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Hydrography of Dhaka City Catchment and Impact of Urbanization on Water Flows: A Review

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Abstract: Dhaka has one of the fastest urban growth rates of the world with around 12 million people in 2006. It is located on extensive sub-continental floodplains of the Ganges and the Brahmaputra with average elevation of 6 m above mean sea level (MSL). It is surrounded by four rivers with well distributed streams, drainage channels, inland and open waters. Physiographical, spatial and temporal environments of these waters profoundly influence inhabitants' life. Mass shrinkage has occurred during the last four decades due to encroachment and filling-up, man-made changes in elevation pattern and siltation with debris from urban development activities. Groundwater storage is on the verge of mass threat because of increasing pollution of surface waters. Water logging has become every-rainy season phenomenon due to unplanned urbanization. Development activities are required to enhance the water environments safe and sustained, and regulations are needed to be imposed to protect these environments.

Key words: Dhaka, mega-city, water management, urban planning, hydrology.

Introduction

Bangladesh is a lower riparian country in the basins of the Ganges, Brahmaputra and Meghna (GBM) rivers. A major portion of the country is formed by the deltas of these large rivers. Tributaries of the Ganges and the Brahmaputra drain the southern and south-eastern slopes of the Himalayas, and the Meghna River system drains the Naga–Manipur hills of the Himalayan range.

Approximately 7% of the GBM basins – a total area of 1.74 million km^2 – lie in Bangladesh. The water regime of Bangladesh is mainly influenced by runoff generated outside the country (80%) in the upper catchments of the GBM rivers while 20% is contributed by local rainfall (Chowdhury, 2007). Annual volume of runoff over the country to the sea would be equivalent to about 12 metres depth over the country's area under the GBM basins. More than 80% of annual rainfall occurs during June to October, and groundwater is recharged during this period.

The city of Dhaka is surrounded by four rivers, Balu, Tongi, Turag and Buriganga. The drainage of the city is generally dependent on the water levels of the peripheral rivers. The drainage channels are well distributed over the city, which collect catchment runoff as well as wastewater and drain to the peripheral rivers. There are also several permanent lakes as well as stored flood water comprising seasonal water bodies during monsoon.

Dhaka, the capital of Bangladesh, has one of the fastest urban growth rates and has turned into one of the mega-cities (i.e., population exceeding 10 million) of the world (Karn and Harada, 2001). Dhaka, a mega-city, has been facing severe deterioration in overall environmental quality; which in exchange should adversely affect the life of the inhabitants and livelihood. One would hardly find some natural phenomena leading to environmental

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deterioration, unless triggered by or solely caused by anthropogenic activities. Urbanization is one of such activities which have broad spectrum of implications on environmental deterioration and consequent problems. This paper reviews how urbanization, as one of the biggest anthropogenic activities taking place in many of the world's mega-cities, has been affecting the water flows and thereby altering hydrography of the waterbodies of Dhaka city.

Environmental Set-up and Climate of Dhaka

The city area of Dhaka lies between 90°20′ E and 90°30′ E longitudes and between 23°40′ N and 23°55′ N latitudes. It is located on the extensive floodplains of the Ganges and the Brahmaputra. Landscape of the city is characterized by Pleistocene pop-up (Morgan and McIntire, 1959) and modifying urbanization. The city is crossed by several faults and lineaments controlling the rivers and stream orientation, and in downthrown subsiding blocks hosting marshy and swampy lands, i.e. wetlands (WASA, 1991; UN, 1999). Based on flood control infra-structure, Dhaka city is divided into two parts – Dhaka west and Dhaka east. The area is gradually sloping towards the east and the landscape is characterized by vast wetlands.

Dhaka is characterized by subtropical and humid climatic conditions. The mean annual rainfall is 2037 mm and the total volume of rainwater in the city for a 256 km^2 area is about 520 million cubic metres (UN, 1999). About 87.5% of a total 1920 mm annual mean rainfall usually is received during May to October of which June, July, and August are the months of heavy rainfall (BBC, 2008). This is reflected by the stage level of the surrounding rivers which carry the largest amount of water during June to October of the year.

Spatial Arrangement of Water Bodies around Dhaka City

Types of Water Bodies around Dhaka City

- **Fluvial water bodies:** These include the surrounding rivers of the city.
- **Streams and drainage channels:** Streams are the transport routes in a drainage basin. This type of water bodies comprise the water bodies locally known as *khals*. *Khals* are streams created naturally and used as channels to drain out the flood as well as rain-water to the surrounding rivers.
- **Inland water bodies:** These comprise the lakes and connecting canals of different water bodies.
- **Open water bodies:** Open water bodies comprise the low lying depressions and marshy areas remaining inundated for significant period of the year.

Major Rivers around Dhaka City

The Buriganga River, branching off from Dhaleswari River, flows from the south-west to south of the city. The Turag River comes from the north and joins the Buriganga near Mirpur. Balu River also comes from the north running through the eastern side of Dhaka, joins Shitalakshma River near Demra. The Tongi River takes water from Turag River and discharges it into the Balu River. The rivers become shallow and narrow during dry season, but turn over-loaded with water during monsoon.

The major rivers around Dhaka city along with use of river banks on both sides up to inland is shown in Figure 1 (Shahjahan, 2006), which represents four major kinds of uses. Starting from south end of Balu River, lands on both sides of the river are being used for navigation and agriculture. Lands around Tongi River are being used for industrial and agricultural purposes, while in case of Turag River it is used for agricultural, industrial as well as for mixed purposes. The lands around Buriganga River do not represent any special kind of use; rather these are used for mixed purposes. The usage pattern of these lands has obvious influence on all sorts of water qualities as well as the rivers' environment.

Streams and *Khal* Network in Dhaka City

A number of retention areas, *khals*, streams and streamlets emptying to the surrounding rivers control the natural drainage of Dhaka city (JICA, 1991). Figure 2 shows that streams and *khals* are well distributed over the city with many linkages with the four major rivers. This implies that the physical drainage of the city was advantageous unless disturbed by anthropogenic activities.

There exists a strong interconnected hydrodynamics between the rivers and stream-streamlets. The water level in the boundary river remains high during monsoon and floodwater enters the area through the *khal* system. In the opposite way, the storm run-off accumulated in the low-lying areas flows through *khals* and ultimately is discharged to the rivers. Major natural *khals* of the city area are Boalia *Khal*, Gobindapur *Khal*, Nali *Khal*, Uzanpur *Khal*, Begunbari *Khal*, Norai *Khal*, Mohakhali *Khal*, Badda *Khal*, Jarani *Khal*, Segunbagicha *Khal*, Dholai *Khal*, Khilgaon-Bashabo *Khal*, Uttar *Khal*, Manda *Khal*, etc. Water flow in many of the *khals* has reduced considedrably and become heavily contaminated during

Figure 1: Major rivers around Dhaka city and their periphery.
Source: **Shahjahan, 2006**

dry periods of the year. It is in the monsoon that most of the *khals* become active component of the hydrological system. There were some other *khals* that have been vanished or lost their surface hydraulic communication due to both urbanization and illegal encroachment. In the early 1960s Dhanmondi Lake was connected with the eastern water bodies of the city through the Begunbari *Khal*. A box culvert is now connecting Dhanmondi Lake to Begunbari *Khal* through Hateer-jheel and Rampura regulator.

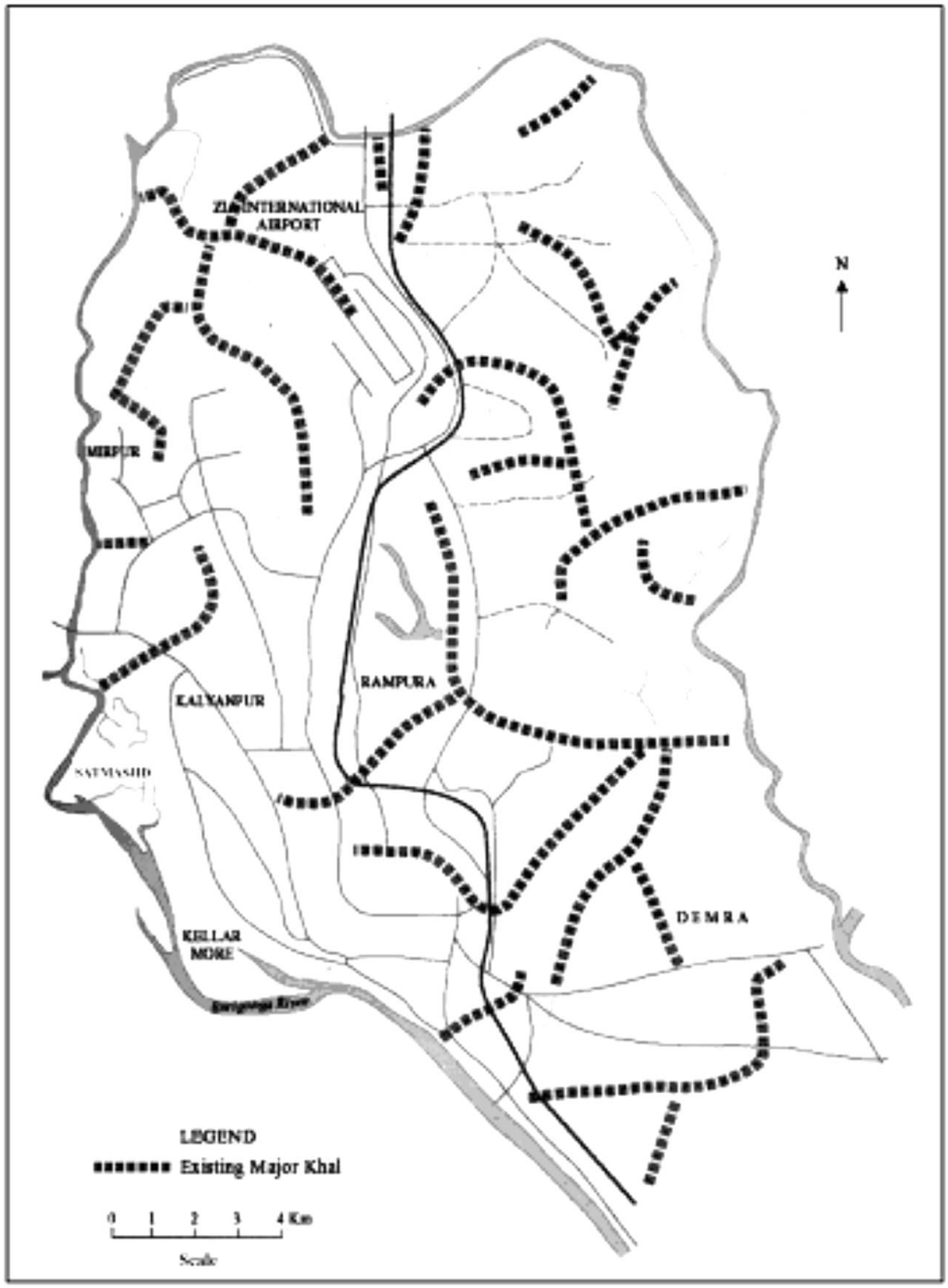

Figure 2: Stream and *khal* network in Dhaka city.
Source: **JICA, 1991**

For the first time a detailed map of natural drainage system of Dhaka city was done by the Survey of Bangladesh in 1955 from aerial photo interpretation, which served as basis for the subsequent studies. JICA (1991) carried out a detailed study on the catchments of Dhaka city as a part of master plan for greater Dhaka.

The Open and Inland Water Bodies of Dhaka

Dhaka city at its edge is mainly covered by floodplain of Balu River in the east and that of the Buriganga and Turag rivers in the west. These floodplains are characterized by low lying depressions and marshy areas remaining inundated for significant period of the year. These

depressions and marshy areas are identified as open water bodies. Most of the eastern part of Dhaka city is covered by marshy land, peat areas, or wetlands (such as Saidabad *beel*) of Balu River floodplain. Western edge of the city is also covered by marshy low lands. These low lands are generated within the floodplains of the Buriganga and the Turag.

The inland water bodies include lakes among which the major ones are Ramna Lake, Dhanmondi Lake, National Zoo Lake, Botanical Garden Lake, Crescent Lake, Banani Lake and Gulshan Lake.

The floodplain depressions and marshy areas identified as open water bodies store rain and flood water while the inland water bodies accumulate storm water through seepage from the catchments. The lowlands and inland water bodies perform important drainage function by storing storm water and keep the relatively higher lands free from rainfall flooding (Chowdhury et al., 1998).

Topography of Dhaka and Its Relation to Water Environment

Dhaka generally represents a flat land area with slight undulations. It is comprised of Madhupur tract and recent sediment. A large part of the city is covered by low lying depressions. There is no problem due to undulatory surface coverage of the city, but due to erosional effects there has formed numerous rounded and elongated blocks. The area represents significant variation in elevation ranging from 1.5 m to 15 m with an average of 6m above mean sea level (MSL). The land area above 8 metres MSL covers about 20 km^2 while the lands ranging from 6 to 8 metres above MSL (intensely urbanized areas) covers 75 square kilometres and the rest 170 km^2 of Greater Dhaka is below 6 metres (JICA, 1991). The area slopes are towards southeast, east, and west; but general slope is from north to southeast where the ground surface merges gently with floodplains of Buriganga River. The elevation of the surrounding floodplains of the area is variable. The average elevation of Buriganga floodplain is about 3m above MSL.

Due to such topographic condition, the rainwater cannot be smoothly discharged to the lakes, *khals*, retention areas and surrounding rivers and the accumulated runoff remains stagnant in low laying areas inside the city creating severe water logging problem. Besides, people have a tendency to develop residential, commercial and industrial areas comparatively in higher ground to save them from water logging or flooding. Therefore, the more affluent members of society make their developments flood-proof through raising the ground level, thus exaggerating the problem.

Temporal Change in Natural Drainage Channels, Catchments and Open Water Bodies around Dhaka

In order to reveal the temporal changes in water bodies, digital maps of the years 1968 and 2001 are analysed. In case of open water bodies, the data layers of two years are overlaid to represent the extent and severity of temporal changes. Drainage pattern and arrangement of the channels are used to define and delineate the localized drainage catchments.

Natural Drainage Channels and Catchments in 1968 and 2001

Figures 3 and 4 clearly show temporal change in drainage channels and catchments of greater Dhaka. The natural drainage system has been subdivided into five drainage catchments, which drain different parts of the city.

1. **North-eastern Catchment:** This catchment drains the north-eastern area of the city generally eastern Uttara, and northern Badda. This catchment drains water from Balu River.
2. **East-central Catchment:** East-central part of Dhaka city, generally Gulshan, southern Badda, and Maghbazar areas are drained by this catchment to the Balu River.
3. **South-central Catchment:** This catchment generally drains the Motijheel, and Jatrabari area. It drains water to Buriganga River.
4. **West-central Catchment:** It mainly drains Mirpur, Adabar, and Mohammadpur area to the Buriganga River.
5. **North-western Catchment:** This catchment mainly drains Pallabi, Cantonment, and Western Uttara to the Turag River.

Besides these, there are some other small catchments draining some small parts of the city such as one in the north, draining to Tongi River and another in the south draining to Buriganga River.

The distribution of drainage channels over the five major catchments has clearly shrunk over the period. These channels have been used up by many anthropogenic activities like encroachment or impeded by infrastructural and industrial activities. Rather than being modernized and more adaptive, the shrinking of drainage

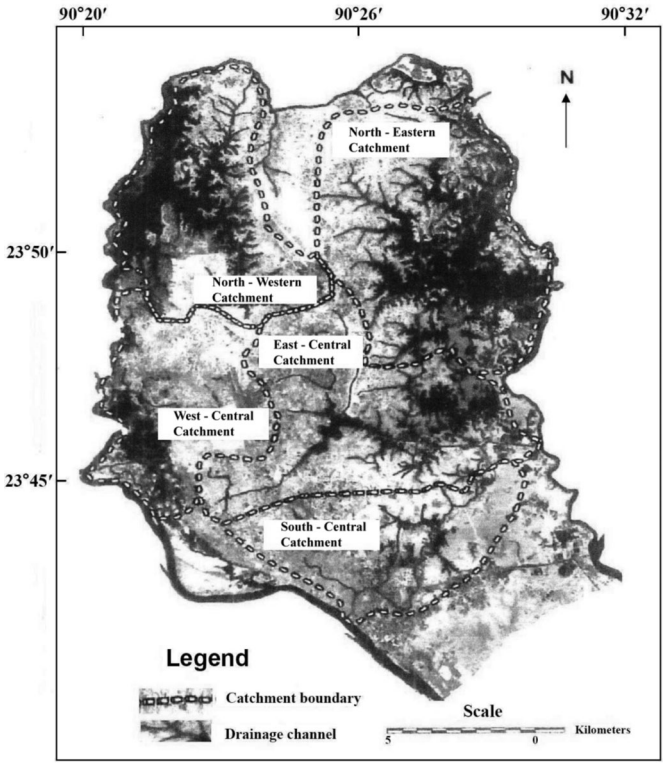

Figure 3: Natural drainage channels and catchments of greater Dhaka in 1968.
Source: **Sultana, 2005**

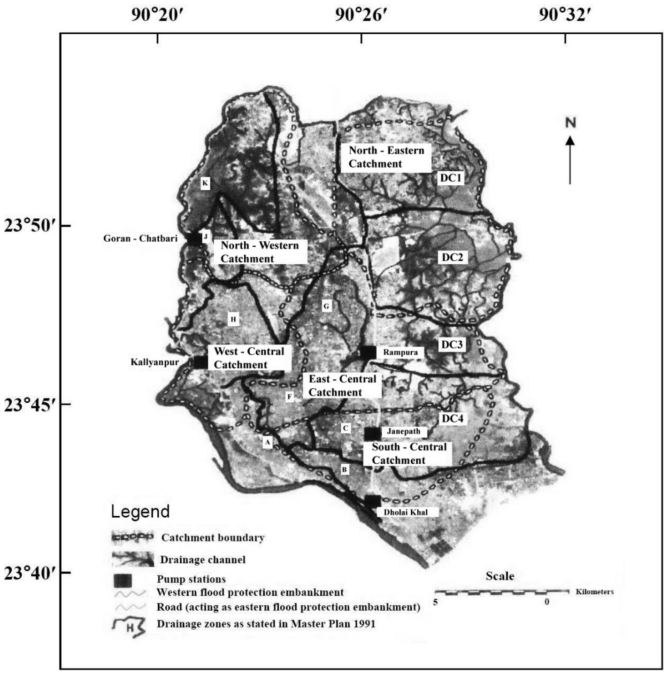

Figure 4: Natural drainage channels in 2001 and drainage zones stated in greater Dhaka Protection Master Plan, JICA (1991).
Source: **Sultana, 2005**

channels clearly indicates failure of managing these water channels by the city dwellers, which is contributing to present-day water logging in the city.

Specifically, changes generally occurred in the Gulshan area (East-central Catchment), Motijheel and Jatrabari area (South-central Catchment), Mohammadpur area (West-central Catchment) of Dhaka as the majority of urbanization occurred in these areas. Impact of land use changes on wetlands and natural storm drainage is discussed by Chowdhury et al. (2001), while Reza and Alam (2002) illustrate the changing scenario in western Dhaka during the years of 1963 to 2000.

Temporal Change in Open Water Bodies of Dhaka

Figure 5 shows temporal change in open water bodies during the period between 1968 and 2001. Substantial decline in open water bodies is clearly evident from the figure and it has deleterious effects on ecosystem equilibrium over the region. The coverage of the water bodies in the eastern part and western edge of the city have been substantially reduced and became sporadic rather than continuous. Reduction in area of open water bodies generally occurred in Boro-maghbazar, Eskatan, Motijheel, Jatrabari over the south-eastern corner of the city. Wetlands in south-western corner of the city retreated towards river in areas over Mirpur and Mohammadpur. Minor reduction of the wetlands occurred in Pallabi – Cantonment area as well, where low lying areas were filled and levelled for urban extension. Overall, the shape of the water bodies changed everyday as the undulating Madhupur clay in the north and east were levelled and filling activities became an essential component of urbanization. Storm water deposits also contributed to the reduction which was not compensated by appropriate preservation initiatives.

The threat to fluvial, open, and inland water bodies mainly affect with ecosystem dysfunction, loss of biological diversity, alteration of aquatic habitats and contamination of downstream. Ecosystem impacts are particularly acute near centres of human activities. It is long since the cities have been the sole source of pollution and destruction of ecological niche. In modern times, modernization of cities essentially incorporate establishment of healthy ecosystem equilibrium so that with supplying the facilities to ease life, the cities can also contribute to furnishing the natural environment. Other than preservation and conservation of inland and open water bodies, a city can never progress to become

environmentally healthy city. Depletion in open water bodies is the result of encroachment and filling-up of water bodies and wetlands for settlements and infrastructure. The seasonal change in open water environment is usually coupled with agricultural activities especially during winter and summer when the lands become dried and irrigation water is available.

Summary of Temporal Changes in Water Bodies

The summary of temporal changes in water bodies are listed in Table 1 (Sultana, 2005).

Groundwater Depletion of Dhaka

The DWASA (Dhaka Water Supply and Sewerage Authority) is responsible for water supply to the city. In 1995, the total water requirement of the city was 262 IMGD (Imperial Million Gallons per day), of which DWASA was only supplying 181 IMGD. The 89% of the supplied water was withdrawn from groundwater source and the rest 11% supplied from surface water treatment plant (IFCDR, 1996). It has been predicted that the total demand of the city will increase to 534 IMGD by the year 2020 (IFCDR, 1996), which would be totally impossible by depending only on groundwater. Presently, groundwater is the main source of potable water supply for domestic and industrial uses of Dhaka metropolitan. As surface water near the city is becoming increasingly polluted and costly to purify, public water utilities and other urban water users have turned to groundwater as potential source of cheaper and safer supply. In 1995, 96% of the total water use (irrespective to the DWASA coverage) was abstracted from underground sources (IFCDR, 1996).

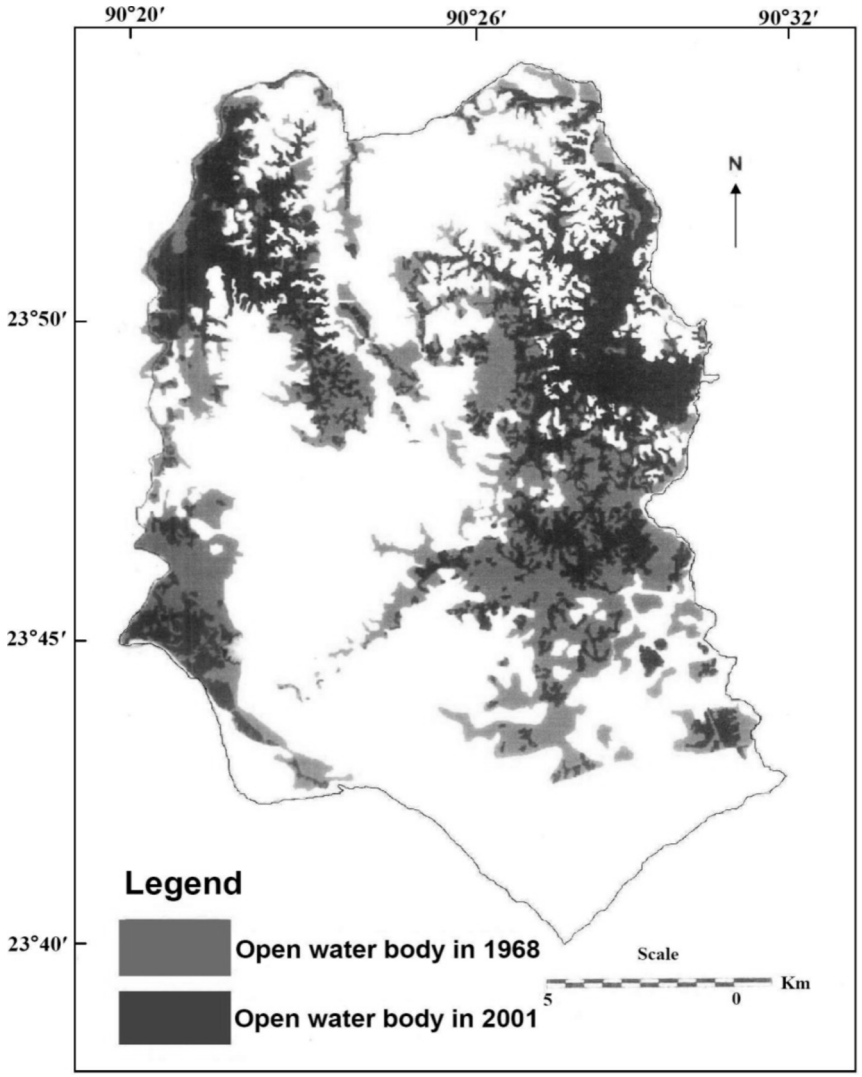

Figure 5: Overlay of open water body of 1968 and 2001.
Source: **Sultana, 2005**

Table 1: Summary of changes in water bodies around Dhaka over a period of time

Water body type/change	*Fluvial water body (km^2)*	*Inland water body (km^2)*	*Open water body (km^2)*
Area in 1968	11.65	5.06	68.66
Area in 2001	10.90	2.30	61.67
Common area in 1968 and 2001	8.88	1.82	60.41
Change (in km)	–0.75	–2.76	–6.99
Change (in %)	–6.44	–54.54	–10.18

Encroachment and Filling Up of Water Bodies and Lowlands

In the 1980s, there were numerous wetlands, *khals*, and canals within and around Dhaka city that would drain the city area efficiently (JICA, 1991). Urbanization took place irrespective of the landform which led to filling up of many canals and depressions. These activities are more pronounced within and nearby the more developed areas of the city. As a result, the canals, wetlands, and depressions which previously acted as drainage basin is obstructed resulting in a miserable water congestion problem (Chowdhury et al., 1998). The newly developed areas such as Demra, Jurain, Dolaipar, Maniknagar, Mugdapara, Manda, Goran, Rampura, Badda, Baridhara, Mohammadpur, Rair Bazar, Kamrangirchar, Abdullahpur, etc., developed by filling low-lying areas and depressions are suffering from the distress of waterlogging (Shams, 1999). Filling activities in natural drainage canals, embankments, and roads with no culverts obstruct the natural drainage flow. Filling activities in depressions and abandoned canals of the city almost create water stagnancy and in some cases foundation failure problems as well while the wetlands could be very effective in controlling local flood level and environmental status of Dhaka (Chowdhury et al., 2001). As Dhaka city has a faster urban growth rate, it may lose its hydrographic features with the progressive urbanization in such ways.

Encroachment of natural drainage system is a common practice in Bangladesh. Most of the natural drainages of Dhaka disappeared or are in way to lose their existence due to illegal encroachment. A good number of *khals* criss-crossing the city, had some of their out falls in these rivers and had been playing a very significant role in the drainage of the city area. During 1960s, there were around 50 *khals* in Dhaka City and their total length was 256 km. But due to encroachment, at present there are only 26 *khals* with total length of 125 km (The Daily Inqilab, 2004). Illegal encroachment of one of the most important lakes in the city, Gulshan Lake has also been reported (Tawhid, 2004).

The filling-up of vast areas in Ashulia, Banashree, Aftabnagar, Meradia, Baunia, Badda, Amin Bazar and Hatirjheel, known as water catchments, increased the hazards of water logging that swamped much of the city. The Dhaka city master plan has clearly marked these areas for water retention purposes, and the 'Wetland Conservation Act, 2000' bars land development in water bodies. According to the Conservation Act, no one has the right to develop land on wetlands, flood flow zones or catchments. But the developers and land owners have been occupying and filling the areas. Such development activity has been reported for housing in Ashulia in the flood flow zone in DMDP (Dhaka Metropolitan Development Plan) (Tawhid, 2004).

A long stretch of the Turag River is being encroached upon and filling up by the influential people and the developed lands are being used for business purposes (The Daily Star, 2008). Illegal encroachment on Buriganga River has been reported leading to reduced carrying capacity of natural drainage system in Dhaka City (Tawhid, 2004).

Flood and Waterlogging in Dhaka

Flooding in Dhaka metropolitan area can be classified into two types. One results from high water levels of peripheral river systems, thus rendering any natural drainage impossible. Another is caused by high intensity storm rainfall runoff in the city area, which causes flooding also in situations where natural drainage might be possible.

Flooding due to rainfall is also a severe problem for the city that is inundated for several days mainly due to the drainage congestion (Huq and Alam, 2003). The water depth in some of the areas may be as much as 50–70 cm, which creates large infrastructural problems for the city and a huge economical loss in production (Mark and Chusit, 2002). During the monsoon (May to October), the water level of the surrounding rivers remains higher than the internal drainage level. Consequently, the drainage of the city depends very much on the water levels of the peripheral river system. At present, the

drainage depends mostly on the difference in water level between the river and the drainage system in the city and when the water level in the river increases the drainage capacity to the river is reduced (Mark and Chusit, 2002).

The unplanned spatial development activities and growth of habitation due to rapid population growth are causing encroachment on retention areas and natural drainage paths with little or no care of natural drainage system thus creating obstacle to proper drainage of urban runoff. Inadequate drainage sections, conventional drainage system with low capacity and gravity, natural siltation, absence of inlets and outlets, indefinite drainage outlets, lack of proper maintenance of existing drainage system, and over and above disposal of solid waste into the drains and drainage paths are accounted for as the prime causes of blockage in drainage system and water logging. In addition, seasonal tidal effect and the topography of the city area also cause water logging.

Again, rain water carry out different construction materials like bricks, sands, and stones, leaves, household wastes, street sweepings, etc., creating hazardous water logging by reducing the runoff capacity of the drainage system. A significant siltation in the *khals* and rivers in and around Dhaka city has taken place due to expansion of the Dhaka metropolitan area over the last few decades. The flood control embankment and sluice gate across the rivers and canals has created siltation problem as riverbed has been raised and carrying capacity reduced. One of the main natural drainage system of Dhaka, Begunbari *Khal*, has been reported to lose its runoff capacity due to siltation (Tawhid, 2004).

Disruption of traffic movement and normal life; damage of structures; destruction of vegetation and aquatic habitats; loss of income potentials are the encountered effects of water logging on city life. The storm water also become polluted as it mixes with solid wastes, clinical wastes, silt, contaminants, domestic wastes and other human activities that increase the water borne diseases. The stagnant storm water leads to the creation of breeding sites and becomes a hazard to health as well as foul smelling bins.

Conclusion

Shrinking of the water bodies due to encroachment and filling up, man-made changes in elevation pattern, and siltation with debris from urban development activities are some of the major concerns for Dhaka. Unplanned urbanization and industrialization occurring in the city are largely responsible for this grave situation. Water Policy of Ministry of Water Resources Bangladesh, published in 1999, recognizes the need to frame rules, procedures and guidelines for combining water and land use planning. Development activities are required to ensure various environments of water bodies, safe and sustained, and regulations are needed to be imposed to protect these environments.

References

BBC (2008). BBC Weather. Dhaka city weather average [online]. http://www.bbc.co.uk/ weather/world/city_guides/results.shtml?tt=TT002040 [accessed 15 May 2008].

Chowdhury, J.U., Rahman, R., Bala, S.K. and A.K.M.S. Islam (1998). Impact of 1998 flood on Dhaka city and performance of flood control works. Report, IFCDR (at present IWFM), BUET, Dhaka, Bangladesh.

Chowdhury, J.U., Kamal, M.M., Khan, N.I., Akhter, M.K. and M.A. Salam (2001). Impact of land use change upon storm water drainage and wetlands in the eastern part of Dhaka. IFCDR (at present Institute of Water and Flood Management), BUET; Department of Geography and Environment, University of Dhaka; and SWMC (at present Institute of Water Modelling) Dhaka, Bangladesh.

Chowdhury, J.U. (2007). Lessons from water management in Bangladesh. *Sustainable Mountain Development*, **53:** 22–24.

IFCDR (1996). An evaluation of Dhaka city groundwater conditions. Institute of Flood Control and Drainage Research (at present Institute of Water and Flood Management), BUET, Dhaka, Bangladesh.

Huq, S. and M. Alam (2003). Flood management and vulnerability of Dhaka city. Bangladesh Centre of Advance Studies (BCAS), Dhaka, Bangladesh.

JICA (Japan International Cooperation Agency) (1991). Master plan for greater Dhaka protection project (study in Dhaka metropolitan area), FAP-8A, Main Report and Supporting Reports I and II. Flood Plan Coordination Organization (at present Water Resources Planning Organization, WARPO), Dhaka, Bangladesh.

Karn, S.K. and H. Harada (2001). Surface water pollution in three urban territories of Nepal, India, and Bangladesh. *Environmental Management*, **28(4):** 483–496.

Mark, O. and A. Chusit (2002). Modelling of urban runoff in Dhaka city. Asian Institute of Technology (AIT), Thailand.

Morgan, J.E. and W.C. McIntire (1959). Quaternary geology of Bengal basin, East Pakistan and India. *Geol. Soc. Amer. Bull*., **70:** 319–342.

Ministry of Water Resources (1999). National water policy. Government of the People's Republic of Bangladesh.

Reza, A.N.M.G. and S.M. Alam (2002). Wetland transformation in the western part of Dhaka city (1963–2000). *Bhugal Patrika*, **21:** 23–40.

Shahjahan, Md. (2006). Quality of water in the major rivers around Dhaka city: studies in environmental geography. MS thesis (unpublished), Department of Geography and Environment, University of Dhaka, Bangladesh.

Shams, N. (1999). Urban geology of Dhaka city for geohazard mitigation and development planning. MS Thesis (unpublished), Department of Geology, University of Dhaka, Bangladesh.

Sultana, M.S. (2005). Analysis of changing scenario of wetlands in Dhaka city using remote sensing and GIS. PG (Dip.) project report (unpublished), Institute of Water and Flood Management, BUET, Dhaka, Bangladesh.

Tawhid, K.G. (2004). Causes and effects of water logging in Dhaka city, Bangladesh. TRITA-LWR M.S. Thesis (unpublished), Department of Land and Water Resource Engineering, Royal Institute of Technology, Stockholm.

The Daily Inqilab (2004). August 9 issue. Dhaka, online version available at http:// www.dailyinqilab.com (published in Bangla).

The Daily Star (2008). July 11 issue. Dhaka, online version available at http://www.thedailystar.net.

UN (United Nations) (1999). Urban geology of Dhaka, Bangladesh. Economic and Social Commission for Asia and the Pacific, Atlas of Urban Geology, Vol. II, United Nations, New York.

WASA (1991). Dhaka regional groundwater and subsidence model. Dhaka Water Supply and Sewage Authority, Bangladesh.