan, many sections of the natural khals were replaced by concrete box culverts. Converted khals include Dhanmondi khal, Paribagh khal, Begunbari khal, Mahakhali khal, Segunbagicha khal, and Dholai khal. These khals are no longer visible. The present storm-water drainage network under Dhaka WASA covers an area of approximately

Figure 9.5 Water level hydrographs for Turag, Tongi, Buriganga, and Balu Rivers and rainfall in Dhaka during 1988



140 square kilometers. Important components of the drainage network are briefly summarized below.

- 22 open canals with widths of 10 to 30 meters and a total length of approximately 65 kilometers.
- 185 kilometers of underground pipes with diameters ranging from 450 to 3000 millimeters.
- 6.5 kilometers of box culvert with sizes ranging from 2.5 meters by 3.4 meters to 6 meters by 4.1 meters.
- 2 storm-water pumping stations with capacities of 9.6 and 10 cubic meters per second at Narinda and Kallyanpur, respectively.
- Recently, Dhaka City Corporation (DCC) constructed one storm-water pumping station with a capacity of 22 cubic meters per second at the outfall of Dholai khal into River Buriganga. Dhaka WASA has taken over the operation and maintenance of the pumping stations.

The Bangladesh Water Development Board is also constructing a pumping station at Goran Chadbari at the outfall of the Degun khal into the Turag River. There are also 65 small pumps with individual capacities of 0.142 cubic meters per second, installed temporarily by Dhaka WASA to drain storm water from various locations.

Moreover, DCC has constructed and maintains at least 130 kilometers of small-diameter underground drains and approximately 1,200 kilometers of surface drains that carry storm water to the main sewer lines. The Capital Development Authority (RAJUK) also constructs underground roadside drainage lines during the construction of new roads.

Conclusions and Recommendations

Two severe floods hit Greater Dhaka City within a decade, causing enormous loss of life and livelihoods and damage to property. Immediately after the 1988 flood, a number of studies were carried out within the general framework of the Flood Action Plan (FAP) that specifically addressed the issue of flooding in Dhaka City. The first

Table 9.4 Flood characteristics of 1988 and 1998 floods in surrounding rivers of Dhaka City

Parameters	*River*	*Gauge station*	*1998*	*1988*
Danger level in meters above PWD datum	Buriganga	Millbarak	6	6.1
	Turag	Mirpur	5.94	5.94
	Tongi Khal	Tongi	6.08	6.08
	Balu	Demra	—	—
Date of crossing-danger-level at rising stage	Buriganga	Millbarak	26/07/98	29/08/88
	Turag	Mirpur	18/07/98	24/08/88
	Tongi Khal	Tongi	22/07/98	28/08/88
	Balu	Demra	—	—
Number of days required by the flood front to arrive at Dhaka City from India-Bangladesh border	Buriganga	Millbarak	7	7
	Turag	Mirpur	6	7
	Tongi Khal	Tongi	6	6
	Balu	Demra	—	10
Number of days required by the highest flood peak to travel from India-Bangladesh border to Dhaka City	Buriganga	Millbarak	4	6
	Turag	Mirpur	4	6
	Tongi Khal	Tongi	5	6
	Balu	Demra	—	8
Height of peak flood level in meters above danger level	Buriganga	Millbarak	1.23	1.58
	Turag	Mirpur	2.03	2.41
	Tongi Khal	Tongi	1.46	1.76
	Balu	Demra	—	—
Duration of flood in days above danger level	Buriganga	Millbarak	56	22
	Turag	Mirpur	69	30
	Tongi Khal	Tongi	65	25
	Balu	Demra	—	—

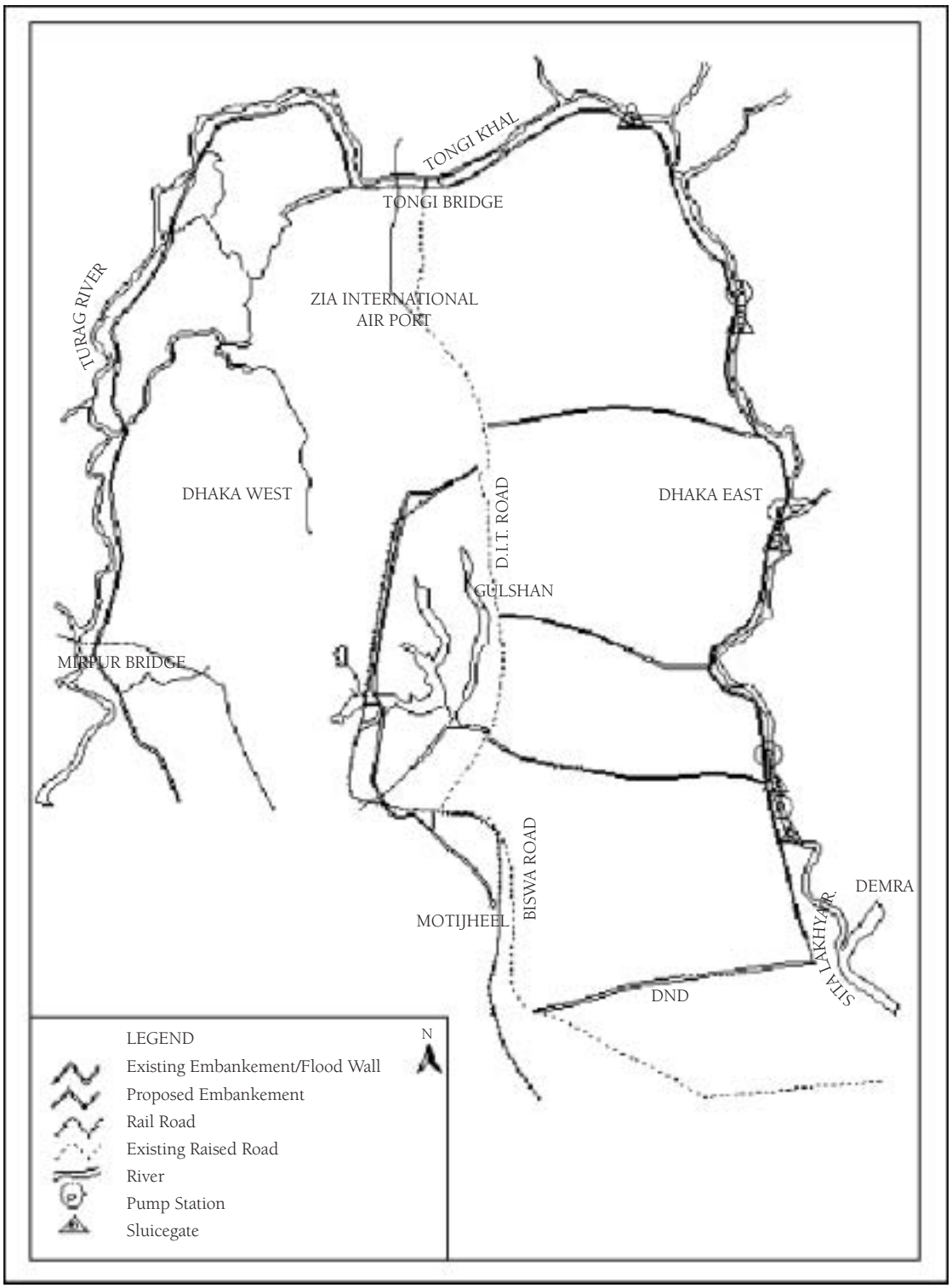
phase of the Greater Dhaka Integrated Flood Protection Project included embankments along the Turag and the Buriganga Rivers to protect Dhaka West. Improvements to the city's internal drainage system had also been completed before the second severe flood in 1998. Moreover, during the 1998 flood some protected areas went under water, indicating that current flood management practices must be improved.

After implementation of the flood-control project in Dhaka West, unplanned and uncontrolled expansion of urban areas stretched rapidly toward the low-lying areas and floodplains adjacent to the flood-protection embankment and river. Residents of these lowlands suffer from inundation due to accumulation of rainwater after heavy rainfall. Land development through land-filling processes in the low-lying areas is causing a drastic reduction in water storage areas. Because of the rapid population increase and scarcity of land in Dhaka West, unplanned expansion is also taking place in Dhaka East at the same pace. It started on the eastern side of Biswa Road, DIT Road, Pragati Sarani, and Mymensingh Road, and is gradually stretching toward the Balu River. The areas where urbanization has already taken place are Mugdapara, Manda, Basabo, Sabujbag, Khilgaon, Goran, and Rampura. Some of these areas were the worst affected during the 1998 flood.

Evaluation of Phase I work revealed that the existing earthen embankment is unstable and cracking in large sections, though some parts have recently been stabilized and other parts of the earthen embankment have been converted to roads. Construction of embankments through low-lying areas without providing adequate drainage facilities has caused internal flooding, adversely affecting the residents in those areas.

The eastern part of the city consists of low-lying floodplains that are submerged during the monsoon season. They still remained unprotected. However, the growing population and land scarcity have forced people to settle in these low-lying areas. Implementation of Phase II of DIFPP will provide flood protection to this part of the city. While designing and implementing the plan, environmental impacts should be kept in mind and an adequate number of drainage facilities should be provided for the proposed embankment. The hydrological data should be analyzed during the design phase of the flood protection infrastructure.

Figure 9.6 Existing and proposed flood control and management infrastructure in Dhaka



Dredging work in the Buriganga, Turag, and Balu Rivers should be regularly carried out to maintain navigability and reduce drainage congestion. In addition to structural measures, nonstructural measures should also be considered to reduce flood damage. These measures include flood zoning, flood forecasting and warning, flood proofing, flood insurance, and evacuation measures. Flood zoning could be one of the most effective measures to ensure that expensive investments are not made in flood-vulnerable areas. It will also help to protect ecologically sensitive areas, natural drainage systems, and the surrounding wetlands that retain water.

Since the western part of Dhaka is already developed, little can be done in this area except protecting the lakes and khals. The government has already issued a decree banning the filling in of any wetland for urban development. In exceptional cases, permission should be secured directly from the prime minister. The eastern part of the city is still largely a floodplain. Proper land development rules should be introduced without delay to minimize the loss from river flooding from the Balu River.

It is anticipated that the city's future flood vulnerability will be aggravated due to climate change. Experts are forecasting that floods with the magnitudes of those in 1988 and 1998 may occur more frequently. Thus, it is imperative that a long-term flood-mitigation and climate-change adaptation strategy be developed for the future management of floods in and around Greater Dhaka City.

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