

Flood Risk Management in Dhaka

A Case for Eco-Engineering Approaches and Institutional Reform



People's Republic of Bangladesh



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ACRONYMS

ADB	Asian Development Bank
A1F1	IPCC scenario based on fossil fuel-intensive development
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
B1	IPCC scenario indicating a relatively high level of environmental consciousness
CEGIS	Center for Environmental and Geographic Information Services
DAP	Detailed Area Plan
DCC	Dhaka City Corporation
DMA	Dhaka Metropolitan Area
DMDP	Dhaka Metropolitan Development Plan
DND	Dhaka-Narayanagn-Demra
DNCC	Dhaka North City Corporation
DSCC	Dhaka South City Corporation
DWASA	Dhaka Water Supply and Sewerage Authority
FFWC	Flood Forecasting and Warning Centre
IPCC	Intergovernmental Panel on Climate Change
RAJUK	Rajdhani Unnayan Kartripakkha



Executive Summary





Rationale

Dhaka is the cultural, political, and financial center of Bangladesh. It is one of the largest and most densely populated cities in South Asia, with a population of approximately 17.5 million people in 2015 and growing at the rate of over 3 percent per year (World Bank 2015). By 2025, the United Nations (UN) predicts Dhaka will be home to more than 20 million people—a population larger than that of Mexico City, Beijing, or Shanghai. It is estimated that almost 34,000 people inhabit each square kilometer of the city, yielding a population density that is among the highest in the world (Dasgupta et al. 2015). The city contributes about 34 percent of the country's gross domestic product (GDP), indicating its economic and strategic importance.

Dhaka is highly prone to water-related hazards such as urban and river flooding, owing to its location, topography, climate, and proximity to rivers. It experiences major floods regularly, as in 1954, 1955, 1962, 1966, 1974, 1987, 1988, 1998, 2004, and 2009. Situated in the lower reaches of the Ganga delta, the Dhaka Metropolitan Area (DMA) is surrounded by rivers and tributaries: the Buriganga to the south, Turag to the west, Tongi Khal to the north, and the Balu-Shitalakhya to the east. The city is low lying, with an elevation that varies from 0.8 to 14 meters above mean sea level, and is drained by numerous natural waterways and canals.

Dhaka is also among the most climate-vulnerable megacities in the world (Maplecroft 2013).¹ Climate variability and change are expected to intensify the city's exposure to environmental risk and heighten the extent and duration of urban flooding and inundation. With rapid and unplanned urbanization, the vulnerability of the city, and particularly of its poorest residents is likely to increase un-

less measures to ensure resilience are put in place. During the 1998 floods, most of eastern Dhaka and some parts of western Dhaka were inundated for almost 65 days. The impact of flooding is widespread: it compromises the sewerage system, degrades drinking water, disrupts traffic, and increases the incidence of water-borne diseases. While city-level cost estimates of the damage from extreme floods are scarce, one study estimates the damage from the 1998 floods at approximately \$171 million.^{2,3}

At present, Dhaka is at a crossroads of development. The main planning agency, Rajdhani Unnayan Kartripakkha (Capital Development Authority, RAJUK) is drafting a Structure Plan (2016–35) for the next 20 years. The design and implementation of this plan will shape infrastructure development and the pattern of urbanization in the city for decades to come. The emerging plans and their implementation will also affect management of the city's water and ecological resources, influx of rural migrants into the city, supply of jobs and affordable housing, and adaptation to climate risks.

Management of flood risks is a critical part of this story. As the city urbanizes, it is imperative that it builds on lessons of the past so that flood risks are fully integrated into urban planning and managed effectively. Although

1. Dhaka ranks first on Maplecroft's Climate Vulnerability index. See <http://www.preventionweb.net/english/professional/maps/v.php?id=29649>.

2. Estimate is developed from data cited in Alam and Rabbani (2007). Costs used include damages to residential and institutional buildings of approximately \$51 million (Bangladeshi Taka, BDT 4 billion) and about \$5.1 million (BDT 400 million) respectively, shelter units of about \$29 million (BDT 2.3 billion), losses to large-scale industry of \$30 million, to small and medium size industry of \$36 million, and damages to urban services (water, sewerages, electricity, gas, and telephone) of about \$20 million. This is based on a partial estimate and does not include health impacts and other costs, which would make the actual costs much more substantial. Exchange rate used is 1 BDT = \$0.013 (Jan. 2017).

3. National-level estimates are more easily available. For instance, the National Strategy for Accelerated Poverty Reduction (FY2009–11) notes that losses of income and assets due to flooding events were \$330 million in 1988, \$2 billion in 1998, \$2.2 billion in 2004, and \$1.06 billion in 2007.



there is an extensive literature on Dhaka's urbanization, flood risk management, and poverty, few studies have assessed the historical drivers of the city's decision making with respect to flood risk management, linkages between urban planning and flood risk, or the political-economic and institutional issues constraining improved flood and urban resilience. This study aims to fill this gap.

Objective

The main objective of this study is to propose recommendations for addressing flood risks in Greater Dhaka. This is based on an analysis of flood risks facing the city, historical analysis of decision-making about flood risk management, and institutional and political economy analysis. Looking ahead, the study also considers how relatively new approaches to managing flood risk—green defense, eco-engineering, or ecosystem-based approaches⁴—might inform the management of flood risk in Dhaka city.

The study was initiated at the request of the Government of Bangladesh and carried out in close consultation with the Ministry of Environment and Forests—the focal agency for the Bangladesh Climate Change Resilience Fund (BCCRF), with the Dhaka North and South City Corporations and RAJUK. It contributes to the goals of the Country Partnership Framework 2016–20 prepared in collaboration by the Government of Bangladesh and the World Bank (World Bank 2016). At present, the World Bank is undertaking an analysis of options to engage in eastern Dhaka and also developing a broader platform for engagement in the city. The study also informs these endeavors. It is fully aligned with the preparation of the Bangladesh Delta Plan 2100, a collaborative long-term planning initiative being

undertaken by Bangladesh's Planning Commission and the Netherlands. Further, it is consistent with the Bangladesh Climate Change Strategy and Action Plan 2009, which highlights the urgency of strengthening resilience to urban flood risks.

Approach

The study is based on extensive fieldwork, documentary research, and consultations with government and other stakeholders. It has the following focus areas: First, to set the stage, an analysis of flood risks facing Dhaka city is undertaken. Using publicly accessible satellite imagery, geographic information system (GIS)-based mapping tools, and available satellite-based analysis, the study assesses spatial changes in urbanization and urban ecosystems that are shaping flood risk in the city.

Second, a historical analysis of flood management interventions in Dhaka and the sequence in which they occurred is undertaken. The analysis shows how planning for flood management evolved historically; the drivers of decision making; the importance and limitations of the measures undertaken, both infrastructural and non-infrastructural; and how decisions regarding flood vulnerability have informed spatial planning and zoning. This historical analysis is critical for understanding options available currently and charting pathways for the future.

Third, an institutional and organizational capacity assessment for urban planning and flood risk management is undertaken. This includes analysis of relevant plans and policies, mandates, and capacity of key organizations such as RAJUK, the Dhaka North City Corporation (DNCC), the Dhaka South City Corporation (DSCC), the Bangladesh Water Development Board (BWDB), and the Dhaka Water Supply and Sewerage Authority (DWASA) in shaping flood resilience. The assessment does not include a broader organizational analysis of these agencies but is limited

4. See, for instance, Hulsman et al. (2011); EU (2012); EPA (2013); Li, Turner, and Jiang (2012). See also https://www.huduser.gov/portal/periodicals/em/winter15/highlight3_sidebar.html.

to shedding light on their roles in flood risk management in the city. Emphasis is on political economy aspects and institutional constraints that need to be addressed. Based on the above analysis, the study provides recommendations for strengthening flood risk as a core element of strengthening urban resilience in Dhaka. This includes recommendations for institutional and organizational reforms, and structural and nonstructural measures that could be undertaken. In proposing these recommendations, an extensive review of international experience using green defense/eco-engineering approaches was undertaken. A brief version is included in appendix A.⁵

Process

The study has been prepared in close collaboration with RAJUK, the Dhaka North and South City Corporations, DWASA, and BWDB. It builds on extensive review of existing literature on urbanization and flood management in Dhaka, fieldwork, and consultations with government and other stakeholders. Three consultation workshops were organized during preparation of this study—among them a workshop on international experiences with eco-engineering approaches to flood risk management and another to develop options for flood risk management using nature based approaches. In May 2016, a stakeholder consultation chaired by the Mayor, DNCC was organized to discuss preliminary findings from the study. Participants in these workshops included representatives of numerous national and municipal government agencies, ward-level officials, and development partners.

Key findings

Key findings of this study are summarized here and presented in more detail in the report.

5. A detailed review has also been prepared and is available upon request.

FLOOD RISKS FACING

DHAKA CITY

- **Areas vulnerable to flooding.** Based on data from past extreme events, areas most vulnerable to flooding are Dhaka East and the low-lying Dhaka-Narayanagn-Demra (DND) area. However, Dhaka West continues to experience waterlogging and drainage congestion. The DND area is expected to be the most vulnerable under future climate scenarios (Dasgupta et. al. 2015). Some of the slum settlements most prone to flooding are Mohammadpur, Kamrangir Char, Rampura, and Khilgaon—all high-priority areas for efforts to improve urban resilience.
- **Different types of hazards affect different areas of the city.** Dhaka West which is embanked, is chiefly vulnerable to intense rainfall resulting in waterlogging. The DND area is embanked from all sides, has limited drainage and is also mainly affected by intense rain resulting in waterlogging. Dhaka East is not embanked and hence vulnerable to both river flooding and intense rainfall. Thus, tailored early warning systems are needed for major areas in the city that take into account the specific nature of the hazard.
- **Urbanization is accompanied by a decline of urban wetlands and groundwater resources.** Urbanization and increase in population growth in Dhaka is accompanied by a steady decline in urban wetlands and increase in built-up area. Moreover, approximately 78 to 87 percent of Dhaka's drinking water comes from groundwater resources. However, according to the Bangladesh Agricultural Development Corporation and Institute of Water Modeling, the groundwater level of Dhaka City is declining by about three meters each year and the city faces serious water shortages in the dry season. The decline of green spaces has also cut recharge capacity, and supporting measures such as the protection of green spaces and rainwater harvesting are needed to help meet rising demand for water and slow the decline of groundwater resources.

PUBLIC SECTOR RESPONSE TO MANAGING FLOOD RISKS

- **Public sector response to flood risk management has primarily been in reaction to extreme events and not as an integral part of urban planning.** Analysis carried out in this report shows that many of the major flood-control infrastructure measures undertaken in Dhaka have been initiated as a reaction to major flood events, not as part of the planned urban expansion of the Dhaka area. The embankments in the DND area were a response to the devastating floods in 1954 and 1955 and the western embankment was constructed in response to extreme flood events of the 1980s. Moreover, in the low-lying DND area, flood-control infrastructure has contributed to the urbanization of the area by encouraging people to settle there even in the absence of an adequate drainage system or adequate provision of municipal services. If flood control infrastructure is contributing to urbanization, then it is important that it be considered as an integral part of urban planning and not initiated in response to extreme events.
- **Efforts to maintain connectivity between inland waterways and outer river system have been limited.** The construction of embankments in the west and DND area, combined with poor maintenance of rivers and other urban water bodies, have delinked the city's internal waterways and canals from the peripheral river system. Parts of the city's internal waterways, particularly in the western and southern parts of the city, are disconnected from the outer river system. As a result, both the Dhaka West and DND areas now must be drained using a large number of pumps, capacity for which is at present, inadequate.
- **Prioritization of structural measures compared to non-structural measures as instruments for rain and river flood management.** The primary solution for addressing waterlogging and managing river flooding in Dhaka has been structural interventions (such as

embankments, flood walls, pumping stations, box culverts, and regulators), with much less attention given to nonstructural measures such as planning, zoning, weather and flood forecasting- or risk-based information services: critical “nonstructural” tools that can help the city manage urbanization, land, and resources in a more balanced way.

INSTITUTIONAL AND ORGANIZATIONAL CHALLENGES

- **Institutional analysis carried out in this report shows that for Dhaka, there is no integrated flood risk management plan.** The Structure Plan (1995–2015) and the Detailed Area Plan (gazetted in 2010 and valid till 2016 with a one-year extension) have de facto been used to make decisions about land use, but without a comprehensive implementation plan or a coordinated approach to managing flood risk. The Town Improvement Act (1953) was prepared over 60 years ago; it bestows enormous powers to RAJUK with little accountability to the public and needs to be revised. Incorporation of flood risk issues into the implementation of the Detailed Area Plan happens on an ad hoc basis.
- **Disconnect between planning and municipal service delivery.** Contrary to good practice, where planning offices and functions typically fall under the purview of the mayor,⁶ in Dhaka, planning is carried out by RAJUK with limited systematic contribution from the planning offices of the DNCC and DSCC. The agencies involved in urban planning and municipal service delivery lie within different ministries and have different accountability structures. RAJUK reports to the Ministry of Housing and Public Works. On the other hand, DNCC, DSCC, DWASA, and the Union Parishads report

6. One example of this is Washington D.C. where the Office of Planning is under the mayor.

to the Ministry of Local Government, Rural Development, and Cooperatives (MLGRDC). BWDB falls under the Ministry of Water Resources. RAJUK has no direct accountability to the MLGRDC even though it makes important decisions about land use, water bodies, and housing that directly affect the citizenry on a regular basis. Moreover, there is a contradiction between RAJUK's regulatory and development roles. RAJUK issues licenses for land use and building construction to private land developers, but it also develops land on its own account with no clear oversight.

- **Unplanned urbanization well underway before falling under Municipal jurisdiction.** Until May 2016, the two city corporations DNCC and DSCC together had jurisdiction over only some of the Dhaka Metropolitan Area (DMA). Significant parts of DMA, the DND area, and Greater Dhaka (outside the DMA area) were *not under any municipal jurisdiction*. Outer parts of the Greater Dhaka and DND areas are even now governed by Union Parishads. If indeed Dhaka's spatial expansion is to be better managed, it would make sense to bring the entire Greater Dhaka area under one or more municipal corporations. The boundaries—and service responsibilities—of the two city corporations have expanded without adequate planning or additional resource allocations. The two city corporations have planning departments but have limited human resources and technical skills needed for planning. Neither city corporation has a long-term strategic plan for drainage or flood risk management. The Union Parishads that provide services in the rest of Greater Dhaka also have very limited capacity for flood risk management.
- **There is no clear ownership of urban water bodies, and the maintenance of natural canals and river systems has been neglected.** While DWASA maintains some *khals* and waterways that are part of its drainage network, it is unclear which agency is ultimately re-

sponsible for managing and protecting Dhaka's lakes, water bodies, and canals; maintaining (not just monitoring) water quality; and preventing encroachment and dumping. Regular maintenance is essential for these lakes to effectively function as retention areas and if water is to drain adequately during monsoon season. Likewise, regular dredging of the surrounding river system, a BWDB mandate, is not sufficiently addressed.

- **Current drainage provided by DWASA covers approximately 38 percent of the DMA.** Although DWASA does a noteworthy task of providing water supply, sewerage, and drainage services, its drainage services cover only 38 percent of the DMA and are absent from most of Greater Dhaka and the DND area. Responsibility for drainage is split between multiple agencies. In Dhaka, some pumping stations are operated by DWASA, others by BWDB. Storm water drainage is provided by DWASA, while DNCC and DSCC manage surface-water drains. However, there is a need for greater coordination between DWASA and the two city corporations on drainage maintenance. No overarching agency is presently responsible for the provision of drainage, sewerage, or wastewater treatment in those parts of Greater Dhaka where DWASA does not operate. Drainage coverage needs to be expanded, especially in Dhaka East, before further urbanization occurs.
- **Capacity for weather early warning systems limited.** The Flood Forecasting and Warning Center (FFWC, under BWDB) is set up to address river floods. But because Dhaka is also vulnerable to intense rainfall, BMD's capacity for precipitation forecasting needs to be strengthened, as does FFWC's capacity to undertake impact-based forecasting to reach communities at risk.



Recommendations

Going forward, three issues are critical to strengthening flood risk management in Dhaka. First, it is important that investments in flood infrastructure take place as part of a comprehensive, integrated, and participatory urban planning and flood risk management process, rather than in reaction to extreme weather and flood events, as has been the case in the past. This means, that significant attention will need to be put in strengthening urban planning and preparedness and considering flood risk management as a key part of this process. Second, a major shift is needed from a primarily infrastructure based approach to flood risk management to an approach that considers nature based infrastructure, the city's river systems, wetlands and land use as integral parts of managing flood risk. The connectivity between the internal natural drainage network of the city and surrounding river system needs to be revitalized and maintained—and is a key aspect of a nature based solution to managing flood risk in Greater Dhaka. Thus, future investments to address flood risk should look at the city in an integrated way and not just focus on one area (for example, Dhaka East) in an isolated way. Finally, and most notably, important institutional and organizational reforms are needed to strengthen urban resilience in Dhaka. These require an array of measures including updating outdated regulations, undertaking difficult agency reforms, strengthening flood risk and land use information systems, and strengthening planning capacity. These recommendations are summarized in TABLE ES.1 and elaborated below.

RECOMMENDATIONS FOR INSTITUTIONAL AND POLICY REFORMS

- **Revise outdated Town Improvement Act (1953).** One of the priority actions going forward is to reform the outdated Town Improvement Act (TIA). The TIA was approved over 60 years ago and should be revised to take into account the current realities, level of urbanization, institutional arrangements, and challenges facing Dhaka. The act should be revised to address the conflicting powers bestowed to RAJUK and similar planning agencies in other major urban areas in Bangladesh. Revision of this act could also offer a blueprint for addressing the disconnect between urban planning and municipal service delivery in other major cities in Bangladesh. Risk informed planning should be an integral part of the revised TIA.
- **Reform RAJUK by clarifying planning functions and moving its monitoring and development functions to city corporations.** RAJUK presently plays the triple role of planner, developer, and regulator—a built-in conflict of interest. Moreover, planning and city management functions are divorced. Planning is done by RAJUK, while municipal services are provided by DNCC and DSCC. To address this disconnect, it is recommended that RAJUK be mainly responsible for overall Structural Planning and zoning. The city corporations will be responsible for more detailed planning, zoning and enforcement within their areas of jurisdiction. Moreover, development and monitoring functions should be moved out of RAJUK and undertaken by the municipal corporations. Private entities can also be engaged in provision of housing. RAJUK's main mandate would be to undertake comprehensive risk informed planning for Greater Dhaka in an integrated way, in coordination with the city corporations, *upazilas*, and communities. The realigned RAJUK should prepare a zoning policy for the Greater Dhaka area which currently does not exist. It would also be responsible for coordinating with the existing (and future) city corporations to ensure that all zoning laws prepared by the city corporations are consistent with the overall plan for Greater Dhaka. RAJUK should become a hub of public information on land use and spatial plans, including databases, risk maps and maps of water bodies for the entire Detailed Area Plan.

- **Establish an interministerial committee on Dhaka's rivers, urban wetlands, waterways, and drainage.** One of the main challenges in land and flood management in Greater Dhaka is maintaining the urban wetlands, water bodies, *khals*, and drainage facilities within Dhaka, as well as the river system surrounding the city. To address this issue, an interministerial committee on rivers, urban wetlands, and waterways is recommended. The committee would provide oversight on the activities of relevant agencies. The BWDB would continue to be responsible for river dredging and DWASA for maintenance of canals and storm water drainage. The city corporations would be responsible for main-

taining urban water bodies (notably lakes) through issuance of land-use plans and zoning ordinances. This committee would report to the prime minister's office and work closely with RAJUK and the city corporations. It would comprise representatives of BWDB; the city corporations; the Ministry of Housing and Public Works; MLGRDC; the Ministry of Water Resources; DWASA; the Department of Environment, and Upazila Parishads. It would meet on a quarterly basis and be responsible for ensuring that high priority and oversight be placed on the management of the urban river system, wetlands, and ecology, in support of sustainable urbanization.

TABLE ES.1 SUMMARY OF KEY REFORMS AND INVESTMENTS

Policy and institutional reforms	Organizational strengthening	Enact Eco-Engineering measures in Greater Dhaka
<ul style="list-style-type: none"> • Bring DMA (including DND area) fully under municipal management • Revise outdated Town Improvement Act (1953); Resolve RAJUK's Development and Regulatory functions through policy reform • Clarify planning functions of RAJUK and City Corporations with the former responsible for broader structural planning and the City Corporations responsible for more detailed planning, control and zoning • Prepare zoning policy, laws and regulations • Clarify City Corporations' mandate for oversight of urban water bodies and waterways • With new Structure Plan, prepare updated DAP without time lag, to accompany new Structure including zoning policies, regulations, and integrated flood risk management plan for DAP area • Consolidate drainage under DWASA 	<ul style="list-style-type: none"> • Establish inter-ministerial steering committee on wetlands and rivers • Substantially improve planning capacity in City Corporations • Strengthen DNCC and DSCC capacity for monitoring and enforcement of development activities • Strengthen RAJUK's monitoring capacity 	<ul style="list-style-type: none"> • Revitalize <i>khals</i>, lakes, and water bodies • Dredge surrounding river system regularly (BWDB) to improve connectivity of urban wetlands and river system across DAP area • Strengthen early warning systems and flood management information systems • Modernize/improve design of flood infrastructure • Extend drainage to entire DMA • Improve solid waste management • Undertake targeted eco-engineering investments (for example, maintenance of buffer zone) in designing new infrastructure with ecosystems functions

Source: Authors' compilation.

- **Bring the DND area and Dhaka East under municipal management.** Until May 2016, Dhaka East and DND area were not under the jurisdiction of any municipal agency and were urbanizing haphazardly. Instead of an ad hoc approach to urbanization, East Dhaka and the DND area should be brought fully under municipal control to ensure systematic management of land, resources, and services.
- **Consolidate drainage under DWASA.** At present, the Dhaka Water Supply and Sewerage Authority (DWASA) provides drainage services to 38 percent of the DMA. This should be expanded to the entire DMA at a minimum and eventually to all of Greater Dhaka—that is, to the entire area covered by RAJUK’s Detailed Area Plan. A basic drainage network should be in place as land is being prepared and serviced for housing construction. Responsibility for the construction and maintenance of drainage should be consolidated under DWASA, which has much more experience providing the services.
- **Task the city corporations with management and oversight of urban lakes, wetlands, and water bodies.** At present, no agency is clearly responsible for ownership, management, and maintenance of urban wetlands and waterways. This responsibility should be clearly assigned to the city corporations. Since the mayors are elected officials, it will enable greater commitment to this vital urban resource.

RECOMMENDATIONS FOR ORGANIZATIONAL REFORMS

- **Strengthen the human resource and planning capacity of the city corporations.** The capacity of the planning departments of the DNCC and DSCC should be strengthened. The city corporations should be responsible for preparing—and able to prepare—detailed land-use plans and zoning ordinances consistent with Greater Dhaka plans. To support this, staff capacity and resources allocated to the planning departments should be strengthened. The two departments should work in close collaboration in the interest of consistency. This approach would allow the city corporations to have more discretion over planning and land use within their areas of jurisdiction. Monitoring of land development, oversight of water bodies, and monitoring of filling functions should also be placed under the city corporations, as they are best placed to monitor activities within their jurisdiction. Because mayors are elected officials, this option would introduce a significant measure of accountability into the planning and zoning system. Staff capacity for monitoring land use and water bodies in their areas of jurisdiction should also be enhanced.
- **Prepare new Detailed Area Plan informed by risk mapping, based on a participatory process and accompanied by zoning policies and regulations.** RAJUK has prepared a Structure Plan, a draft of which is available. A new Detailed Area Plan (to succeed the earlier one) is apparently under preparation. Given past problems in implementation, and the time lag between the preparation of the Structure Plan and the past Detailed Area Plan, this process should be expedited. Further, the new Detailed Area Plan should be prepared for the entire area to be covered, and with public consultation and input. Risk mapping should be embedded and an integral part of urban planning. Moreover, the new plan should be accompanied by clear zoning policies and regulations.
- **Demarcate areas into zones and prepare local area plans and zoning regulations.** The entire area covered by the Detailed Area Plan should be divided into zones and the city corporations should prepare local area plans and zoning laws/ordinances for each zone based on a participatory process in accordance with the updated plan. In the past, even though the Detailed Area Plan was gazetted, RAJUK or the city corporations did not prepare a zoning policy or regulations. Without



these, it was extremely challenging to implement or enforce the plan and manage densification, housing development, or urban growth. Going forward, this will be essential.

- **Enhance investments in early warning systems and develop systems that are tailored to the hazards facing specific areas of Dhaka.** Different areas of Dhaka face different types of hydro-meteorological hazards—Dhaka East and the fringe area are mainly exposed to river floods and rainfall; DND and Dhaka West are mainly vulnerable to rain-induced waterlogging. These require tailored early warning systems. The capacity of the Bangladesh Meteorology Department (BMD) to provide short duration rain alerts and early warnings should be strengthened through improving rainfall monitoring and radar systems.⁷ This will particularly support users such as BWDB and DWASA and residents of the Dhaka West and DND areas. Further, BWDB’s Hydrology Unit should set up a Flood Risk Information System for developers and the public.⁸ Flood risk maps can support preparation of flood zoning regulations for the entire area and help identify areas more or less prone to flooding. These flood maps should be made available to the public and to planning agencies in Dhaka to inform planning and zoning. The Hydrology Division of BWDB should strengthen its capacity for location specific forecasts for Dhaka, specifically Dhaka East, including impact-based forecasting. These measures would greatly help to manage flood risk in Dhaka.⁹
- **Allocate sufficient funding to maintenance.** Extensive investments in infrastructure require proportionate

long term but routine investments in maintenance. While it was difficult to determine the amounts allocated for maintenance by BWDB and the city corporations, it was evident that given the state of the river system in urban waterways, the investments in maintenance are not sufficient. This needs to be enhanced.

- **Strengthen engagement and partnership with private developers.** At present, private developers are openly filling up land and developing low-lying areas. There is no mechanism between public and private sector agencies and developers to address the problems of urbanization, including flooding. Such a mechanism needs to be developed.

RECOMMENDATIONS FOR INTEGRATED FLOOD RISK MANAGEMENT WITH PRIORITY ACTIONS

In many of the world’s cities, flood risk mitigation has mainly relied on infrastructure-based solutions. However, there is a growing realization that while these are needed in many instances, they are not necessarily the optimal solution and may increase flood risk.¹⁰ Eco-engineering complements and can in many cases replace costly infrastructure investments (appendix A). *Application of eco-engineering solutions in the context of Dhaka implies consideration of the overall connectivity of the hydrological system across the city’s urban catchment, ensuring the connectivity of the internal waterways with the surrounding river system, and balancing structural and nonstructural interventions.* The focus should be to revitalize the natural urban canals and water bodies, dredge the peripheral river system, expand the storm water drainage network, promote innovative infrastructure design, prioritize maintenance, and maintain links between the internal waterways and peripheral river system. *Application of eco-engineering approaches also implies that the institu-*

7. This is being underpinned by the World Bank-supported Weather and Climate Services Regional project.

8. For an example of such a system, see <http://fris.nc.gov/fris/Home.aspx?ST=NC>

9. A recently effective (May 2017) World Bank project is expected to support BMD’s and BWDB’s forecasting services for Dhaka.

10. <https://www.gfdr.org/sites/default/files/publication/role-of-flood-risk-management.pdf>.

tional and organizational reforms proposed above would need to be undertaken to ensure the success of these measures. Within this broader framework, specific measures could be supported in major areas of Greater Dhaka, as described below.

Dhaka West. The western part of the DMA has developed as an unplanned urban area since the 1960s. Flood infrastructure has depreciated over time and illegal encroachment of natural canals and wetlands has exacerbated flooding problems. Recommended measures include (i) revitalizing silted up or encroached *khals*, and reclaiming and revitalizing lakes (Dhanmondi, Banani, and Uttara); (ii) ensuring that agencies maintain the connectivity of the storm water drainage network and the natural canal and river systems with a strong commitment to maintenance and a very strong monitoring mechanism in place; (iii) introducing eco-engineering options to protect the *khals*, deter encroachment, and raise the recreational value of public spaces. Options include building perforated sidewalks and 2–3 meter green strips on both sides of the canals; (iv) dredging peripheral rivers to maintain their conveying capacity, environmental flow rates, and connectivity with *khals*; (v) creating multiuse buffer zones to protect rivers and facilitate the smooth passage of flood flows; (vi) expanding storm water drainage with regular maintenance, to cover all of Dhaka West, including regular cleaning of all box culverts; (vii) preserving water retention areas for pumping stations and converting them into permanent wetlands, which can act as eco-touristic public spaces and attenuate flood peaks; (viii) improving solid waste management systems to include ecological options such as conversion into green fertilizer; and (ix) improving infrastructure design (for example, of sluice gates and their placement).

Dhaka East. At present, the eastern part of the DMA is not yet protected against river flooding, nor does it have a storm water drainage system. In the absence of any municipal organization to provide services to this area, limited land-use zoning, and limited oversight by RAJUK,

the area is being used for haphazard landfilling and urbanization. Recommended measures include (i) revitalizing and protecting natural *khals*, which are degraded and should be reexcavated on a priority basis; (ii) protecting canals and rivers through eco-engineering measures such as protective green strips bordering canals, as buffer zones for rivers with low embankments to store flood water to a certain limit during monsoon season and to prevent encroachment; (iii) developing the floodplain inside the embankment for multiuse purposes (eco-touristic public spaces, water retention during flood peaks); (iv) dredging peripheral rivers to allow interconnectivity and smooth discharges; (v) promoting eco-tourism by protecting wetlands; (vi) deploying innovative eco-engineering measures such as planted drainage channels, plaza planters, rainwater harvesting, permeable paving, and so on; and (vii) integrating the installation of a storm water drainage network with overall spatial planning and connecting it with natural *khals*, with regular maintenance of such a network. Any consideration of the eastern bypass should be preceded by institutional and organizational reforms and reforms related to planning and zoning discussed above.

DND Area. The low-lying DND area lies in the flood plain of the Meghna River. Most of the former agricultural lands have become unplanned residential and industrial areas, disrupting the natural runoff to the canals. The DND area is encircled by embankments and floodwalls with roads topping the embankments. Drainage canals built by BWDB to carry water toward the pumping station are badly dilapidated and clogged owing to unauthorized encroachment and solid waste. About 87 percent of the area becomes affected by waterlogging and inundation with a depth of 1–3 meters during moderate storms, making it the area most at risk to inundation under climate change. Recommended measures include (i) re-excavating and maintaining major drainage canals, as well as other primary and secondary drainage canals and protecting them against encroachment; (ii) building green strips and fencing on both sides of the canals to infiltrate water



into the ground, prevent erosion, dissipate wave energy, and discourage encroachment and use for recreational purposes; (iii) practicing land-use zoning and enforcement, particularly in non-built-up areas to ensure that any future development of these areas would be subject to risk zoning and enforcement; (iv) ensuring preservation of a minimum wetland area, with at least 20 percent of the area declared as permanent wetland for water-retention purposes (and emphasized in the draft structural plan); (v) establishing a storm water drainage network for the area to be maintained by DWASA; (vi) increasing pumping capacity and locations of stations; (vii) maintaining the existing embankment (31 kilometers of embankment topped by a road)—to be done by BWDB; (viii) improving the design of existing infrastructure (hydraulic structures to be remodeled and renovated using an eco-engineering approach, regulators and sluices to be automated, and so on); and (ix) creating buffer zones on the Lakhya River to increase carrying capacity and discourage encroachment of the riverbank.

Outer Fringes of Greater Dhaka. This area extends over 1,130 square kilometers, to mostly suburbs and semi-developed areas but includes lowlands, rivers, floodplains, and agricultural lands. No storm water drainage network exists in this area. Flooding of the area is controlled by flows into the major rivers and their tributaries. The expansion of Dhaka poses an immense threat to the risk profile and ecology of this area. Recommended measures include (i) dredging peripheral rivers regularly by BWDB; (ii) maintaining the existing canals and using eco-engineering concepts such as buffers and green strips; (iii) protecting the area's wetlands; and (iv) developing integrated drainage management investments to enhance water retention and improve drainage for the future expanded Dhaka, thus reducing drainage congestion. It would also expand ecosystem services in the area (recreational, cultural), encourage eco-tourism, and beautify the city.

In conclusion, the experience of other cities, such as Singapore, that decades ago faced a situation similar to

Dhaka's, shows that transformative solutions are possible and can provide insight into improving livability and resilience in Dhaka, which lies at the cusp of such a transformation. ■



1 · Introduction



Dhaka is the cultural, political, and financial center of Bangladesh. It is also one of the largest and most densely populated cities in South Asia, with a population of approximately 17.5 million people in 2015 and growing at the rate of almost 3 percent per year.¹¹ Situated in the lower reaches of the Ganges delta, the Dhaka Metropolitan Area (DMA) is surrounded by Turag to the west, Tongi Khal to the north, Balu-Shitalakhya to the east, and Buriganga to the south. In addition, the city is drained by numerous natural waterways and canals. Dhaka is low lying, with its elevation varying from 0.8 to 14 meters above mean sea level.

Owing to its location, topography, climate, and proximity to rivers, Dhaka is highly prone to water-related hazards such as urban and river flooding. During the 1998 floods, most of eastern Dhaka and some parts of western Dhaka were flooded due to spillover from surrounding rivers, with inundation lasting for almost 65 days. Waterlogging compromises the sewerage system, degrades drinking water, disrupts traffic, and increases the incidence of water-borne diseases.

Dhaka is also among the most climate-vulnerable megacities in the world.¹² Climate variability and change are expected to intensify the city's exposure to increased heat waves, intense rainfall, and heighten the extent and duration of urban flooding and inundation. The high economic losses caused by floods include direct losses (for example, damage to infrastructure, property and assets) and indirect losses (such as impact on incomes and livelihoods). While city-level damage cost estimates for extreme flood events are scarce, one estimate for the 1998 floods (covering damages to residential and institutional buildings, shelter units, losses to industry and enterprises, as well

as to urban services) is approximately \$171 million.^{13 14} With rapid and unplanned urbanization, the vulnerability of the city and particularly of its poorest residents is likely to increase unless measures to ensure resilience are put in place.

At present, Dhaka does not have an integrated long-term flood risk management plan or a wetland management plan. Urban expansion is increasing rapidly in low-lying flood flow zones outside the core city. One of the biggest challenges for city officials is how to develop new areas outside the urban center in a planned way. A large number of agencies are involved in urban planning and activities related to flood risk management, with often overlapping institutional mandates, contributing to inefficiencies in the delivery of public services. Historically, the main focus of flood management has been to use a range of infrastructural measures. While the emphasis on infrastructural interventions for flood risk management is not unique to Dhaka, international good practice suggests an integration of structural with nonstructural measures for managing flood risk (Jha, Bloch, and Lamond, 2012). However, in the case of Dhaka, it is unclear the extent to which the city is balancing these tools. Further, there is a growing awareness of more hybrid alternatives referred to variously as “green water defense” or “eco-engineering”

11. World Development Indicators (WDI) (World Bank 2015).

12. http://eprints.whiterose.ac.uk/74383/2/10.1007_s11069-012-0234-1.pdf; https://maplecroft.com/about/news/ccvi_2013.html.

13. Estimate is developed from data cited in Alam and Rabbani (2007). Costs used include damages to residential and institutional buildings (approximately \$51 million or BDT 4 billion and about \$5.1 million or BDT 400 million respectively), shelter units (about \$29 million or BDT 2.3 billion), large-scale industries (\$30 million), small and medium size industries (\$36 million), and urban services (water, sewerages, electricity, gas, and telephone—\$20 million). This is based on is a partial estimate and does not include health impacts and other costs, which would make the actual costs much more substantial. Exchange rate used—1 BDT = \$0.013 (Jan 2017).

14. National-level estimates are more easily available. For instance, the National Strategy for Accelerated Poverty Reduction (FY2009–11) notes that losses of income and assets due to flooding events were \$330 million in 1988, \$2 billion in 1998, \$2.2 billion in 2004, and \$1.06 billion in 2007.

approaches to flood and water management (appendix A) (World Bank 2012). Instead of relying primarily on infrastructural interventions such as construction of embankments, eco-engineering approaches combine structural and nonstructural interventions, making extensive use of eco-systems services to reduce flood hazard and strengthen resilience to climate risks. Ecosystems, as is well documented, play a crucial role in regulating hydrological and meteorological processes and thus shape the potential impact of floods and storms. Services provided by ecosystems can include managing surface and subsurface flow regimes, modifying wave dynamics in coastal areas, provision of barriers to flooding (for example, by natural terrain elevation, dunes), and reduction of waterlogging (through improved filtration and drainage, improved use of green space, conservation of wetland areas, and construction of multipurpose infrastructure that maximizes ecosystems services). Such an approach recognizes the multiscale nature of biophysical and human systems and considers flood risks and climate adaptation at multiple scales and through the interaction between different spatial levels. While use of eco-engineering or green defense approaches has been successfully tried elsewhere (for instance, in the Netherlands, the United States, and Japan), it is unclear how they could be implemented to address flood risks in a highly dense megacity such as Dhaka.

At present, Dhaka is at the crossroads for planning its future development pathway. The main planning agency, Rajdhani Unnayan Kartripakkha (RAJUK, or “capital development authority”), is in the process of preparing its Structure Plan and associated implementation plans for the greater Dhaka area. How these plans are designed and implemented will likely have a long-lasting impact not just on how urbanization unfolds over the next several decades, but also on how the city manages its resources, addresses rural-urban migration, provides job opportunities for people, and adapts to climate risks. Management of flood risks and resilience is a critical part of this story. It relates to how the city manages its land, urban ecology,

canals, waterways and rivers. It has to do with choices and decision making about infrastructure, groundwater management, and drainage. Most importantly, it has to do with the capability of institutions and leaders in addressing these issues. As the city embarks on its next phase of urbanization, it is critical to learn lessons from the past to plan for the future. While there is extensive literature on Dhaka’s urbanization, flood risk management, and urban poverty, few studies have assessed the drivers of decision making regarding flood management in the city historically, linkages between urban planning and flood risk management, or the political-economic and institutional constraints for improving flood risk in the city. Recent studies (Dasgupta et. al., 2015) have assessed the impact of climate change on future flooding and inundation and associated damage costs, but there is a dearth of research on how the city came to be in its current predicament, its current institutional and infrastructure challenges, and how to better link flood risk management as a key part of urban planning. This study aims to address this gap.

Objective

The main objective of this study is to propose recommendations for strengthening flood risk in Greater Dhaka. Building on existing literature, the study assesses the drivers of decision making about flood risk management in the city and its focus on infrastructural measures, and makes a case for balancing both infrastructural and non-infrastructural solutions for managing flood risk. Further, based on a detailed review of international experience with innovative eco-engineering approaches to flood risk mitigation (appendix A), the study suggests how these approaches might inform flood risk management in Dhaka. At present, RAJUK has prepared a draft structure plan for the next 20 years and is in the process of consulting and finalizing it. Findings from this study are also expected to inform implementation of the structure plan.





Approach

The study is based on extensive fieldwork, documentary research, and consultations with government and other stakeholders. It has the following main focus areas:

First, to provide necessary context, the study provides an analysis of flood risks facing Dhaka city. Using publicly accessible satellite imagery, geographic information system (GIS)-based mapping tools, and available satellite-based research, the study assesses spatial changes in urbanization and urban ecosystems that are shaping flood risk in the city.

Second, the history and sequence of flood management interventions in Dhaka are presented. The analysis shows how planning for flood management evolved historically; the drivers of decision making; the importance and limitations of the measures undertaken, both infrastructural and noninfrastructural; and how decisions regarding flood vulnerability have informed spatial planning and zoning. This analysis is critical for understanding the options available currently and designing a road map for the future.

Third, the study assesses the institutional and organizational capacity for urban planning and flood risk

management. This includes analysis of relevant plans and policies, mandates and capacity of key organizations such as RAJUK, Dhaka North City Corporation (DNCC), Dhaka South City Corporation (DSCC), the Bangladesh Water Development Board (BWDB), and the Dhaka Water Supply and Sewerage Authority (DWASA) in shaping flood resilience. The assessment does not include a broader organizational analysis of these agencies but is limited to shedding light on their roles in flood risk management in the city. Emphasis is on political economy aspects and institutional constraints that need to be addressed. Based on the above analysis, the study provides recommendations for strengthening flood resilience in Dhaka. This includes recommendations for institutional reforms, and structural and nonstructural measures that could be undertaken. In proposing these recommendations, an extensive review of international experience using green defense/eco-engineering approaches was undertaken. A brief version is included in appendix A.¹⁵

Process

The study was initiated at the request of the Government of Bangladesh, and has been prepared in close collaboration with RAJUK, Dhaka's North and South City Corporations, DWASA, and BWDB. Extensive fieldwork, data collection, and consultations with government and other stakeholders were undertaken as part of this study. Three consultation workshops were organized during the course of preparation—among them a workshop on international experiences with eco-engineering approaches to flood risk management and another to develop options for flood risk management. In May 2016, a stakeholder consultation was organized to discuss preliminary findings from the study chaired by the Mayor, DNCC. Participants in

these workshops included representatives of numerous national and municipal government agencies, ward-level officials, and development partners.

The study is fully aligned with the preparation of the Bangladesh Delta Plan 2100, a collaborative long-term planning initiative being undertaken by Bangladesh's Planning Commission and the Netherlands. It is also fully consistent with the Bangladesh Climate Change Strategy and Action Plan 2009, and the World Bank's Country Partnership Framework 2016–20 (World Bank 2016), both of which emphasize the need for efforts to increase the resilience of urban populations to natural disasters. At present, the World Bank is undertaking an analysis of options for engagement in eastern Dhaka and also developing a broader engagement platform for the Dhaka area. The study also contributes to these endeavors.

Organization of the report

The report is organized as follows. Following the introduction, chapter 2 provides an analysis of flood risks facing Dhaka city. Chapter 3 provides an historical analysis of flood management interventions and the sequence in which they occurred. The analysis reveals how decisions about flood vulnerability shaped urbanization and options available at present for addressing flood risk. Chapter 4 assesses the institutional and organizational capacity for urban planning and flood risk management. Chapter 5 presents recommendations for strengthening flood risk in the city. ■

15. A detailed review has also been prepared and is available upon request.



2 · Understanding Flood Risk in Greater Dhaka





To set the stage, it is important to understand the patterns of urbanization and land use in Dhaka, as well as the hydrological and physical characteristics that affect flood risks in the city. This chapter addresses these issues, examining factors contributing to flooding. The chapter also highlights areas that are more or less vulnerable to flood risk currently and over the long term. Many different terms have come to define Dhaka. How we use these terms in this report, is clarified in box 2.1 and further illustrated in figure 2.1.

Demographic changes

While largely rural, Bangladesh is rapidly urbanizing, with 34.3 percent of its population residing in urban areas (World Bank 2015). This is expected to rise to an estimated 55.7 percent by 2050 (UN Urbanization Prospects 2014). The single-largest urban area in the country, Dhaka, accounts for 32 percent of the country's population, and with an estimated growth rate of 3.4 percent (World Bank 2015). Dhaka alone contributes about 34 percent of the country's gross domestic product (GDP), indicating the economic importance of the city.

Since the 1950s, the population within the Dhaka Metropolitan Area (DMA) has steadily increased; it is one of the fastest-growing megacities in the world (TABLE 2.1). Between 2001 and 2015, its population rose from 10 million to 17.6 million and is expected to reach over 27 million by 2030 (Ahmed 2014; World Bank 2012; UN-Habitat 2010, UN Urbanization Prospects 2014).

There are about 3,394 slum areas with approximately 176,000 households in Dhaka North and South (BBS 2014). *The Human Development Report: Urbanization Challenges and Opportunities 2014*¹⁶ estimates that approximately 40 percent of Dhaka's population live in slums, and about 60 percent of city residents are prone to frequent flooding

16. Mahbub ul Haq Human Development Center 2014.

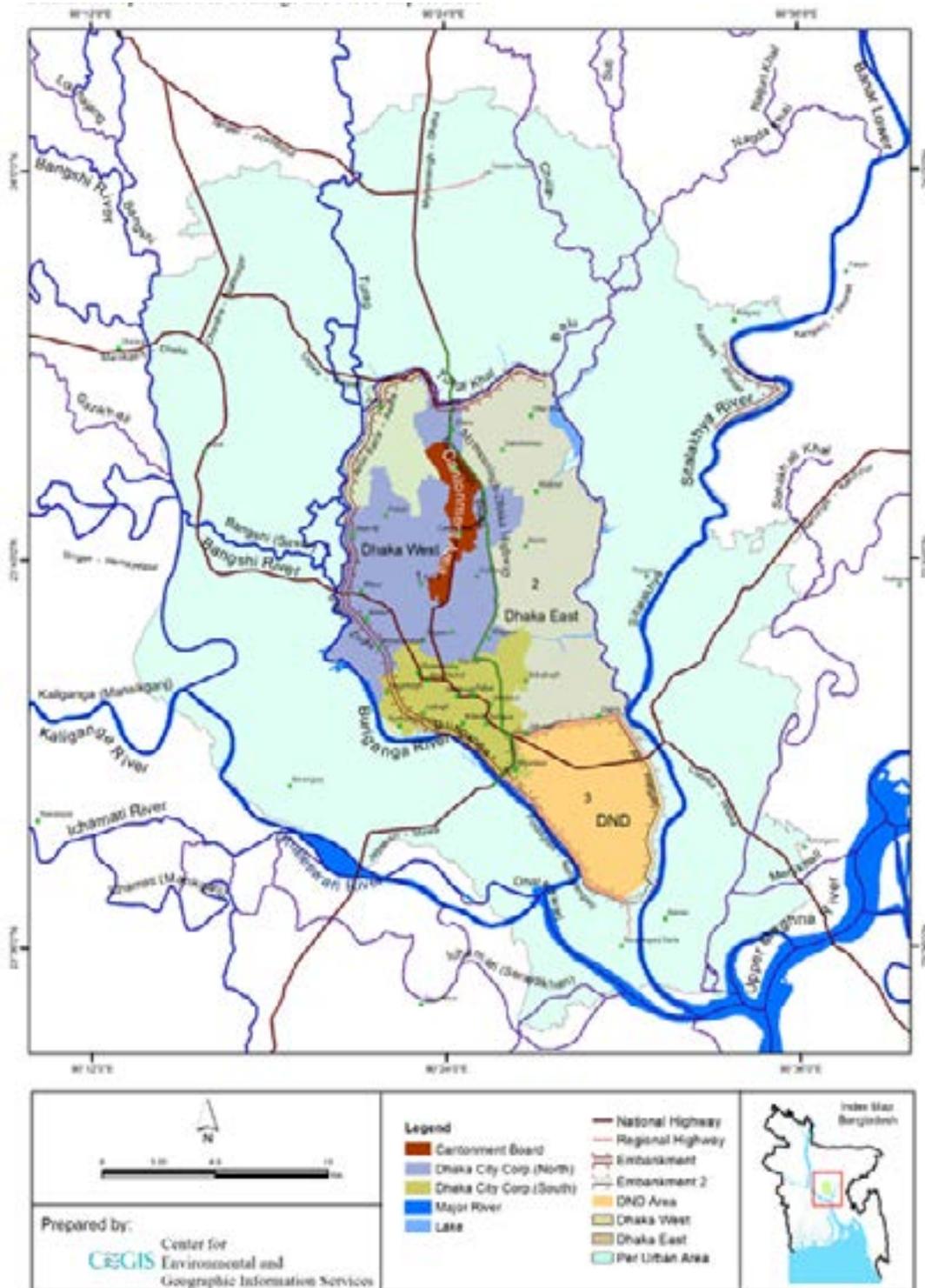
(UN-Habitat 2008/2009, cited in Alam [2014]). Between 1997 and 2014, slum populations increased by 60 percent (BBS 2014). The increase in the populations of slum settlements (bastees) can be traced to rural-urban migration and to the rising cost of housing in Dhaka. Migration for economic reasons is the biggest factor, however 8 percent of slum dwellers indicated river flooding and erosion, and natural disasters as their primary reasons for migration. According to some estimates, almost 34,000 people inhabit each square kilometer of the city, yielding a population density that is among the highest in the world (Dasgupta et al. 2015). Historically, urbanization has occurred from south to north, with the city expanding gradually from the banks of the Buriganga northwards and eastwards (FIGURE 2.2).

River systems

Bangladesh is located in a vast deltaic plain at the confluence of the Brahmaputra, Ganga, and Meghna basins and their tributaries. The country is divided into eight hydrological regions of varying natural features that reflect the geohydrological and morphological influence of their basins. The North Central region in which Greater Dhaka lies is defined by the Jamuna (Brahmaputra), Old Brahmaputra, Padma, and Meghna rivers. The river system is interconnected and interdependent, with the rivers being both a source of flooding from overbank spillage during periods of high discharge and a restriction on the outflow of drainage water to the Meghna River during dry periods.

A defining feature of the metropolis is the intricately woven network of rivers and canals that crisscross Greater Dhaka. This forms the ecological and hydrological backbone of the city and its natural drainage system. Dhaka is immediately surrounded by the Turag-Buriganga river system to the west, the Balu and Shitalakhya rivers to the east, and the Tongi khal (canal) to the north (FIGURE 2.3) and (TABLE 2.2). Because these waterways are distributaries of the Brahmaputra, water levels and rainfall runoff

FIGURE 2.1. GROWTH OF THE DHAKA METROPOLITAN AREA AND ENVIRONS



Source: Study team, based on RAJUK data.

Note: The blue-tinted areas are outside the Dhaka Metropolitan Area but still covered by the Detailed Area Plan.



BOX 2.1.

The Dhaka Metropolitan Area and Greater Dhaka

This report uses the term Dhaka Metropolitan Area (DMA) to refer to the inner 350 square kilometers (sq km) of the city. The term “Greater Dhaka” is used to refer to the broader area defined in Rajdhani Unnayan Kartripakkha’s (RAJUK’s) Dhaka Metropolitan Development Plan (DMDP) and Detailed Area Plan (DAP). Greater Dhaka includes the outer area of the city, which consists of a mixture of rural and urban landscapes interlaced with wetlands and rivers. It covers approximately 1,528 sq km. Specific areas of the city mentioned in the report are:

- Low-lying areas, referred to as Dhaka-Narayanganj-Demra (DND, approximately 57 sq km)
- Dhaka East (approximately 121 sq km)
- Dhaka West (approximately 143 sq km)
- Dhaka North City Corporation (DNCC)
- Dhaka South City Corporation (DSCC)

Dhaka East and Dhaka West are roughly divided by the Mymensingh–Dhaka Highway, which runs north to south. The DAP/DMDP area also includes the partial township areas of Narayanganj, Savar, Gazipur, and Tongi.

The boundaries of DNCC and DSCC are not fixed (they changed during the course of writing this report, with new wards coming under their oversight). As such, the demarcations and area coverage indicated here should be considered not as fixed boundaries but as close approximations.

Source: Study team.

TABLE 2.1. HISTORICAL POPULATION GROWTH IN DHAKA, 1608–2011

YEAR	Periods	Population	Area (square kilometers)
1608	Pre-Mughal	30,000	2
1700	Mughal	900,000	40
1800	British	200,000	4.5
1867	British	51,636	10
1872	British	69,212	20
1881	British	80,358	20
1891	British	83,358	20
1901	British	104,385	20
1931	British	161,922	20
1941	British	239,728	25
1951	Pakistan	411,279	85
1961	Pakistan	718,766	125
1974	Bangladesh	2,068,353	336
1981	Bangladesh	3,440,147	510
1991	Bangladesh	6,887,459	1,353
2001	Bangladesh	10,712,206	1,528
2011	Bangladesh	More than 14 million	1,528

Source: Taylor 1840; BBS 1977, 1997, 2001; and table drawn from Hossain (2008) and then adapted to add 2011 figures based on BBS (2012).

TABLE 2.2. CHARACTERISTICS OF THE RIVERS OF GREATER DHAKA

River	Length (Km)	Width (Meters)	Tidal effect	Slope	Embankment
Buriganga	29	302	Yes	1 cm/km	5.75 km (on left bank)
Turag	70	82	No	2 cm/km	12.5 km (left bank)
Tongi Khal	15	55		-	No
Balu	44	79	Yes	-	No
Shitalakhya	108	228	Yes	-	1.4 km

Source: CEGIS 2016.

TABLE 2.3. PEAK FLOOD LEVELS (m PWD) IN DHAKA'S RIVERS DURING FOUR FLOOD YEARS

Station	Peak flood level in major flood years			
	1988	1998	2004	2007
Tongi (Tongi Khal)	7.84	7.54	7.13	6.87
Mirpur (Turag River)	8.35	7.97	7.29	6.62
Mill Barak (Buriganga River)	7.58	7.24	6.68	6.01
Demra (Balu River)	7.09	6.97	6.98	6.27

Source: CEGIS estimate based on NWRD data.

in the broader basin also affect the drainage system in the city. The depressions, channels, wetlands, and other low-lying areas within Greater Dhaka serve as retaining basins for the overflow of rivers and storm water.

Over the past few decades, high population growth, unplanned urbanization, the encroachment of waterways and canals, dumping of untreated sewage and industrial effluents, and poor pollution control have worsened the conveyance capacity, navigability, and water quality of the river system. Many of the *khals*, lakes, and canals that had been connected with peripheral waterways have either been closed or disconnected through encroachment or other physical interventions. Other morphological and anthropogenic changes to the wider river system have also contributed to gradual sedimentation in the Buriganga, Turag, Balu, and Shitalakhya rivers, resulting in reduced conveyance capacity and limited flow during the dry season. As such, pollution of the river water has become a chronic ecological problem. Pollution, drainage congestion, and poor water quality now pose a serious threat to public health and local ecosystems. They also impose costs and enhance unsustainable use of ground-water.

High river stages usually occur in July, August, and September and are triggered by the monsoon rainfall in the upper catchments of the Ganges, Brahmaputra, and Meghna rivers.

Monsoonal rain and intense short-duration rainfall

Like the rest of Bangladesh, Dhaka receives more than 70 percent of its annual rainfall during the monsoon months that extend from June to September (FIGURE 2.4). Historical rainfall patterns in Dhaka (1961–2013) show that the highest rainfall (about 375 millimeters, mm) occurs in July (FIGURE 2.5). Dhaka is also exposed to precipitation in the pre- and post-monsoon seasons. Average annual rainfall in the city is about 2,050 mm, somewhat less than the country average of approximately 2,300 mm. But rainfall varies from year to year, and, as would be expected, higher rainfall increases the risk of flooding.

Although monthly rainfall averages provide some sense of urban flood risk, more important are heavy downpours of the sort that brought the city to a grinding halt in July 2009, when about 333 mm of rain fell over a 24-hour period—the highest in 53 years.¹⁷ Some 250 pumps had to be deployed to drain out the water. On September 13, 2004, 151 mm of rain fell, with 334 mm more on the following day, both deviating from the daily norm for the period 1961–1990 (FIGURE 2.5). The excessive rainfall was the major cause of flooding that month. Such short-duration rainfalls contribute to waterlogging (or urban flooding), aggravated by the city's limited drainage capacity

17. <http://www.independent-bangladesh.com/environment-news/cloud-burst-breaks-53year-record.html>.

FIGURE 2.2. URBAN EXPANSION OF DHAKA, 1600–2002

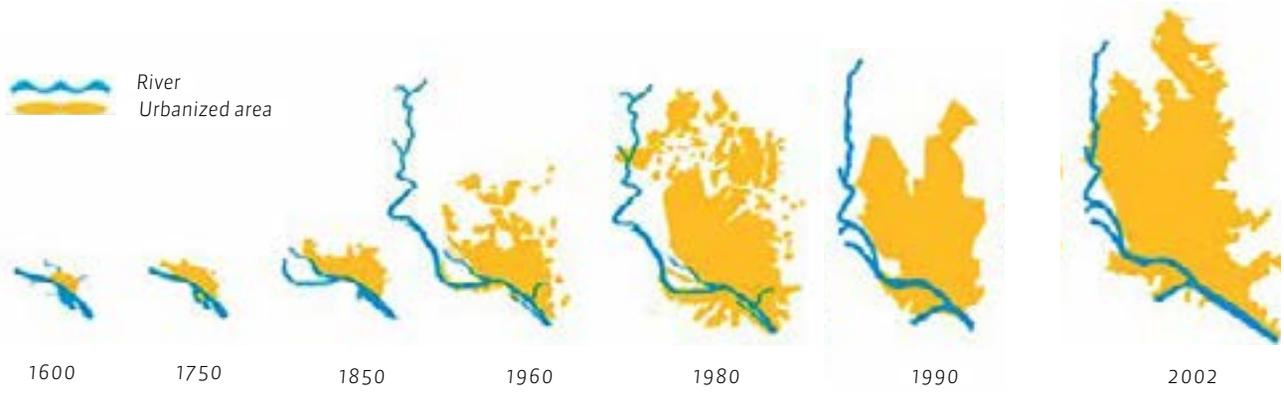
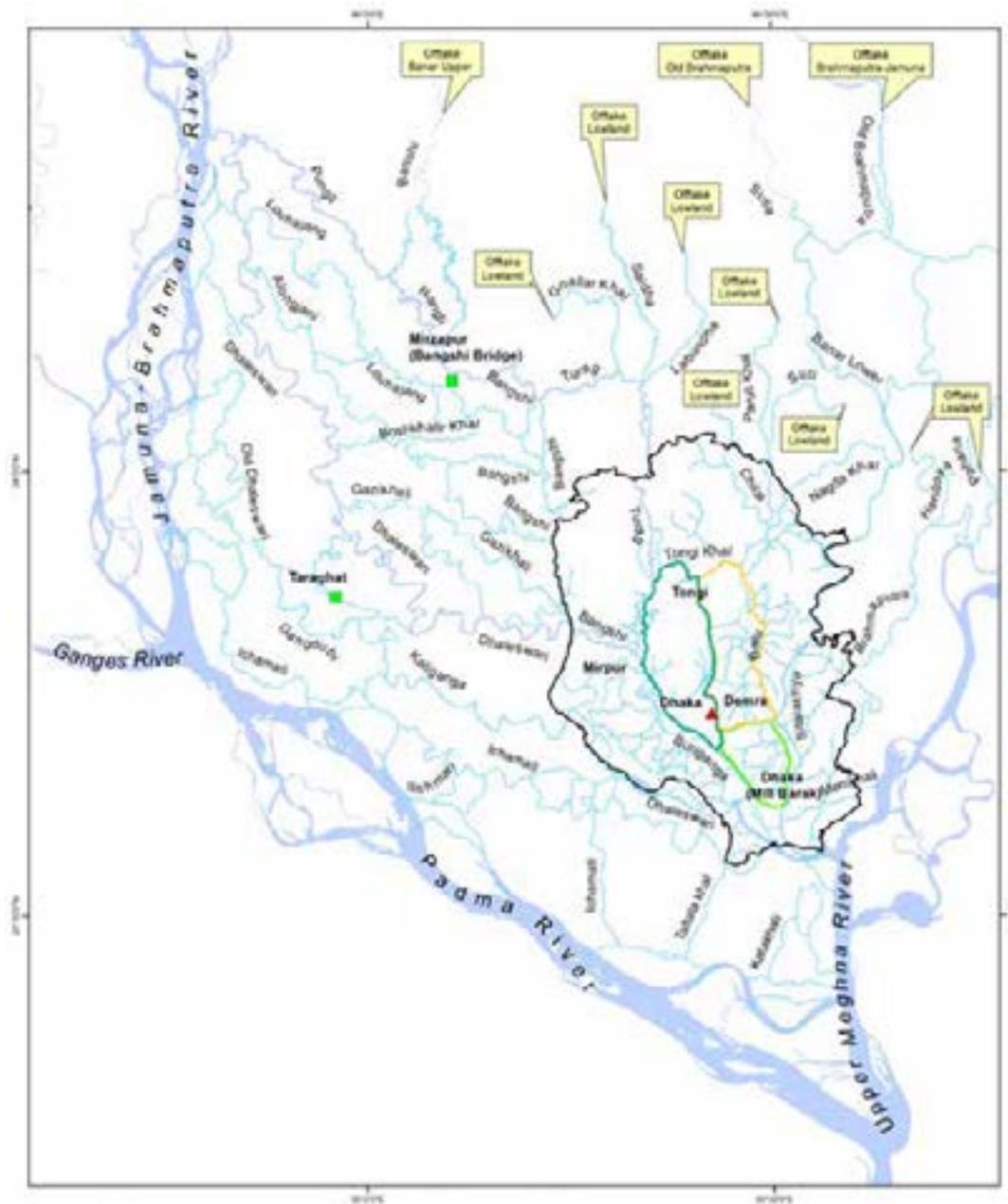
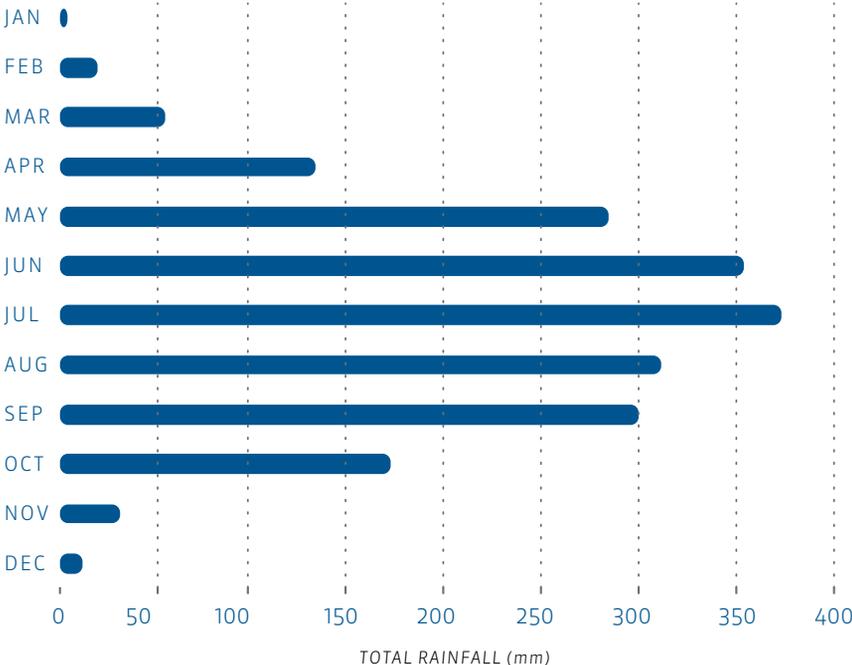


FIGURE 2.3. MAJOR RIVER SYSTEMS AROUND DHAKA



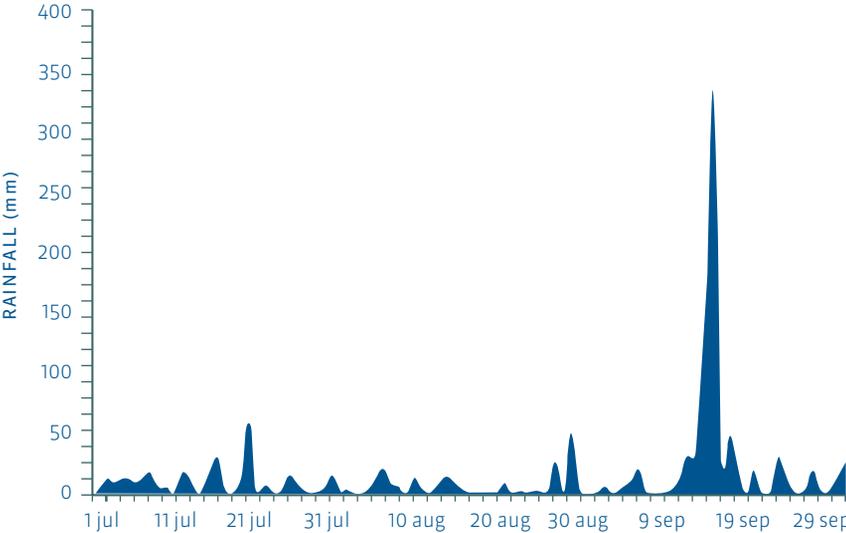
Source: Study team.

FIGURE 2.4. AVERAGE MONTHLY TOTAL RAINFALL IN DHAKA, 1961–2013



Source: Study team, based on BMD data.

FIGURE 2.5. TEMPORAL VARIATION OF RAINFALL DURING JULY–SEPTEMBER 2004 IN DHAKA



Source: Study team, based on BMD data.

(Dasgupta et al. 2015). High water in the surrounding river system can further obstruct and delay the discharge of rainwater. The coincidence of extreme local rainfall events and high river stages poses the greatest flood risk.

Major flood events and underlying factors

Dhaka has experienced major floods regularly including in 1954, 1955, 1962, 1966, 1974, 1987, 1988, 1998, 2004, and 2009. Historically, the key factors behind flooding are high water in the surrounding rivers and heavy rainfall during the monsoon season (Faisal, Kabir, and Nishat 1999). Among the most severe events were the 1988 and the 1998 floods. The 1988 floods stemmed chiefly from excessive transboundary inflow from the surrounding rivers. (Dhaka received less than average rainfall during these floods.) At that time, there was no flood protection embankment on the western side of Dhaka, and 85 percent of the area within Dhaka City was inundated (World Bank 2003). The 1988 floods peaked early and lasted for about three weeks, setting records for some of the highest water levels (TABLE 2.3).¹⁸

Unlike the 1988 floods, the 1998 flood resulted from very high rainfall in the entire catchment area (43 percent more rainfall in July and 67 percent more in August than the averages for those months), coinciding with spring tide in the bay. The 1998 flood lasted more than two months, the longest in the city's history. Most of eastern Dhaka was extensively flooded, and 20 percent of the western part of the city, which had already been embanked at the time, was also flooded, showing that despite flood embankment in the west, the flooding problem had not

disappeared entirely (Faisal, Kabir, and Nishat 1999; see also Hasnat 2006). In central Dhaka, approximately 66 kms of *khals* and 80 kms of storm water drains were impaired (Huq and Alam 2003; Dasgupta et al. 2015).

The 2004 flood event was another catastrophe for the city, affecting nearly 5 million people. The city received almost 315 mm of rainfall over a 24-hour period. Residents faced a severe shortage of drinking water, and the sewerage system failed across a wide area. While the duration of the 2004 floods was shorter than that of the 1988 and 1998 floods, it took longer for the water to drain out. Of the city's 22 *thanas*, 18 were inundated (Dasgupta et al. 2015). While the eastern part of the city was most affected, many parts of Dhaka West also endured waterlogging (FIGURE 2.6).

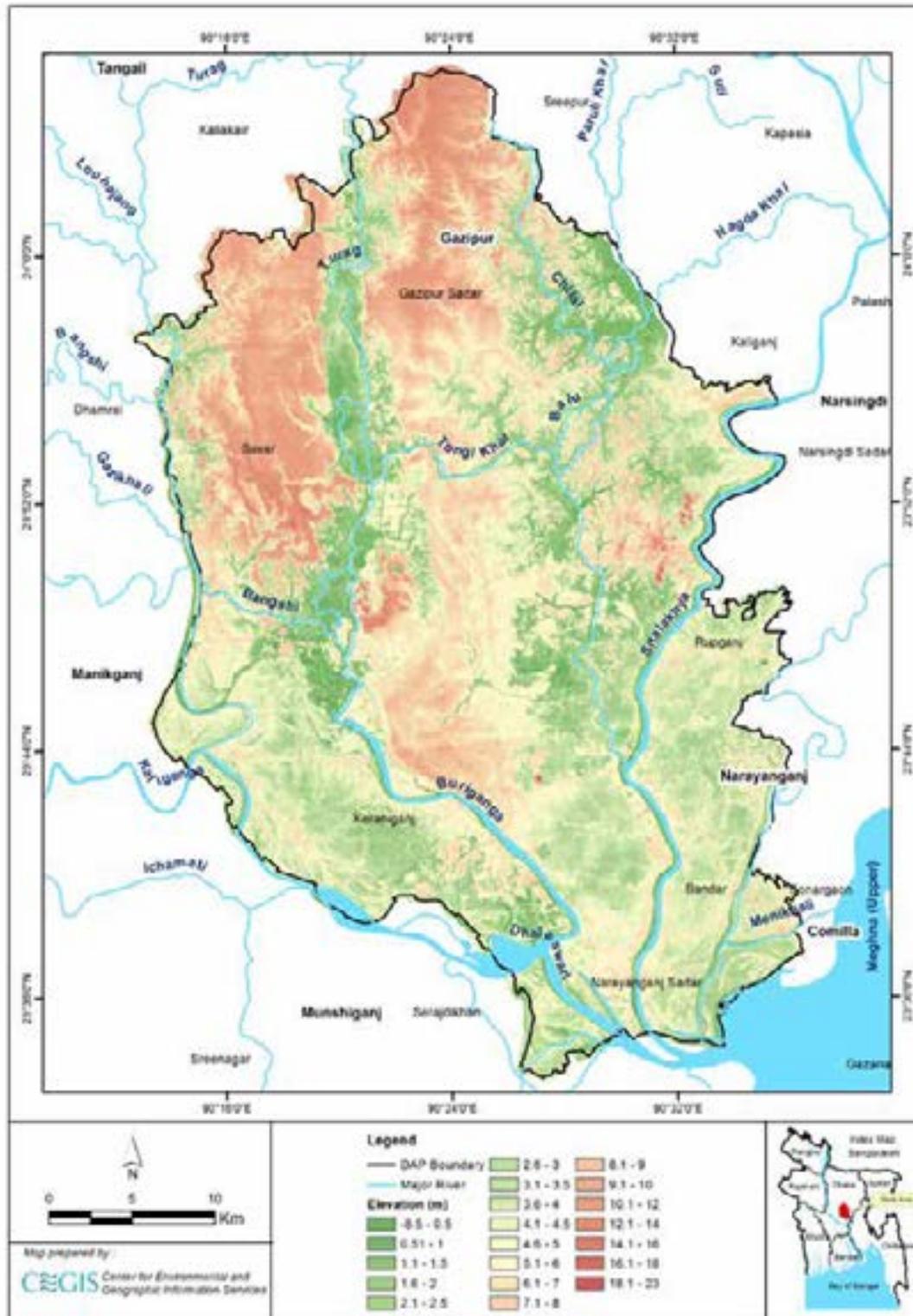
The 2009 flood resulted from an erratic rainfall pattern. Although the year's monsoons involved 20 percent less rainfall than normal (Flood report 2009), higher-than-normal rainfall on July 26–27 (76.57 mm and 324.75 mm) caused an unprecedented flood. Even though the water level of the surrounding five rivers was below the danger levels, excessive rainfall within a short duration, combined with an inadequate drainage system, caused the city's inundation (CEGIS 2009).

Topography, soil, and land use

Dhaka has an elevation of between 0.8 and 14 meters (Ahmed and Bramley 2015). Most of the built-up area, particularly Dhaka West, has an elevation of 6–8 meters (FIGURE 2.7). Agriculture is still a viable source of living in Greater Dhaka (FIGURE 2.8). Parts of Dhaka and surrounding areas are spread over the old Meghna estuarine floodplain (11 percent), Jamuna floodplains (22 percent), and the old Brahmaputra floodplain (8 percent). The rest (59 percent) lies on the terraces of the Madhupur Tract, which consist

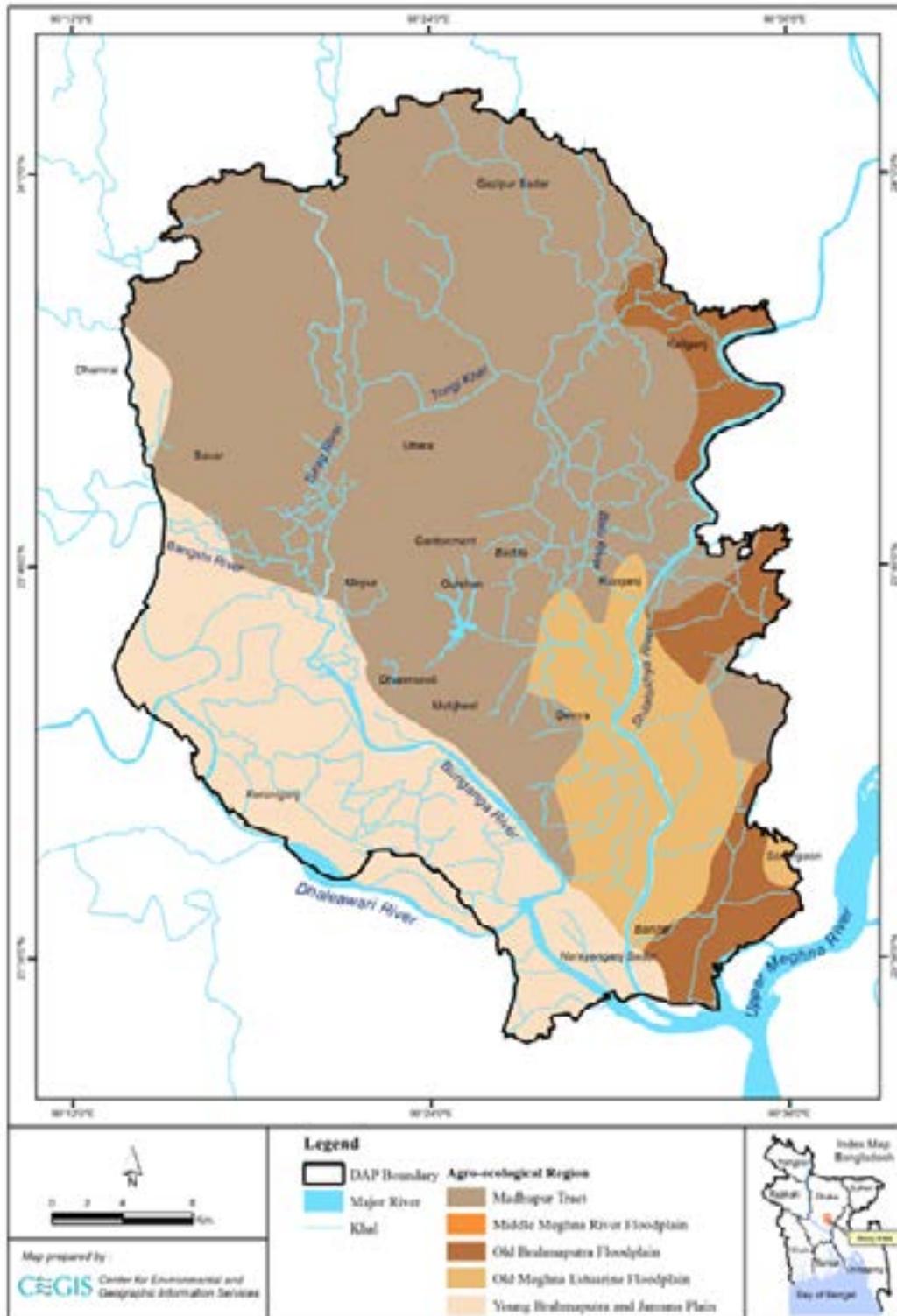
18. There are four metering stations in Greater Dhaka that have recorded water levels since 1981: (i) Dhaka (Mill Barak) station on the Buriganga, (ii) Demra station on the Balu, (iii) Mirpur station on the Turag, and (iv) Tongi station on the Tongi khal.

FIGURE 2.7. ELEVATION OF DHAKA AND SURROUNDING AREAS



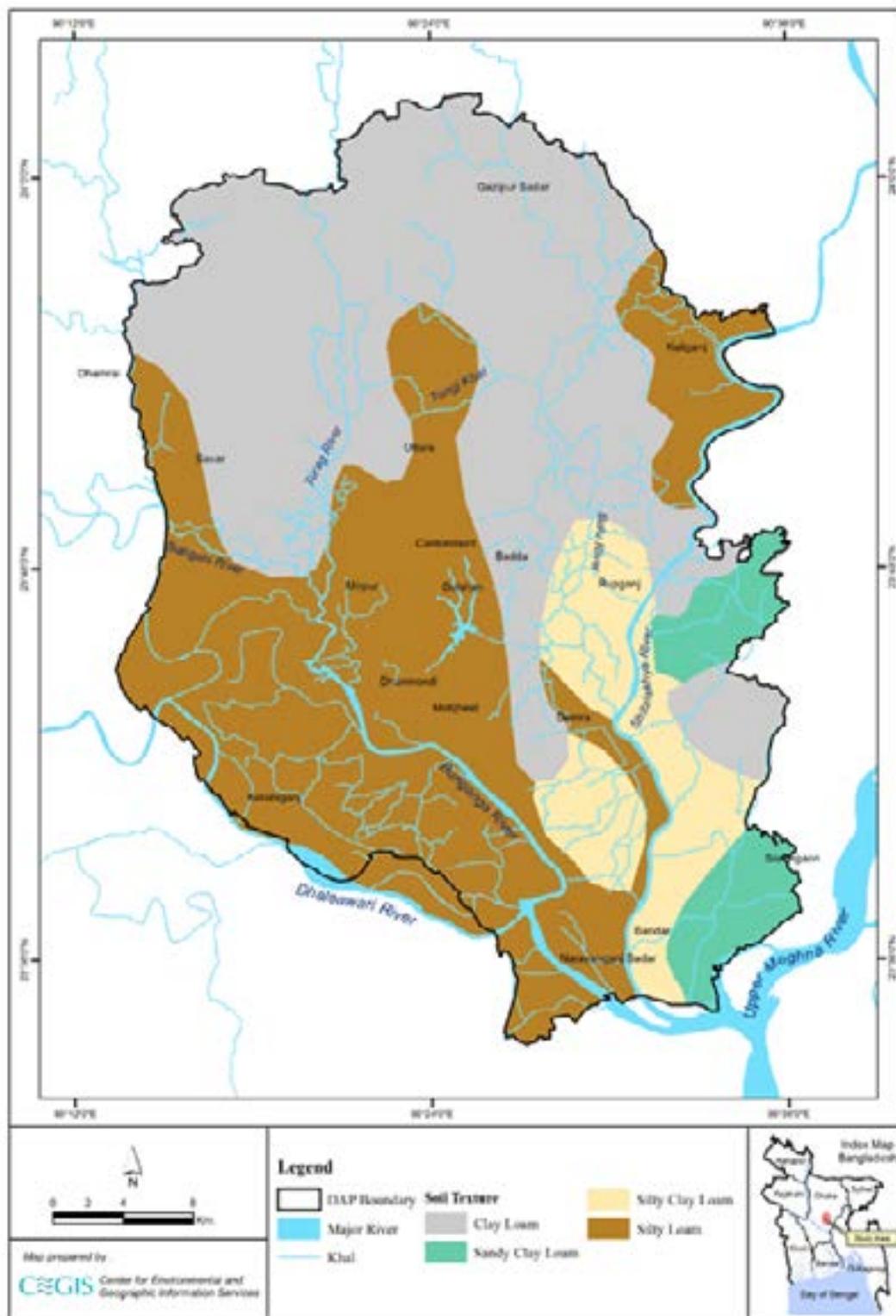
Source: CEGIS, based on data collected from Bangladesh Agriculture Research Council.

FIGURE 2.8. AGRO-ECOLOGICAL REGIONS IN GREATER DHAKA



Source: CEGIS, 2016 (based on data collected from Bangladesh Agriculture Research Council).

FIGURE 2.9. SOIL TEXTURE MAP OF GREATER DHAKA



Source: CEGIS, 2016 (based on data collected from Bangladesh Agriculture Research Council).

mainly of red clay soil mixed with silt (Hossain 2001). Within Greater Dhaka, four layers of soil are visible: clay loam (43.2 percent), silty loam (40.8 percent), silty clay loam (10.7 percent), and sandy clay loam (5.3 percent) (FIGURE 2.9). The metropolitan area has a mixture of mostly clay and silty soils. In the low-lying Dhaka-Narayanganj-Derma (DND) area, the soil is a combination of silty clay loam and silty loam, which can be characterized as largely impervious. The imperviousness of much of the Dhaka region's soil contributes to flood hazards. Most rainwater infiltrates unpaved areas when precipitation starts, but once the soil is saturated rainwater no longer sinks in but runs off and causes ponding in low-lying areas.

Land use is an important determinant of the patterns and pathways of flooding. It affects the infiltration capacity of the soil, the transitory storage capacity of wetlands and depressions, and the conveyance capacity of rivers and *khals*. Land development and urbanization shrink natural storage areas and aggravate the imperviousness of the soil, thus slowing storm runoff during flood peaks and making waterlogging a common phenomenon in the rainy season. Urban growth over the past decades has led to a considerable increase of impervious surfaces and a reduction of the natural drainage system (Dewan and Yamaguchi 2009; Sultana, Islam, and Islam 2009; Ahmed et al. 2012; Dewan 2013), aggravated by the city's aging drainage infrastructure (Dasgupta et al. 2015).

Analysis of Landsat satellite images shows a gradual reduction of natural water-retaining areas and an expansion of built-up area (CEGIS 2012). Between 1967 and 2010, settled areas of Greater Dhaka increased from 37 percent to 47 percent and were accompanied by a significant shrinkage of wetlands (FIGURE 2.10). With ongoing land-filling and development, the villages at the periphery of Greater Dhaka are slowly morphing into urban built-up areas, and many rural settlers are gradually leaving their home ground.

Other recent analysis based on Landsat images from 1960 to 2014 confirms that urban wetlands and water bodies that are a vital part of Dhaka's ecosystem have steadily declined (TABLE 2.4).¹⁹ While built-up area has increased, cultivated area, water bodies, and urban wetlands have all steadily diminished. The analysis shows that approximately 8,888 hectares of the urbanized area in Dhaka in 2000 had been cultivated areas, wet/lowlands, or water bodies (Uddin et al. 2014). Further, during 2000–14 and 1960–2014, 7,399 and 16,287 hectares, respectively, of the newly urbanized areas were developed by converting cultivated area, vegetation, water bodies, and wet/lowlands. In the DND area, where there has been substantial urbanization, there has also been a substantial decline in wetland and agricultural area (TABLE 2.5).

A significant number of natural channels and wetlands that help Dhaka cope with storm water have been filled in and restricted owing to accumulations of solid waste, particularly in slum areas where wastes are frequently thrown into nearby canals. Uncollected solid waste often clogs storm water drains and manholes, slowing the evacuation of rainwater from the affected areas and causing localized flooding. Greater Dhaka's *khals* have deteriorated owing to the dumping of solid waste, the encroachment of development, and poor maintenance. Currently, only 26 of 43 *khals* in the city are in a functional state.²⁰

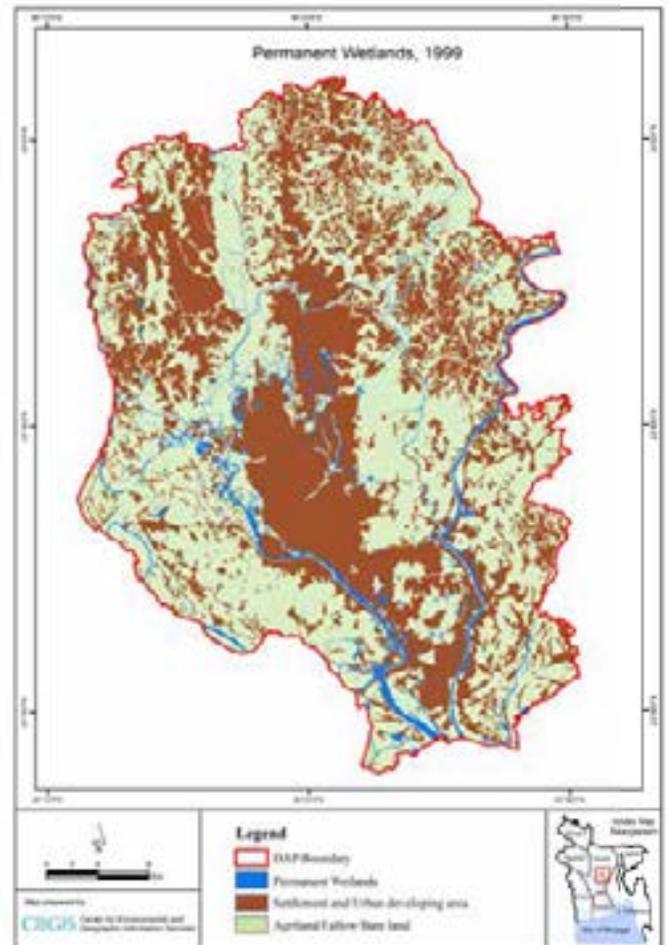
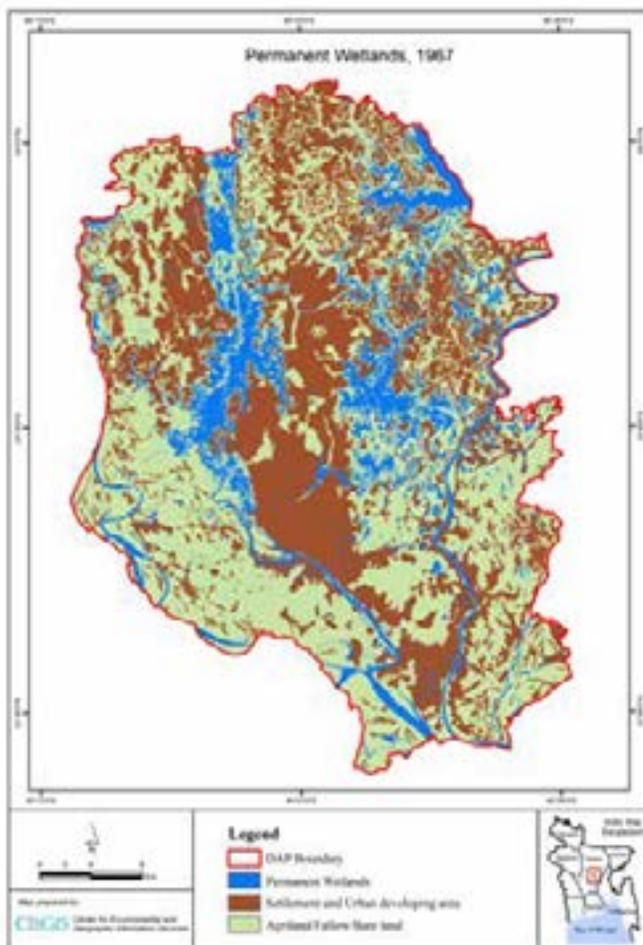
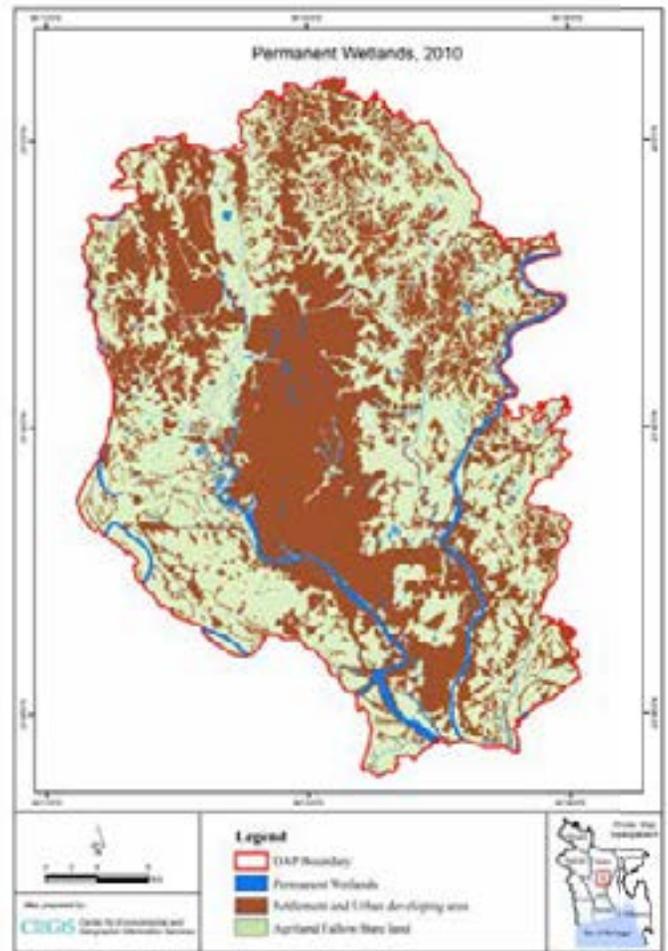
The decline of urban *khals* and wetlands has important implications beyond flood risk management. Since wetlands play an important role in carbon sequestration, their decline also has a bearing on mitigating the effects of climate change. Further, given Dhaka's vulnerability to seismic risks, the decline of wetlands and associated

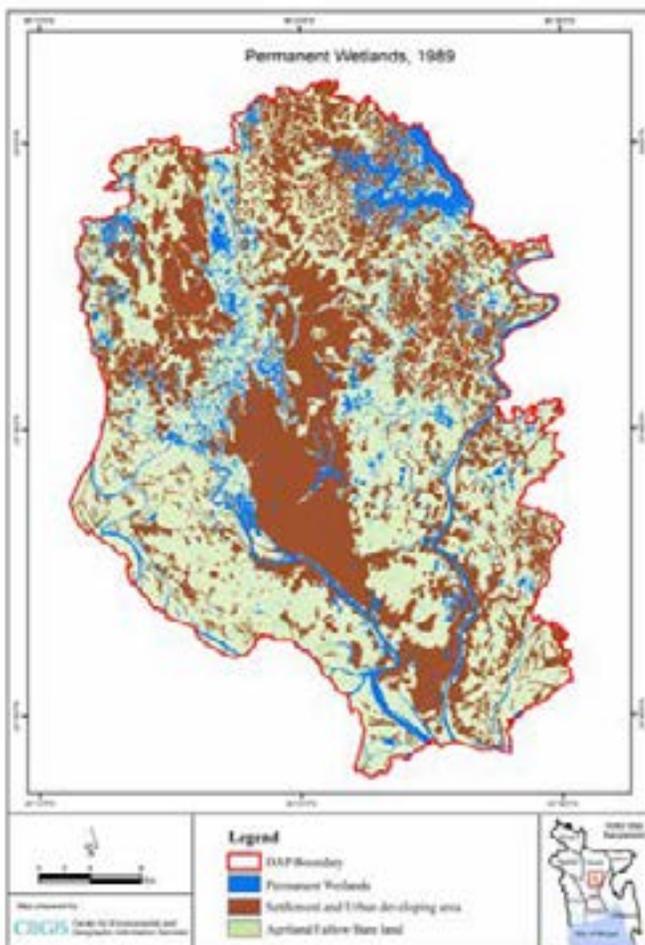
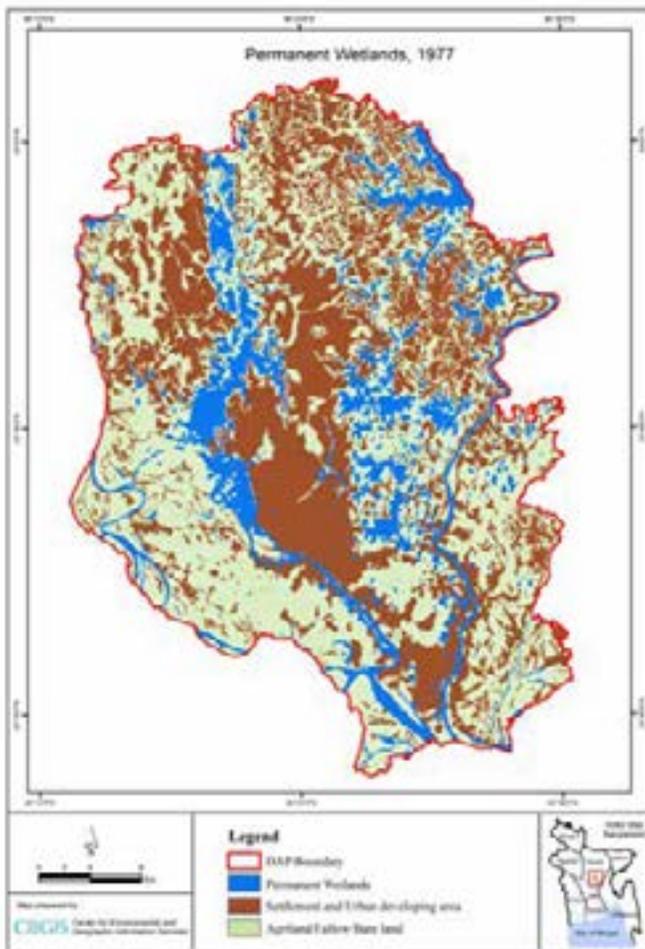
19. <http://www.banglajol.info/index.php/JESNR/article/view/22217>.

20. Poor waste management also impedes effective flood modeling in Dhaka because the presence of unpredictable impediments compromises the accuracy of the mathematical model used to compute drainage rates.

FIGURE 2.10. HISTORICAL CHANGES IN LAND USE FROM 1967 TO 2010, DERIVED FROM LANDSAT5 TM

Source: CEGIS 2012.





landfilling is alarming as the filled lands are highly prone to liquefaction²¹ effects (Mowla and Islam 2013).

Decline of groundwater levels in Dhaka

Most of Dhaka's drinking water comes from groundwater. Estimates vary from approximately 87 percent (Sumon and Abdul Kalam 2014) to about 78 percent (DWASA 2015a). Approximately 546 deep tube wells operate across the city. According to a study by the Groundwater Monitoring Survey Report of the Bangladesh Agricultural Development Corporation and Institute of Water Modeling, the groundwater level of Dhaka city is declining by about three meters each year. Between 1996 and 2009, groundwater levels of the deep aquifers regressed from about 27.6 meters to about 67 meters. Tube wells are drilled at increasingly deep levels, as 15 percent of existing tube wells become defunct each year (Sumon and Abdul Kalam 2014). In the dry season, the city faces serious water shortages. The decline of green spaces has also cut recharge capacity. Supporting measures such as the protection of green spaces and rain-water harvesting can help meet rising demand for water and slow the decline of groundwater resources.

Impact of climate vulnerability on flood hazards in Dhaka

According to the Intergovernmental Panel on Climate Change (IPCC AR5 2014), the frequency and intensity of extreme events is likely to increase with climate change.²²

21. Liquefaction refers to a process under which soil under certain conditions, such as earthquakes, exhibits the characteristics of liquids. Landfilling is understood as increasing Dhaka's exposure to seismic risk. Impacts include collapsing of buildings and infrastructure. See <http://lib.buet.ac.bd:8080/xmlui/bitstream/handle/123456789/463/Full%20%20Thesis.pdf?sequence=1>.

22. <http://ipcc-wg2.gov/AR5/images/uploads/WGIAR5-Inte>

TABLE 2.4. TRENDS IN LAND USE IN DHAKA, 1960–2014

LAND-USE CATEGORIES	1960 Area (ha)	2000 Area (ha)	1960–2000 Changed Area (ha)	% of Changed Area	2014 Area (ha)	2000–14 Changed Area (ha)	% of Changed Area	1960–2014 Changed Area (ha)	% of Changed Area
Built-up	7,742	16,630	8,888	114.80	24,029	7,399	44.49	16,287	210.37
Cultivated	13,404	10,395	-3009	-22.45	8,050	-2,345	-22.56	-5,354	-39.94
Vegetation	7,615	5,418	-2,197	-28.85	2,589	-2,829	-52.21	-5,026	-66.00
Water bodies	3,725	3,196	-529	-14.20	2,068	-1128	-35.29	-1,657	-44.48
Wet/lowlands	8,982	5,829	-3,153	-35.10	4,732	-1097	-18.82	-4,250	-47.32

Source: Uddin et. al. 2014.

Note: ha = hectares.

TABLE 2.5. CHANGES IN LAND USE IN LOW-LYING AREAS, 1967–2010 (HECTARES)

Year	Permanent wetlands	Settlement and urban development area	Agricultural land, vegetation, fallow, or bare land
1967	251	2,780	3,022
1977	541	2,772	2,741
1989	322	2,853	2,879
1999	232	3,904	1,918
2010	70	4,157	1,827

Source: CEGIS 2012.

Note: Data are for the Dhaka-Narayanganj-Derma (DND) area.

All models under all scenarios project an increase in mean and extreme precipitation within the South Asian monsoon system.²³ The frequency of extreme precipitation is on the rise, whereas mild rain events are decreasing.²⁴ In Asia, this is expected to contribute to increased riverine, coastal, and urban flooding, and widespread damage to infrastructure, livelihoods, and settlements. Using scenarios from the IPCC 4th assessment report (A1FI and B1²⁵), Dasgupta et al. (2015) reached similar findings. Their

analysis indicates that the Ganga, Meghna, and Brahmaputra basins are likely to experience erratic rainfall for the rest of the century due to climate change. Average monsoon flows are expected to increase 13.6 percent by 2050 under the high-emissions scenario (A1F1). The water level of the peripheral rivers around Dhaka is also expected to rise under this scenario compared with 2004 (FIGURE 2.11). Frequency analysis of rainfall data showed that the return period of intense rainfall events is decreasing (FIGURE 2.12), implying that, with climate change, extreme events are occurring more frequently than they did historically (Dasgupta et al. 2015: 213).

grationBrochure_FINAL.pdf ; <http://cdkn.org/wp-content/uploads/2014/04/CDKN-IPCC-Whats-in-it-for-South-Asia-AR5.pdf>.

23. http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-PARTB_FINAL.pdf.

24. Ibid.

25. A1FI: IPCC scenario with future based on fossil-fuel-intensive development; B1: IPCC scenario with future based on a high level of environmental and social consciousness

combined with a globally coherent approach to more sustainable development.

However, despite increased rainfall and higher river levels, the Dasgupta et al. (2015: 200) study suggests that the area of Greater Dhaka that is prone to flooding under future climate scenarios will shrink. The main reason is that the study assumes that land levels will continue to rise with ongoing landfilling and also suggests that this should be accelerated to manage future flooding.²⁶ With planned investments, the analysis shows that the city will be able to manage medium rainfall events (200–250 mm/day), but additional investments in drainage will be needed to manage events exceeding 300 mm/day. Despite this, some areas, the study suggests, such as the low-lying DND area, will be more vulnerable than they are now. For example, with a 16 percent increase in rainfall in 2050, flooding in the DND area would increase by about 12 percent, while other areas would experience no more than a 3 percent increase. (Dasgupta et al. 2015: 160). It is to be noted that during the flood of 2004, almost 17.5 percent of Dhaka West and 94.2 percent of Dhaka East were inundated. Interestingly, Dasgupta et. al. (2015: 200) found that by 2050, with planned and additional investments, including an increase in land levels from urbanization, flooding in both western and eastern Dhaka would decrease. The study makes various assumptions that should be pointed out. It assumes that Dhaka East will be embanked along the right bank of the Balu River, though it remains uncertain that this will actually occur. In assessing future flood impact, the study also assumes that improvements identified in RAJUK's Detailed Area Plan (DAP 2010–15) will be implemented (Dasgupta et al. 2015: 31). However, the DAP expired in 2015, was extended until December 2016, and a new one is being prepared that may have different implications for future flood risk.

26. This recommendation is questionable because, as indicated in chapter 4 of this report, landfilling is ongoing in Dhaka with little oversight, often without clearances and adherence to existing laws by both public and private sector entities.

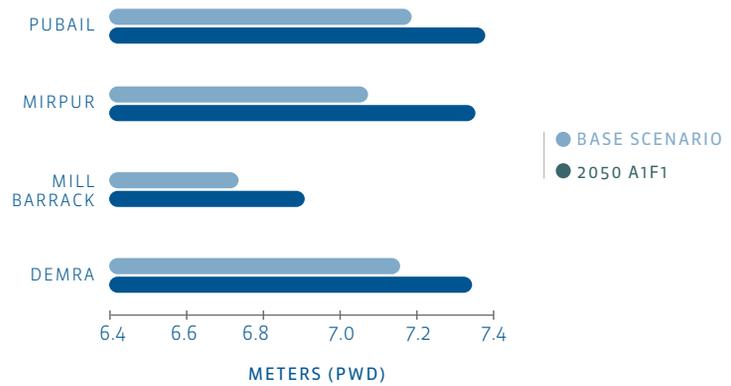
Flood vulnerability and poverty

With an estimated 300,000–400,000 people migrating to Dhaka each year from rural areas, and the conversion of agricultural and wetland areas, Dhaka has developed some 3,394 slum settlements, or *bastees* (RBS 2014). As previously noted, about 40 percent of the city's population resides in slum areas. More than 90 percent of the poor lack secure tenure of their homes, but a large percentage (approximately 80 percent) pay rent. FIGURE 2.13 shows the prevalence of slum areas within Greater Dhaka and the area prone to flooding based on 2004 floods. Some areas, such as Mohammadpur, Kamrangir Char, Rampura, and Khilgaon are among the worst affected owing to limited or poor drainage. Not all slum areas are prone to flood inundation due to moderate floods (such as, for instance, Korail, as it is located on relatively higher land). Floods in dense, poorly serviced settlements can breed water-borne diseases, such as diarrhea, cholera, dysentery, and typhoid—in addition to other hazards. During floods, water supplies are at risk of becoming contaminated, as poorly maintained pipes in slum areas are likely to be damaged or leak. Most of the people living in the DND area belong to lower-income groups and are vulnerable to waterlogging.

Overlaying slum areas and critical assets with flood vulnerable areas also indicates areas that could reasonably be targeted by efforts to reduce poverty, flood vulnerability, and provide urban services (SEE FIGURES 2.13 AND 2.14). FIGURE 2.13 shows that slums are located in areas that are prone to flooding and inundation but also in areas that are embanked and less exposed to riverine flooding. These latter slum areas face rainfall induced water logging resulting from the congested drainage system. The slums that fall within the flooded zone lie primarily in two locations. One is adjacent to the Balu river on the eastern side which is not embankment. The other is a pocket towards the north-western side which primarily falls within the Ashulia depression zone. These area experiences a combination of both riverine and rainfall induced flooding on

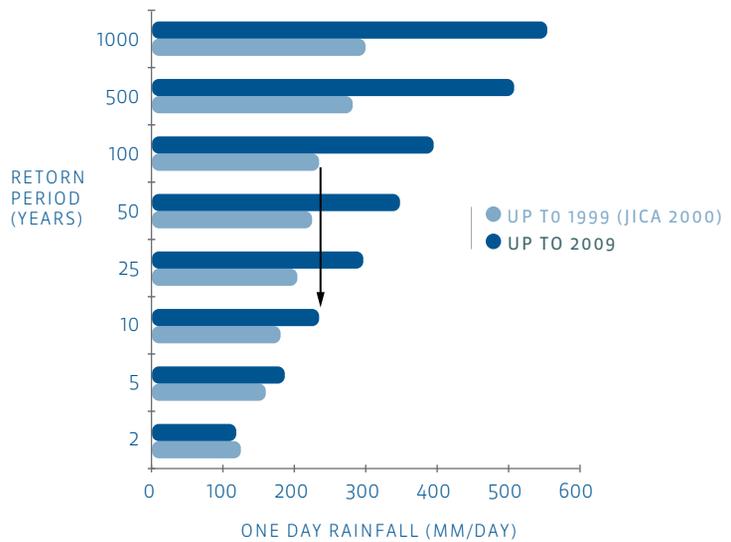
a regular basis. FIGURE 2.14 illustrates key assets (educational institutions, industries) exposed to flooding. It shows that even flood control structures are in a vulnerable state due to various anthropogenic factors such as unplanned settlements, limited solid waste collection that clog up both natural and constructed drainage during flood events.

FIGURE 2.11. FORECASTED CHANGES IN PEAK RIVER LEVELS AROUND DHAKA DUE TO CLIMATE CHANGE: TWO SCENARIOS



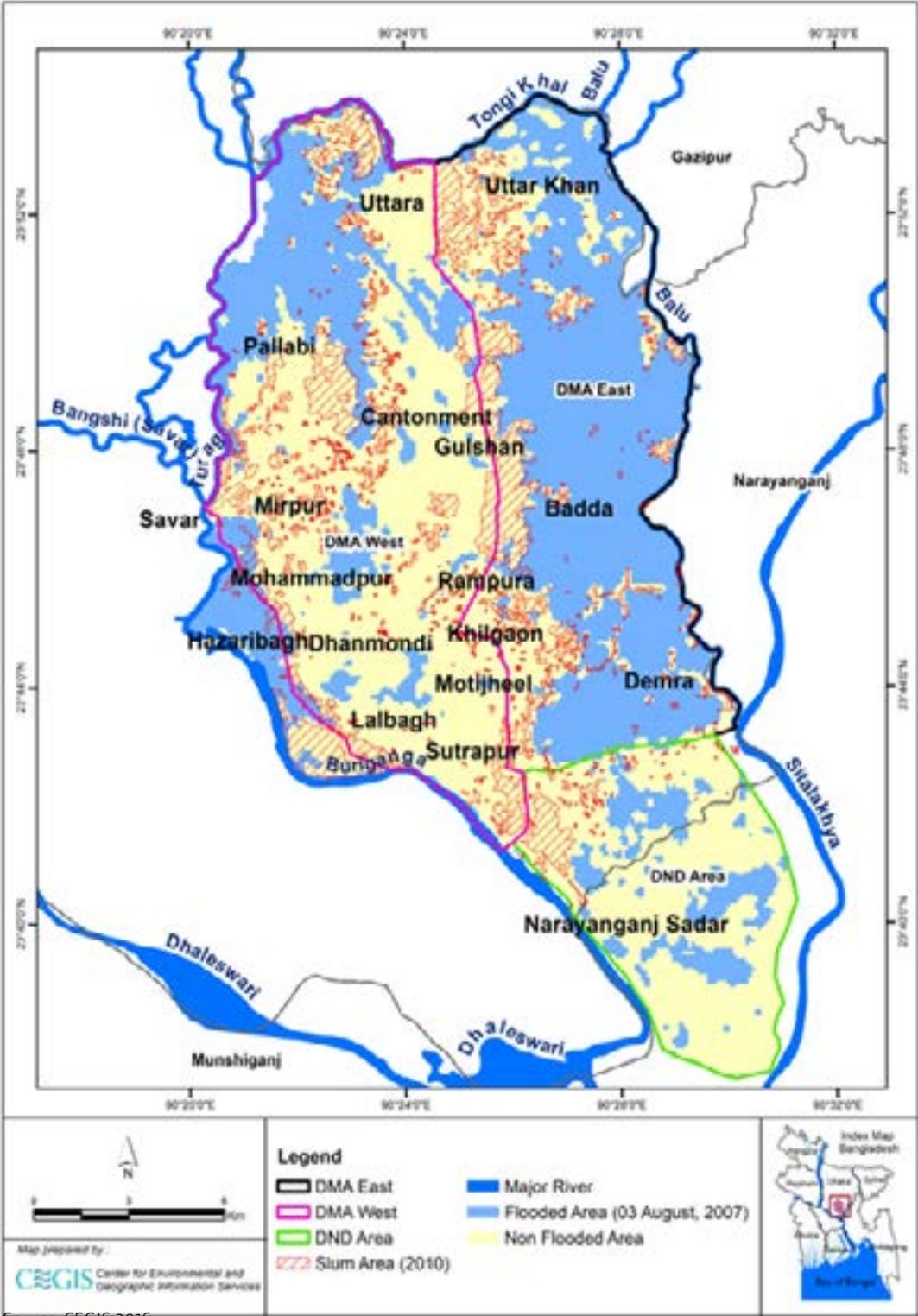
Source: Dasgupta et al. 2015.

FIGURE 2.12. CHANGES IN RETURN PERIODS OF DAILY RAINFALL EVENTS AT BWDB DHAKA STATION



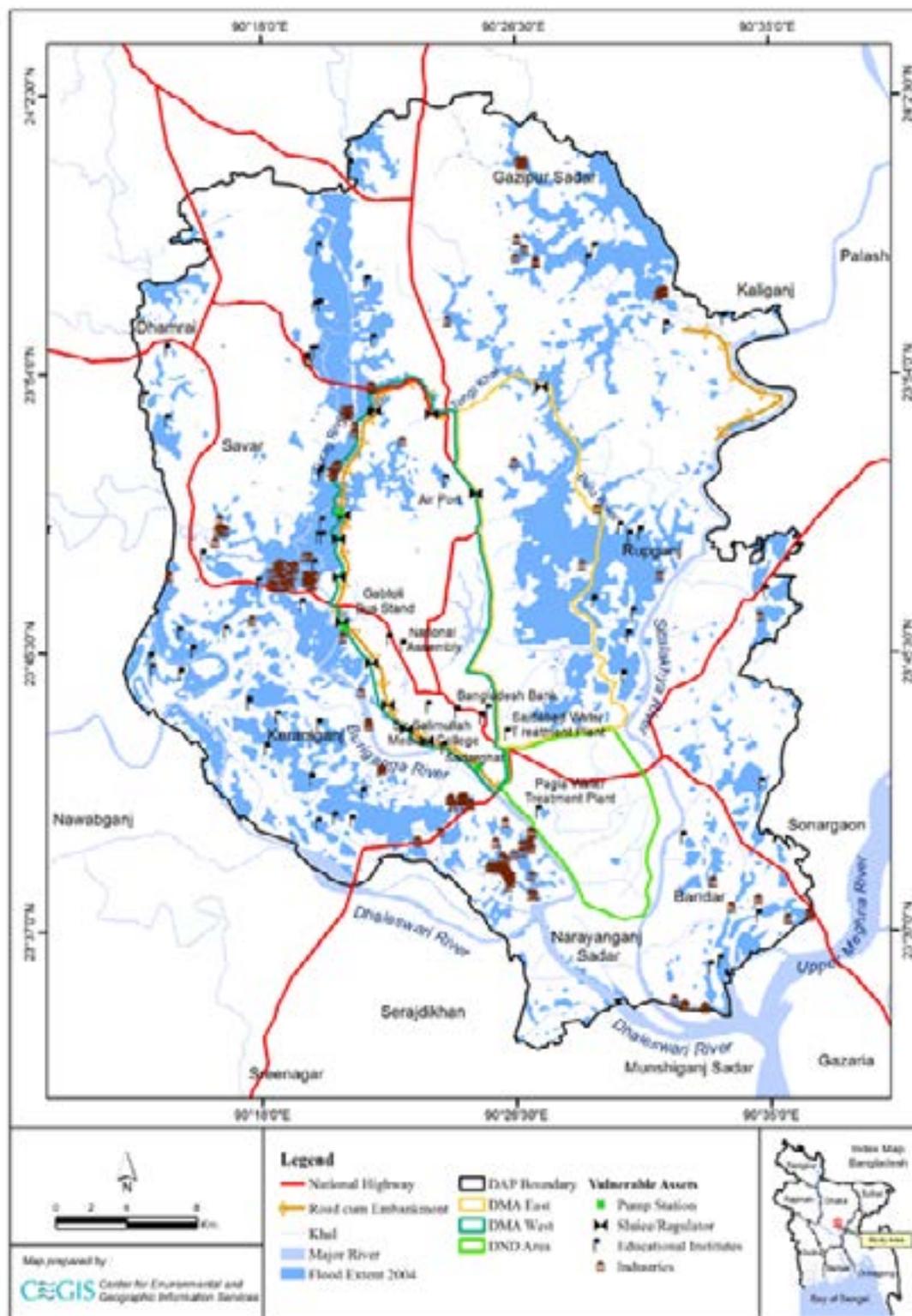
Source: Dasgupta et al. 2015.

FIGURE 2.13. SLUMS AND AREAS VULNERABLE TO FLOODING



Source: CEGIS 2016.

FIGURE 2.14. KEY ASSETS VULNERABLE TO FLOODING



Source: CEGIS 2016.



SUMMARY

- **Rapid Increase in urban population.** Dhaka's population is increasing rapidly, in part owing to rapid rural-urban migration.
- **Climatic and nonclimatic factors related to flooding.** Several weather-related factors contribute to flooding in Dhaka, including increased inflow from upstream rivers, intense rainfall, and increases in water levels from surrounding rivers. With climate change, all three factors are expected to grow in importance. Investments in solid-waste management and drain maintenance measures are also needed to manage urban waterlogging.
- **Decline of urban wetlands.** Satellite imagery reveals a steady decline in Dhaka's water bodies and wetlands and an increase in built-up areas.
- **Decline of groundwater resources.** Urban water supply is largely based on groundwater resources resulting in rapid depletion of this resource.
- **Areas vulnerable to flooding.** Based on data from past extreme events, the areas most vulnerable to flooding are Dhaka East and the low-lying DND area. However, Dhaka West continues to experience urban flooding because of drainage congestion.
- **Different types of hazards affect different areas of the city.** Because the waterways in Dhaka West are embanked, the area is chiefly vulnerable to intense rainfall resulting in waterlogging. The DND area is embanked from all sides, has limited drainage, and is also mainly affected by intense rain, resulting in waterlogging. Dhaka East is not embanked and hence vulnerable to both river flooding and intense rainfall. Thus the solutions for addressing flood risk need to be tailored to each area.
- **Poverty and flood vulnerability.** There are more than 3,300 slum settlements (bastees) in Dhaka. Some of the slum settlements most prone to flooding are Mohammadpur, Kamrangir Char, Rampura, and Khilgaon—all high-priority areas for a poverty-focused urban resilience strategy.



3 · Public Sector Responses to Flood Risk: A Historical Perspective





Perspective

Bangladesh has long-standing experience in addressing flood risk in the greater Dhaka area. An understanding of this history, evolution of flood management efforts, and the sequence in which they occurred is important for understanding how the city arrived at its current predicament, identifying actions that can be taken to reduce risk at present and providing options for what could be done in the future. Flood risk mitigation in Dhaka is closely linked with flood management efforts at the national level. As such, this chapter starts with an analysis of national-level initiatives followed by public sector responses to flood management (both structural and nonstructural) in Dhaka city, and the complexity of the current scenario. The chapter shows the drivers of public sector response, the types of solutions the city has prioritized, and provides a rationale for why an eco-engineering approach is important for a megacity such as Dhaka.

Early efforts: Flood events in the 1950s and the national public sector response

Until the early 1950s, flood management in Bangladesh was not a national government priority. However, in 1954 and 1955, Bangladesh faced devastating floods. These caused severe damage to life and resources, affecting around 35–40 percent of the country. The government of what was then East Pakistan sought the help of the United Nations to confront the enormous problem of flooding, protect agricultural lands, and attain self-sufficiency in food production. The importance of flood control for agricultural production was recognized from the outset. The Krug Mission, headed by J. A. Krug, a former U.S. Interior Secretary, was organized in 1955. As a result of its recommendations, the East Pakistan Water and Power Development Authority (EPWPDA) was formed in 1959, now known as the Bangladesh Water

Development Board. In 1964, the International Engineering Company Ltd. (IEC) commissioned by the EPWPDA, prepared a master plan that proposed large-scale flood control, drainage, and irrigation programs for the country (World Bank 1989; Dewan et al. 2003). This master plan for water resources development marks the beginning of efforts to develop an integrated plan for flood control and water resources development for the country. The plan was based on the experience gained with flood protection in the Mississippi River and included infrastructure such as flood embankments with gravity drainage, sluice gates, and pump drainage (Dewan et al. 2003). However, the chief focus of the Krug mission was to increase agricultural production. The plan did not deliver the desired benefits because the infrastructure it promoted suffered from poor maintenance and delays in implementation (Dewan et al. 2003).

The 1954 and 1955 floods contributed to identification and genesis of the first major flood control project in the Dhaka area, specifically in the Dhaka-Narayanganj-Demra (DND) area. In the 1950s and 1960s, in what comprises the major portion of Dhaka today, there was little development in the region. In the DND area, flood control measures were initiated in 1962. DND was a low-lying rural area of about 60 square kilometers (sq km) and important from an agricultural perspective. Given its location close to the Sitalakhya River, it was highly prone to flooding. Since it was an agriculturally important area, it was selected for physical interventions and embanked on all sides to sustain agricultural production.

The DND project implemented by the EWAPDA, initiated in response to the 1950s floods, was one of the first flood management projects in the greater Dhaka area. It was implemented during 1962–68 as a flood control, drainage, and irrigation (FCDI) project primarily to protect Dhaka city and the town of Narayanganj from floods and to save croplands from overflowing rivers. Initial physical works that had a bearing on flood risk management were introduced primarily for irrigation purposes and

to enhance agricultural production. A flood wall and embankment along the trunk road surround most of the area and provide protection from fluvial flooding.

Through the early 1970s, the focus of most of the country's water-sector development schemes was almost exclusively on achieving national self-sufficiency through increased agricultural production. The emphasis was on large schemes that included components for flood control, drainage, and irrigation. A 1972 World Bank study contributed to a significant shift away from large-scale embankments to minor irrigation schemes, low-lift pumps, and shallow tube wells to improve agricultural production (World Bank 1989; Dewan et al. 2003).²⁷ These spread rapidly, but before long conflicts among various water users surfaced. Low-lift pump irrigation interfered with fishing, and irrigation using shallow tube wells conflicted with household tube wells. Sustainable flood risk mitigation remained elusive.

In 1983, with the help of the World Bank, the Government of Bangladesh initiated the National Water Plan (NWP, 1985–2005) with the objective of maximizing agricultural production while meeting the basic water needs of

27. http://www.preventionweb.net/files/2802_multipage.pdf.

other users—industry, transport, and fisheries. The NWP, initiated under the Master Plan Organization (MPO), continued the emphasis on minor irrigation schemes in the short term but also focused on managing rivers using barrages and other infrastructure (World Bank 1989). The NWP proposed raising the country's flood-protected area from approximately 32 percent to 73 percent by providing flood control and drainage facilities over a 20-year period (1991–2010).

Major flood events of the 1980's and ensuing public sector response

In 1987 and 1988, Bangladesh faced another set of devastating floods. The flood of 1987 inundated more than 40 percent of the country. The 1988 flood, considered one of the most devastating in recorded history, inundated nearly 61 percent of the country. In contrast to the 1987 event, its primary cause was heavy rainfall in the upper catchments of the basins of the Ganges, the Brahmaputra, and the Meghna. The situation became catastrophic when flooding in all three basins peaked simultaneously. Approximately 85 percent of Dhaka was submerged in up to 4.5 meters of water; 60 percent of the city's residents



were affected. Entire eastern sections of Dhaka as well as the low-lying areas of the western part were flooded.

In response to these severe floods, the Flood Action Plan (FAP, 1990–95) was conceived by the country's development partners. The effort was to develop a flood plan as a durable solution to the recurrent flood problems. The FAP emphasized year-round water management, a high degree of protection for urban areas, the integration of river management in water development projects, and a combination of structural and nonstructural interventions. On behalf of the government, the FAP was coordinated by the Flood Plan Coordination Organization (FPCO), which eventually became the Water Resources Planning Organization.

The FAP marked the first time that flood management for Dhaka was comprehensively addressed. Among the 26 studies conducted, two action plans (FAP 8A and 8B) focused specifically on addressing flood risk in Dhaka. FAP 8A was conducted by the Japan International Cooperation Agency and covered a cumulative area of 850 sq km focused on the Greater Dhaka area. It consisted of plans for the broader area covered by the Detailed Area Plan, including the DND area and also Tongi, Savar, and Keraniganj on the outskirts (JICA 1991). The plan proposed

physical measures to improve the drainage system, such as improved pumping capacity and dredging of *khals*, and nonstructural measures, such as flood forecasting and evacuation systems, land regulation, and zoning. FAP 8B, conducted by Louis Berger International and funded by the Asian Development Bank, focused on flood mitigation and storm water drainage plans for the core city area. These studies led to recommendations to construct major flood interventions such as the western embankment.

The extreme events of 1987 and 1988 thus induced the government to undertake major flood-control interventions, starting with densely populated Dhaka West. The Dhaka Integrated Flood Protection Project (DIFPP) supported flood protection works carried out by the Bangladesh Water Development Board (BWDB), notably construction of the western embankment; drainage improvements carried out by the Dhaka Water Supply and Sewerage Authority (DWASA); and an environmental improvement program carried out by the former Dhaka City Corporation (DCC). Among other measures, the project supported construction of a 30-km embankment from Tongi to Kellar More, a 3.8-km floodwall, a 16.5-km access road from Mirpur to China Friendship Bridge, re-excavation of 30 km of *khals*, 20 sluice gates, three pump houses (Goranchatbari, Kallayanpur, and Dholaikhal), and a 258-hectare water res-



ervoir. Dhaka East, which is bound by the Balu River and encompasses approximately 124 sq km of low-lying area, was not embanked.²⁸

Based on the FAP studies and the NWP, Bangladesh developed, in 1995, a Water and Flood Management Strategy that acknowledged the need for integration of various entities in formulating and implementing flood-disaster management policies. A five-year (1995–2000) program was begun to prepare the National Water Management Plan (NWMP). Of 27 programs designed to benefit the country's North Central Region, four exclusively targeted Dhaka's pressing need for water supply, sanitation, sewerage, flood protection, and storm water drainage. Of these, two (the Dhaka Flood Protection and Dhaka Storm Water Drainage projects) specifically addressed the problem of flooding (WARPO 2001).

After Dhaka East was inundated in the 1998 floods, there were proposals for BWDB to construct flood-control infrastructure along the right bank of the Balu, including a flood embankment, flood wall, and drainage sluices (WARPO 2001). However, these were not carried out at the time due to the unavailability of funding. In 2004, as noted in chapter 2, the Dhaka area experienced another major flood event, and the eastern side of the metropolitan area again suffered extensive damage. This provided renewed impetus to address flooding in Dhaka East; a feasibility study conducted by Halcrow Group Ltd. in 2006 proposed constructing an embankment extending from the Tongi railway bridge to Demra Ghat as well as other infrastructure. However, the project was never implemented, in part due to difficulty in mobilizing funds (Express 2012).

In 2012, BWDB submitted a fresh development plan to the Ministry of the Water Resources (MOWR) on the Dhaka Integrated Flood Control Embankment (also known as the Eastern Bypass Road Multipurpose Project) (Express 2012). However, consultations undertaken during fieldwork for

this report revealed considerable debate about whether the eastern side of Dhaka should be embanked. One school of thought is that the embankment is necessary to address flood risks in Dhaka East, while others believe that doing so would result in embanking the city from all sides.²⁹ With intense rainfall events on the rise and limited constructed drainage in the area, the embankment of Dhaka East would effectively fully embank the core Dhaka area from all sides and trap water inside the Dhaka Metropolitan Area (DMA), requiring increasing resources be spent on pumping out the accumulated water and on maintenance of the existing canals, *khals*, and their connectivity with the surrounding river system.

Dhaka's rapid growth has been accompanied by increases in built-up area, which, as noted, have increased runoff rates, impeded infiltration, and aggravated waterlogging. These developments have highlighted the need for investments in storm water drainage. Multiple projects have been undertaken by DWASA to mitigate the city's drainage problem by providing a drainage system—from the collection of water at the street level to the disposal of the accumulated water through pumping stations. DWASA recently prepared a Storm Water Drainage Master Plan based on which large investments in sewerage and drainage improvements are planned.

The current situation in major areas of the city

Analysis carried out for this study shows that major areas of Dhaka have specific sets of structural constraints. These are shaped by the hydrological and geophysical characteristics of the areas, by the infrastructure that has been put in place historically for flood management, and by the pattern of urbanization that has unfolded.

28. For a review of the FAP, see Brammer (2010).

29. Study team's communication with DWASA, MD.

THE DHAKA-NARAYANGANJ-DEMRA (DND) AREA

In the 1960s, the low-lying DND area was primarily agricultural. Since then, it has grown into a congested urban area, still low lying but now embanked on all sides (FIGURE 3.1). Because of haphazard and unplanned land development, waterlogging frequently occurs during the monsoon period, as excess water within the embanked area cannot pass out into natural channels but must be pumped out. There is no constructed drainage system in the DND area. A single two-way pumping station at Shimrail with a discharge capacity of 14.52 cubic meters per second (cumec) is operational. But it has proven to be inadequate to prevent waterlogging during the monsoon. Pumping capacity needs to be increased.

Encroachment by unplanned urbanization and poor maintenance have limited the functioning of the natural *khals* and former irrigation canals that could provide drainage services to the area and require regular maintenance. The link to the external river system is also diminished and needs to be restored to improve connectivity to the peripheral river system.

DHAKA WEST

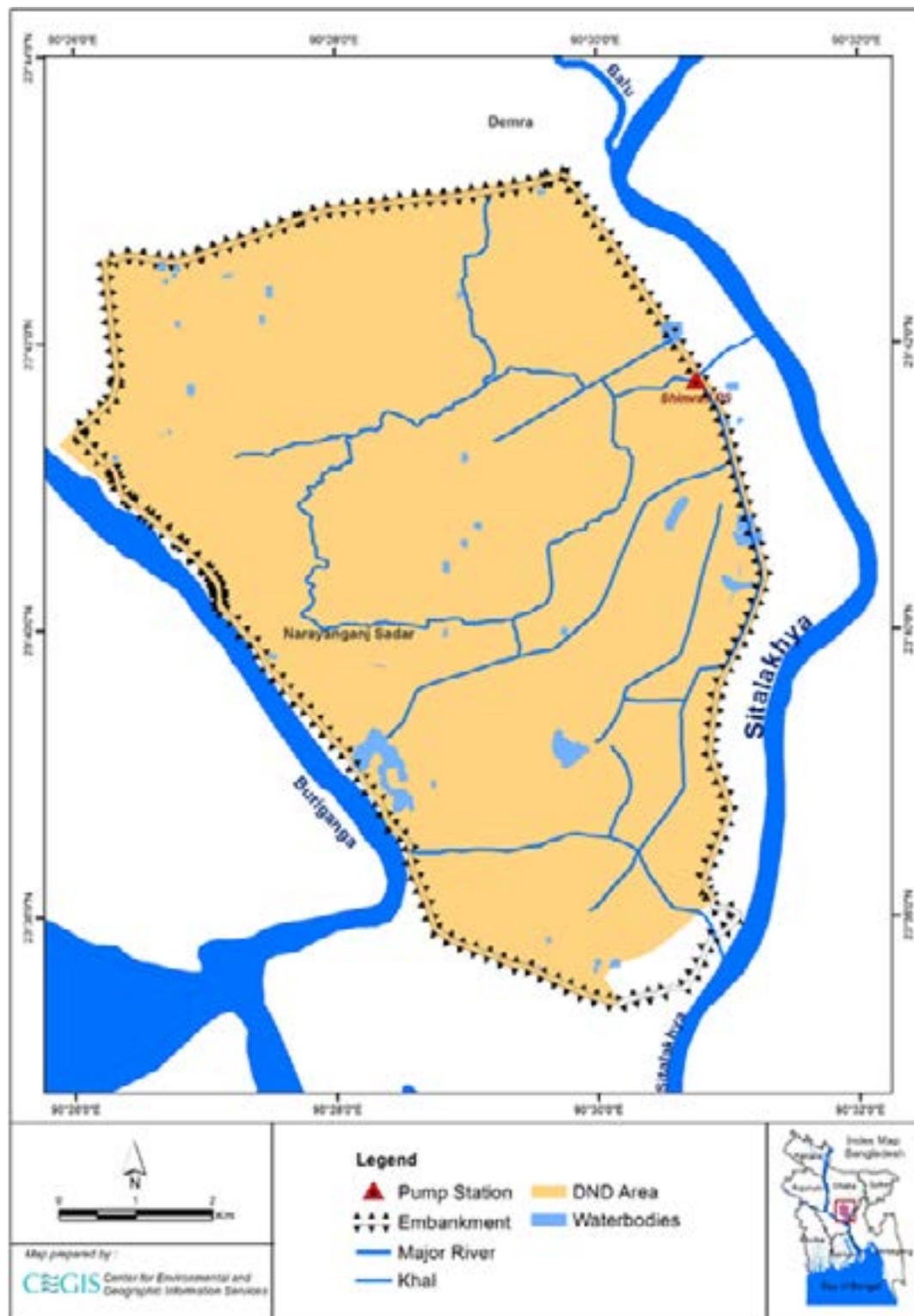
The western embankment constructed after the 1988 floods usually protects Dhaka West from river flooding—but not always. In the 1998 floods, approximately 20 percent of the area was inundated despite the embankment. The floodwall along the Buriganga River was never completed because public pressure prevented removal of some structures, such as the Sadarghat inland port (Faisal, Kabir, and Nishat 1999). During high tide, flood water enters Dhaka West through the port and at other places where people have removed some parts of the structures to allow easy movement of water. The sewerage pipes buried under the floodwalls, which carry domestic waste into the river, also allow water to flow back through the pipes into the city.

The storm water drainage system of Dhaka West includes *khals*, storm sewers, and tertiary drains and pipes (FIGURE 3.2). Storm water passes into storm sewers through tertiary drains and pipes. The storm sewer then carries the water to *khals*, which ultimately convey it to pumping stations.³⁰ The western embankment has disconnected the *khals* and canals in the city from the outer river system (Hossain, Miti Nawshad, and Rahman 2013).

At present, there are several pumping stations operated by BWDB: Goranchat Bari, with a capacity of 25 cumecs; Dholaikhal at Mill Barrak with a capacity of 22 cumecs; and pumping stations at Kamalpur and Shimrail. These discharge into the Tongi Khal, Turag, and Buriganga rivers. The Kallyanpur pumping station (15 cumecs) and a recently completed station at Rampura are operated by DWASA. Besides these, temporary pumps are installed at various locations surrounding the western embankment and floodwalls to drain storm water during the monsoon and other periods of heavy rainfall. Thirty-eight percent of the DMA has a drainage network operated by DWASA. It consists of approximately 43 natural canals with a total length of 145 km, about 280 km of storm sewer lines, and 10.5 km of box culverts that drain an area of about 140 sq km. In addition to this, the city corporations also maintain surface drains within their areas of jurisdiction. Historically, Dhaka West possessed drainage channels and low-lying lands that drained the area naturally. With the encroachment of rapid, unplanned urbanization, most of these channels and floodplain pockets have been filled up. Over the years, land development projects have severed many of the connections between *khals* and the surrounding rivers, further impeding drainage and contributing to waterlogging.

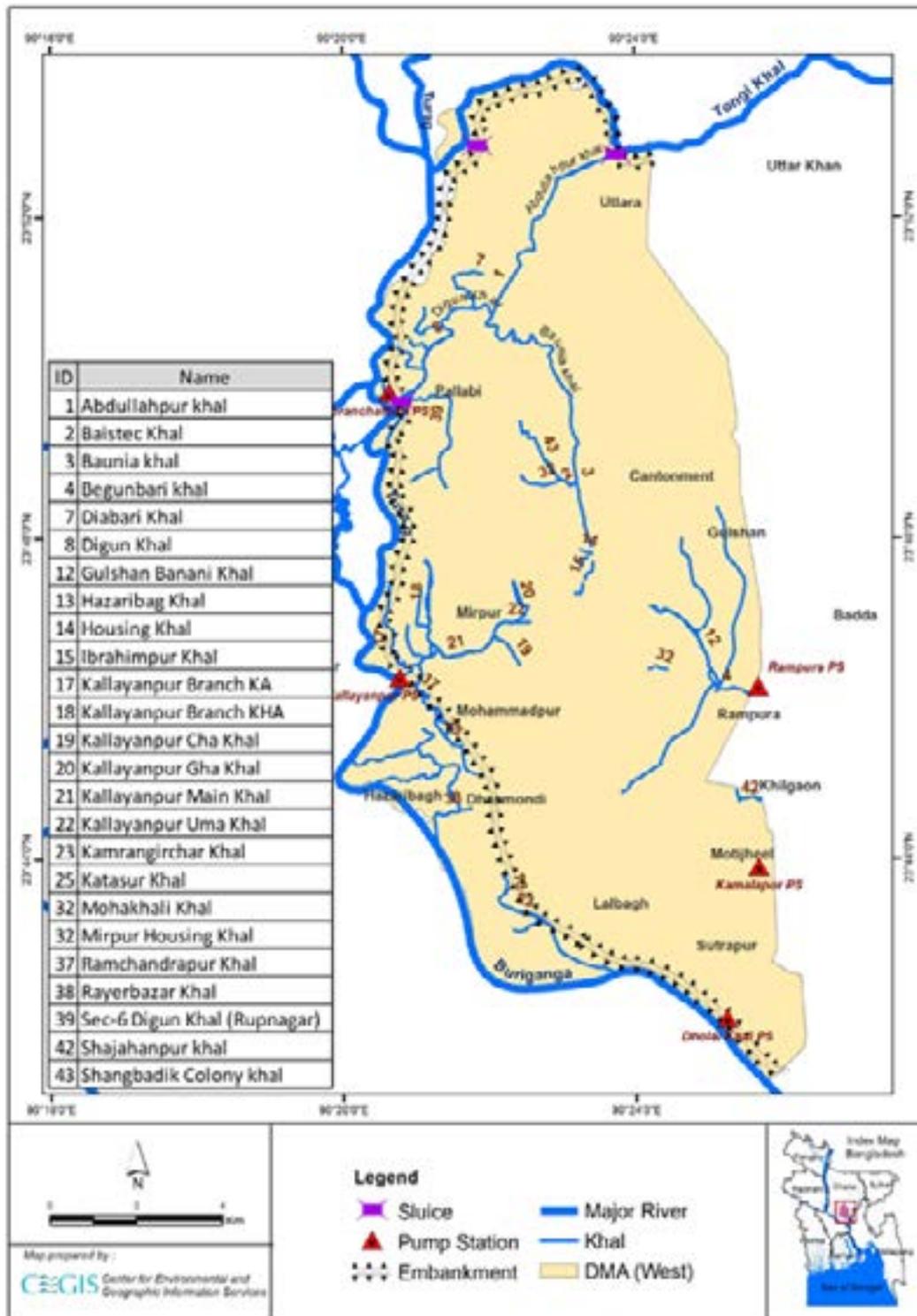
30. http://www.spatialcapability.com/Library/Liz/Floods_in_a_Megacity.pdf; <http://classes.geology.uiuc.edu/11SprgClass/ES222/FAP.pdf>.

FIGURE 3.1. THE DHAKA-NARAYANGANJ-DEMRA (DND) AREA



Source: Study team 2016.

FIGURE 3.2. EXISTING KHALS, PUMPING STATIONS, AND WETLANDS IN DHAKA WEST



Source: Study team 2016.

DHAKA EAST

Dhaka East has no major embankments similar to those in the DND area and Dhaka West. Nor does it have a dedicated storm water drainage network as in part of Dhaka West. Instead, its drainage system remains for the most part natural and open. The vast area is drained by numerous depressions connected to main drainage channels, through which water is discharged into the Tongi Khal and Balu rivers (FIGURE 3.3). Although most of Dhaka East is still agricultural and rural, the land is slowly being converted to residential areas and becoming urbanized in an unplanned way. Land owners tend to develop their lands using unregulated and improper land filling, causing obstructions to the original drainage system. As a result, Dhaka East is regularly flooded during the monsoon months.

Investments in urban weather forecasting and early warning systems

Early warnings about intense rain and precipitation are critical for the management of urban infrastructure, and inform key steps such as preparing pumps to drain water into rivers to avoid waterlogging. Compared with investments in infrastructure, investments in urban weather forecasting and early warnings have been historically very limited. At the time of this report's preparation, the Bangladesh Meteorology Department (BMD) was operating one rainfall monitoring station for the entire city, supplemented by an S-band radar unit obtained with support from the Japan International Cooperation Agency. The radar has not been calibrated and the automatic weather stations needed to calibrate it are not functional. The unit is also more appropriate for long-range weather events such as cyclones than for short-range events. The BMD presently uses a 20-km resolution to generate weather forecasts. The resulting forecasts indicate whether rainfall will be heavy, moderate, or light and include warnings for extreme hot or cold temperatures. The public receives

a 24-hour forecast and a 2–5 day outlook. A separate weather forecast for metropolitan Dhaka, valid for six hours and updated four times daily, is issued but is not location specific. Location-specific forecasts for quick on-set intense rainfall are not made. Thus, BWDB and DWASA, the organizations that operate pumps on the western and southern sides of the city, do not receive advance warnings that would tell them when to drain the water out of the Dhaka West or DND areas. They also do not receive information about the intensity and duration of the rain.

In Dhaka East, where river flooding is the main issue, flood forecasts are needed. These are provided by the Flood Forecast and Warning Center (FFWC) under the Hydrology Division of BWDB. BWDB monitors the water levels, river flow, rainfall, and groundwater levels in Greater Dhaka (and also the rest of the country). BWDB's urban monitoring infrastructure includes water level monitoring stations in the Buriganga, Turag, Tongikhal, Balu, Shitalakhya, and Dhaleswari rivers that monitor water levels five times a day at ten manually operated stations and two rainfall stations. FFWC has a Digital Elevation Map (DEM) of Dhaka which has a resolution of 300 meters. It issues river forecasts for Greater Dhaka at Banish, Dhaleswar, Tongi Khal, Turag, Buriganga, Balu, and Lakhaya. However, it does not provide location-specific forecasts or inundation forecasts for Dhaka East. Assessments of hazard, vulnerability, and flood risk for the DMA or Greater Dhaka are not made. Flood maps or flood risk information services for different uses such as for urban planning or insurance are also not provided. ■

FIGURE 3.3. EXISTING KHALS, PUMPING STATIONS, AND WETLANDS IN DHAKA EAST



Source: Study team 2016.

SUMMARY

- **Major infrastructural interventions from the public sector have come in response to extreme events.** Many of the major flood control measures undertaken in Dhaka have been initiated as a reaction to major flood events, not as part of planned urban expansion of the Dhaka area. While these have protected the Dhaka West and DND areas from river flooding, they have also contributed to changing the nature of the hazard that different areas are exposed to. The Dhaka West and DND areas that are embanked are no longer mainly exposed to river floods but to rain-induced waterlogging. These infrastructure investments involve a path dependency and imply that the city must make additional investments in pumping infrastructure to pump water out into the peripheral river system in a more effective and efficient manner and also allocate adequate funds to maintain the infrastructure to minimize waterlogging in these areas. In parallel, these areas have also seen a decline of the natural drainage system in the form of canals and inland waterways.



- **Experience in the low-lying DND area shows that flood-control infrastructure has itself contributed to the urbanization of the area by encouraging people to settle there even in the absence of an adequate drainage system or provision of urban services.** This, combined with proximity to Dhaka and Narayanganj, has helped transform DND from a primarily agricultural to a highly congested urban area.
- **The construction of embankments in Dhaka West and the DND area, combined with the poor maintenance of rivers and other urban water bodies, have delinked the city's internal waterways from the peripheral river system.** Cut off from their natural connections with the rivers, both the Dhaka West and DND areas now must be drained using a large number of pumps.
- **The primary solution for addressing waterlogging and managing river flooding in Dhaka has been structural interventions (such as embankments, pumping stations, box culverts, and regulators), with much less attention given to nonstructural measures such as weather and flood forecasting or risk-based information services.**





4 · Planning, Political Economy, and the Case for Institutional Reform





The most complex and difficult challenges in managing flood risk in the Dhaka Metropolitan Area (DMA) and the Greater Dhaka area are institutional and organizational. The complexity arises from the multiplicity of actors and agencies involved (See Appendix B) and the political economy issues at play. A wide range of public sector agencies are involved either directly or indirectly, often with overlapping mandates. Some are national-level agencies such as the Bangladesh Water Development Board (BWDB), while others are municipal-level agencies such as Rajdhani Unnayan Kartripakkha (RAJUK). Moreover, while Dhaka is perceived as a city, in reality only parts of the city are under municipal management: vast swaths of the area under the jurisdiction of Union Parishads with little capacity for flood risk management or urban planning. Urban planning is still driven by archaic laws that need urgent revision. This chapter provides insight into some of these issues and lays the groundwork for much-needed institutional reform.

The Town Improvement Act, 1953, and emergence of urban planning

The Town Improvement Act (TIA), 1953, approved over 60 years ago, and amended in 1987, continues to guide urban planning in major urban areas in Bangladesh today. It provided the foundation for the establishment of the Dhaka Improvement Trust (DIT) in 1956. Modern city planning in the Dhaka area began with the DIT and preparation of the DIT master plan in 1959. The plan covered an area of roughly 570 square kilometers (sq km) (later extended to 829 sq km) inhabited by about a million people. In 1987, DIT evolved into the Rajdhani Unnayan Kartripakkha (RAJUK), which remains the main planning agency for Greater Dhaka.

The TIA provides the legal basis for the formation of *Kartripakkhas* and vests enormous powers in the agency. Based on this Act, RAJUK and other *Kartripakkhas* have

the authority to acquire and use land; raise and lower land; demolish and construct buildings; lay out or alter streets, bridges, and culverts; enlarge open areas; provide drainage schemes; and “any other matters consistent with this Act which the *Kartripakkha* may think fit” (TIA 1953). The Act allows the *Kartripakkha* to “frame schemes (herein called re-housing schemes) for the construction, maintenance and management of such and so many dwellings and shops as they may consider ought to be provided for persons of the poorer and working classes who (a) are displaced by the execution of any improvement scheme sanctioned under this Act; or (b) are likely to be displaced by the execution of any improvement scheme which it is intended to frame, or to submit to the Government for sanction under this Act.”

Moreover, it also gives RAJUK power over corporations to make final decisions in the case of complaints from the public. As explained later in the chapter, the Act allows RAJUK to play conflicting roles of planner, developer, and regulator with little accountability to the public. As such, the Act needs to be updated and revised.

Urban planning and the first Detailed Area Plan³¹

In the early 1990s, RAJUK began preparing the Dhaka Metropolitan Development Plan (DMDP). The DMDP included the Structure Plan, the Urban Area Plan, and the Detailed Area Plan (DAP). Although not directly focused on disaster or resilience, this three-tiered plan had a direct bearing on flood risk management in the way it addressed land use, water resources, and flood plains in the Greater Dhaka Area.

The Structure Plan (1995–2015) was a long-term development strategy for the 1,528 sq km of Greater Dhaka. It

31. http://cseindia.org/userfiles/RAJUK_Presentation_August72011.pdf; <https://www.adb.org/sites/default/files/project-document/77480/39298-013-ban-tacr-01.pdf>.

BOX 4.1

Policies and legislation affecting flood management in Greater Dhaka

A large number of policies and regulations, both national and municipal, shape flood risk management and urbanization in Dhaka. *The National Housing Policy (1993 and updated in 2008)*, aims to ensure housing for all, particularly the poor. It articulates the role of the government as one of supplying serviced land at reasonable cost and promoting housing finance. It also aims to reduce encroachment and ensure environmental conservation in new housing construction. In the context of Dhaka, the reality of providing housing is particularly challenging. Although several public agencies are active in housing provision, no workable strategy to upgrade slums settlements is in place (Islam 2014).

The scarcity of formally serviced land has left the development of the city largely to the informal sector. *The National Urban Sector Policy (2011)* was developed by the Ministry of Local Government, Rural Development, and Cooperatives. It addresses numerous aspects of urban development—among them employment, resource mobilization, housing and slum improvement, environmental management, infrastructure and services, and rural-urban migration. However, implementation of many of these issues in Dhaka is weak. For example, rural-urban migration is a critical issue in urbanization. Yet there is no strategy or plan to manage it.



The National Land Use Policy (2001) highlights the importance and modalities of zoning for integrated planning and management of land resources of the country. In Dhaka, implementation is mixed because of vested interests illegally occupying land, a lack of political will, inefficiencies in the way land administration is organized, and absence of a systematic database on land resource availability in the city. *The National Water Policy (1991)* emphasizes sustainable management of surface and groundwater water resources to ensure a decent standard of living for all and protection of fisheries and the environment.

The policy has not been updated to address climate risks. *The Bangladesh Water Act (2013)* regulates water resources management, natural drainage, and flood control. It also prohibits draining of wetlands that support migratory birds. The extent to which its enforcement provisions are implemented is unclear. Various other policies contain provisions to protect and manage wetlands. *The Bangladesh Haor and Wetlands Development Board* was established in 2000 for the integrated development and protection of wetlands. However, it is more of a policy-making body and plays no implementation role in wetlands management in Greater Dhaka.

projected urban growth and provided a series of policy guidelines to achieve its objectives (Seraj and Islam 2011).³² The Urban Development Plan (1995–2005) was a medium-term development strategy. While the Structure and Urban Plan were prepared by 1995, the DAP was not completed until 2004.³³ Moreover, it was gazetted by the Government in 2010 and only then had a legal status. Produced with the assistance of the United Nations Development Programme (UNDP) and United Nations Centre for Human Settlements, its purpose was to control land use and development and provide guidelines for public and private investment priorities. The DAP expired in 2015 and was extended until December 2016.³⁴ The DAP applied to 350 sq km of Dhaka proper, 1,528 sq km covered by the DMDP, as well as Savar, Narayanganj, Tongi, and Gazipur. For specific subareas, it provided detailed proposals for infrastructure, roads, services, facilities, and land use. With regard to flood management, it emphasized both structural measures (embankments, sluice gates, box culverts, siphon, drainage canals) and nonstructural measures (protection of *khals*, reexcavation of major *khals*, demarcation and fencing of retention ponds upstream of pumping stations, and integration of the drainage system with other flood protection infrastructure). It also emphasized public participation in the land-development process.

Implementation of the DMDP faced numerous challenges. First, there was a significant gap between the approval of the Structure Plan (SP), Urban Plan (UP) and the approval of the DAP in 2010 as a gazetted document. During this time, housing construction in the DAP area continued unabated in a haphazard way (Rahman 2013). Second, even after the DAP was gazetted and had legal grounding, housing construction in areas defined as

flood-flow zones (but not always clearly demarcated as such) continued, undermining the land-use zones proposed in the DAP. Further, the SP and the UP of the DMDP allowed “rural” development in the flood-flow zones, creating ambiguities in implementation (Roy, Jahan, and Asaduzzaman 2011). Moreover, enforcement of the DAP was left to RAJUK and not the city corporations. Importantly, the DAP was not accompanied with any implementation plan or local area plans or zoning laws to guide enforcement of the DAP at the local level (Rahman 2013: 123).

While DAP was gazetted and had legal status, it was not accompanied by any zoning policy, ordinances, or regulations regarding land use or density management. The city corporations also did not prepare any zoning regulations or ordinances to enforce the plan within their areas of jurisdiction. Thus enforcement of the DAP has been extremely challenging. Ordinances specific to each zone can serve a variety of purposes, such as managing housing growth and construction, reaching consensus on neighborhood development, streamlining the issuance of construction permits, and protecting people and assets from flooding and other hazards. They can help municipal agencies manage land use and create transitional land-use patterns to buffer against incompatible land uses. Zoning plans and ordinances can also help to balance the interests of different social groups and increase climate resilience by managing urban density and patterns of transportation and growth.³⁵ Further, even though DAP addressed the protection of flood zones and water bodies, mechanisms for reducing risks posed by disasters were not mainstreamed in the plan (GOB 2013). DAP has also been critiqued for the fact its preparation and implementation involved little public consultation (Farooqe 2012; Rahman 2013;). RAJUK’s plans are sometimes not available to local offices, meaning that many local officials lack

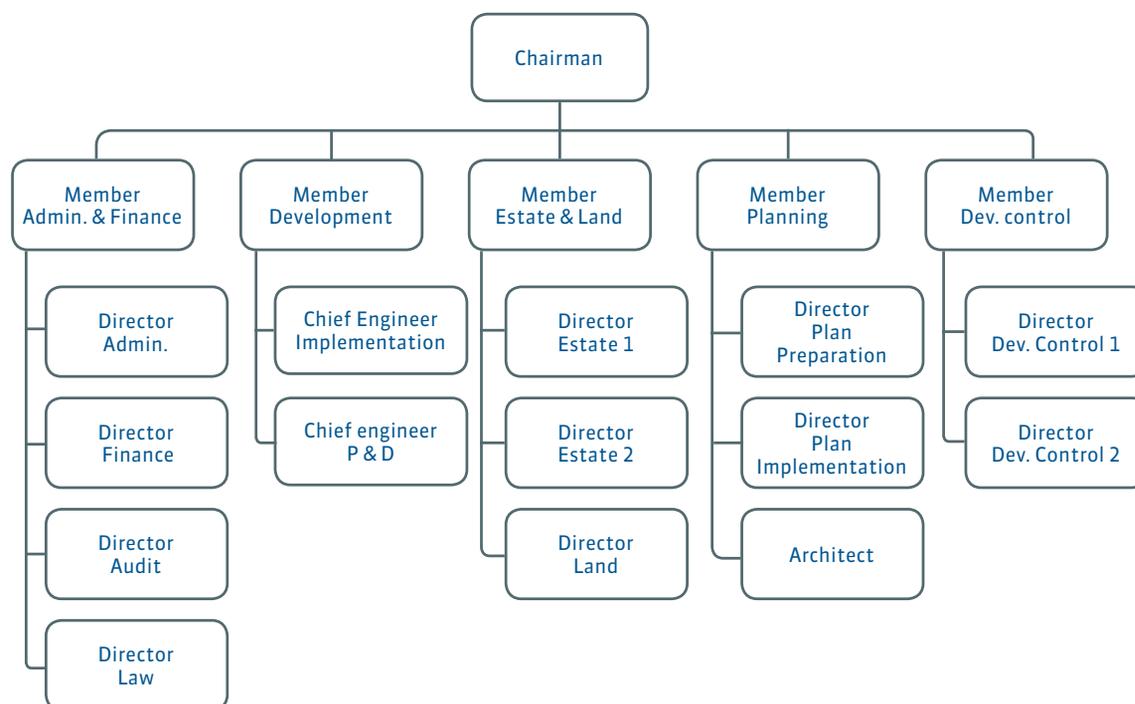
32. http://www.bip.org.bd/SharingFiles/journal_book/20140427150129.pdf.

33. http://www.slideshare.net/AkhterChaudhury/a-short-history-of-urban-planning-in-bangladesh-new?next_slide-show=1.

34. Communication with RAJUK officials, October 2016.

35. <http://www.doingbusiness.org/~media/GIAWB/Doing%20Business/Documents/Annual-Reports/English/DB15-Chapters/DB15-CaseStudy-Zoning-Urban-Planning.pdf>.

FIGURE 4.1. ORGANIZATION OF RAJUK



Source: RAJUK 2015a

awareness of existing zoning and regulation. Finally, the DAP was not accompanied by cost estimates for its implementation.

RAJUK has prepared a new draft Structure Plan (2016–35) under the Regional Development Planning Project funded by the Asian Development Bank (ADB). It is in the process of preparing a new DAP for the period 2016–35. It is important to ensure that the new DAP and related implementation efforts build on lessons from the past.

The Rajdhani Unnayan Kartripakkha (RAJUK)

RAJUK, the main planning agency for Greater Dhaka, is situated under the Ministry of Housing and Public Works. Its mandate is to plan, develop, and regulate development within Greater Dhaka (RAJUK 2015a). As discussed below, there is significant conflict of interest in its multiple roles.

ORGANIZATION, BUDGET, AND STAFF

RAJUK is governed by a chairman appointed by the Ministry of Housing and Public Works. The chairman is supported by five members responsible for the agency's five wings (FIGURE 4.1).

RAJUK is a profit-making organization and earns revenue through a variety of sources including sale of developed land, apartments, asset transfer fees, fees for land-use and building construction permits, and fines. In 2014–15, its revenue income was about \$30.25 million (Bangladeshi Taka, BDT 238 crore³⁶) and expenditures were about \$6.74 million (BDT 53 crore), resulting in a surplus of about \$23.5 million (BDT 184.71 crore); these numbers indicate vast resources and profits (RAJUK, 2015a). RAJUK also receives grants from the government. Given its resources, RAJUK generally does not rely upon funds from development partners.

36. Using an exchange rate of 1 BDT = \$0.013 (January 4, 2017).

TABLE 4.1. RAJUK'S FIVE WINGS AND THEIR STAFF STRENGTH

Administration and finance	35	395	430
Planning	30/91	56	147
Development	45	30	75
Development control	70	105	175
Estate and land	9	112	121
Total	250	698	948

Source: Staff list of RAJUK website.

Note: Based on conversation with town planner in October 2016, RAJUK has about 25–30 planners. However, the website shows that there are 91 planners. It is possible that the website is not updated.

RAJUK AS PLANNER

One of RAJUK's core mandates is to prepare plans and strategies for the development of the Dhaka area (FIGURE 4.2). This is undertaken by the planning wing. There are approximately 30 town planners at RAJUK. Some of the main tasks undertaken by RAJUK's planners include reviewing and processing requests for land use plans. Given the vast area for which they are responsible, for a population of about 17–18 million people, and the level of demand for processing land clearances, staffing is limited.³⁷

Urban planners typically must have access to many kinds of data—for example, on patterns of population growth, poverty levels, land use, job patterns, demand for various services, urban mobility, and hazards. They must synthesize those data, undertaking consultations in order to develop options and strategies for further growth and development. RAJUK, however, does not have ready access to many of these types of data to inform planning on a regular basis. Its planners also do not have adequate

training in land-use planning, zoning, geographic information system (GIS) and spatial analysis, and other skills and techniques (Seraj and Islam 2011).³⁸ In the absence of these resources, the agency relies heavily on external consultants. Discussions with the planning wing revealed limited coordination with local people and communities in the preparation of plans. As was the case of the first DMPD plan, preparation of the new Structure Plan was not carried out by RAJUK's planners but contracted to a consultancy firm with support from ADB funding. Strong in-house planning capacity needs to be built for the planning division to prepare and adjust plans to meet the needs of the local communities.

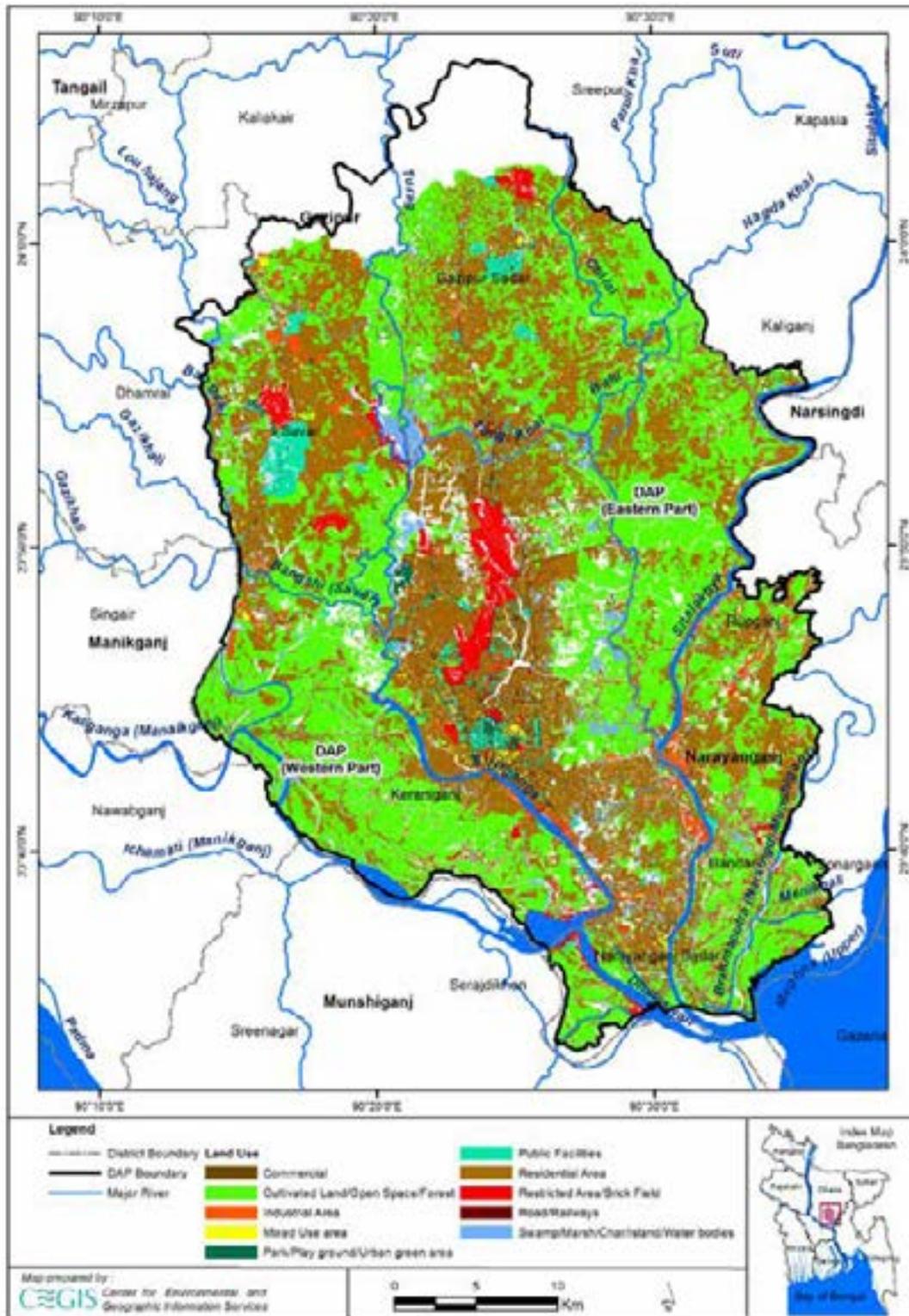
RAJUK AS DEVELOPER

RAJUK's development wing implements the agency's development activities, including preparation and estimation of projects, procurement, supervision of construction, operation and maintenance (O&M), and so on. Its main strength is a cadre of experienced engineers who are

37. Personal conversation, Chief Town Planner, RAJUK.

38. http://www.bip.org.bd/SharingFiles/journal_book/20140427150129.pdf.

FIGURE 4.2. MAP OF RAJUK'S DETAILED AREA PLAN, 2010-15



Source: CEGIS 2016.

capable of handling and supervising construction and development projects.

RAJUK provides serviced land for housing construction, often acquiring the land from private owners or from local government agencies at artificially low prices. It also builds housing even though, under the National Housing Policy, government is supposed to limit its role to maintaining an enabling environment, leaving housing construction to private firms or individuals (World Bank 2010).³⁹ The agency's building activities include excavation, filling of land, and construction of roads, culverts, and bridges. Some of RAJUK's developments have purportedly violated the agency's own rules. For example, the Purbachal New Town Project required filling in part of the floodplain of the Shitalakhya River in violation of existing laws and the DMDP (Farooqe 2012).

It is reported that RAJUK often turns developed land over to the city corporations, private individuals, or developers as described later in this chapter, without any drainage facilities. Because these entities are not involved in planning or implementing drainage facilities in the areas developed by RAJUK they must do so after the fact, cutting through existing roads in the developed area. Fieldwork suggested that in some cases DWASA is reluctant to assume responsibility for drainage for newly developed urban areas after the land and road construction has already taken place.

RAJUK AS REGULATOR

In its regulatory role, RAJUK exercises control over Dhaka's growth and development by issuing land-use and construction permits and overseeing development activities.⁴⁰ The building construction permits are given by

RAJUK's development wing. Through the issue of permits, site visits, and monitoring of physical establishments, RAJUK also aims to ensure compliance of development activities with the agency's plans and legal instruments.

However, the permitting process is complex and time consuming (Doing Business 2015). RAJUK has not prepared any zoning laws to implement and enforce the DAP at the local level. Builders must obtain land-use clearance from the planning wing. After publishing their construction plans, they must obtain another clearance, from the development wing, before starting construction work. The process is challenging and may take years to complete because of lack of zoning ordinances and weaknesses in both wings in inspection and reporting, with inspectors potentially susceptible to influence (Mahmud 2013: 49).

RAJUK is responsible for inspecting buildings and other structures in the DAP area. According to discussions with agency officials, the number of building inspectors is not sufficient to monitor unauthorized development. The city's eight zones are monitored by two inspection units, both of which are understaffed. It is unclear, moreover, who is empowered to enforce the existing regulations on water bodies and floodplains. Overall, the number and capacity of the wing's personnel are not commensurate with the agency's requirements for development activities.⁴¹ RAJUK's monitoring activities, such as ensuring compliance with existing land-use policies and plans and preventing and reporting illegal landfilling and development that undercuts the flow of water or floods, are often hampered by the lack of skilled manpower. Given RAJUK's surplus in revenues, it is unclear why additional funds are not allocated to improve planning capacity in the agency or strengthen enforcement of the DAP.

RAJUK's multiple roles open up a space for conflicts between its mandate and activities. As regulator, RAJUK issues permits for land development to private land

39. <http://siteresources.worldbank.org/SOUTHASIAEXT/Resources/223546-1269620455636/6907265-1284569649355/CompleteReportSARHousingFinanceOctober2010.pdf>

40. http://www.bip.org.bd/SharingFiles/journal_book/20130718115951.pdf

41. Conversation with Chief Town Planner with study team.



developers and builders, while it is itself engaged in the process of housing and land development. Its dual roles as inspector and developer are not consistent and need to be reconciled. Further, RAJUK builds in areas that are designated as flood zones in the DAP (Alam 2014). This makes its charge as the enforcer of existing regulations extremely complex and challenging. RAJUK has built both Purbachal New Town and Jhilmil on flood zones, converting wetlands into housing projects. Given this conflict, it is difficult for the agency to play its monitoring and enforcement role effectively.

Bangladesh Water Development Board (BWDB)

The Bangladesh Water Development Board (BWDB) within the national Ministry of Water Resources (MOWR) plays a very important role in shaping flood-risk management in Dhaka. As the country's key water resources management agency, BWDB's activities are national in scope. It undertakes projects and programs related to irrigation, flood control and protection, drainage, river bank erosion, river dredging, prevention of salinity intrusion, and land reclamation (BWDB 2016). The board generally follows the plans of the Water Resources Planning Organization (WARPO) as well as the National Water Policy (1999), the National Water Management Plan (2004), and other relevant plans and policies, including its own five-year strategic plans (BWDB 2009).

ORGANIZATION, BUDGET, AND STAFF

BWDB is headed by a director general. Five additional director generals (ADGs) are responsible for administration, finance, planning, implementation, and O&M for the board's eastern and western regions (MOWR 2015). Construction of flood management infrastructure for Greater Dhaka falls under one ADG (ADG East), whereas flood forecasting is the responsibility of another (ADG Planning). A chief engineer within the Central Zone of BWDB's

East Region is responsible for flood risk management in the DAP area delineated by RAJUK. Two divisions under the Central Zone headed by executive engineers look after flood management in the DMA. An executive engineer and supporting staff work full time for the city's Flood Forecasting Circle. The board's Flood Forecasting and Warning Center (FFWC) provides flood forecasts for Greater Dhaka as well as the rest of the country. But FFWC staff do not perform any hazard, vulnerability, or risk analysis. Using public funds and with support from development partners, BWDB implements numerous projects. However, it was not possible to determine its budget for pumping, and O&M activities in the Dhaka area.

Overall only 15 percent of BWDB's employees are technical staff, most of whom are engineers (Rahman 2006).

According to BWDB officials, additional technical staff are needed for flood forecasting, impact studies, construction, and maintenance related in Greater Dhaka.

BWDB'S DUAL ROLE IN FLOOD INFRASTRUCTURE AND EARLY WARNINGS IN DHAKA

With respect to flood risk management in Dhaka, BWDB plays a dual role in constructing flood infrastructure and embankments and being responsible for river forecasting.

Structural activities. BWDB has undertaken major infrastructural projects, such as the construction of embankments in the DND area and Dhaka West, and continues to be responsible for flood management through the O&M of regulators and pump houses. It is also responsible for dredging surrounding rivers to promote and protect natural drainage. However, consultations with officials revealed that the effort devoted to maintaining and dredging Greater Dhaka's river system is insufficient, which contributes to waterlogging during the monsoon season.

Forecasting and early warning. Weather and rainfall forecasting are under the mandate of the Bangladesh



FIGURE 4.3.
POORLY
MAINTAINED
REGULATORS IN
DHAKA WEST

Source: Study team.

Meteorology Department (BMD). As discussed in chapter 3, BMD's rainfall monitoring and forecasting capacity is weak and needs to be strengthened.⁴² The Flood Forecasting and Warning Center, as its name implies, is responsible for issuing flood forecasts and warnings. It obtains precipitation data from BMD and uses it in its own models to issue forecasts for Dhaka's peripheral rivers. FFWC has the capability to issue five-day flood forecasts at 54 points on 28 rivers of the country, including four locations in Greater Dhaka (MoWR 2015).⁴³ While the rivers are monitored throughout the year, flood forecasts are issued during the monsoon season. An interactive voice response system has been used to disseminate flood warnings to the public, which is quick and effective during the rainy season (MoWR 2014). BWDB does not conduct any vulnerability analysis as part of its flood risk assessments for Greater Dhaka, and thus is not in a position to issue area-specific alerts or warnings to urban communities.

FFWC has budgetary approval to employ seven employees; six positions are relevant to flood forecasting (one executive engineer, two subdivisional engineers, two assistant engineers, and two assistant programmers). At present, it has only five staff, and positions for one subdivisional engineer and one assistant programmer are vacant. Additional personnel with skills in computer programming, GIS, and remote sensing are needed. The center also needs greater capacity to employ its weather research forecast model.

Dhaka Water Supply and Sewerage Authority (DWASA)

The Dhaka Water Supply and Sewerage Authority (DWASA), which falls under the Ministry of Local Government, Rural Development, and Cooperatives (MLGRDC), is an autonomous provider of commercial services. Established in 1963, it is responsible for (i) supplying safe water to residential, industrial, and commercial consumers in Dhaka and Narayanganj; and (ii) building, developing, and maintaining sewage systems and storm-water drainage lines (DWASA 2015a). It assumed responsibility for drainage in Dhaka in 1989. Although drainage is typically a service provided by municipalities, in the 1990s DWASA was vested with the mandate since the Dhaka City Corporation (DCC) lacked sufficient capacity to provide drainage.⁴⁴ Water supply is sourced mainly from groundwater (approximately 78–87 percent) through deep tube wells. However, the authority is trying to find other sources such as from the rivers, owing to the environmental risks posed by groundwater depletion. The agency provides water at no charge to some slum areas in an effort to be pro-poor.

42. This will be strengthened through the World Bank-supported Weather and Climate Services Regional Project.

43. <http://www.ffwc.gov.bd/?id=div>.

44. Study team's communication with DWASA Managing Director.

TABLE 4.2. REVENUE INCOME AND EXPENDITURE, IN \$ MILLIONS (BDT CRORES), FISCAL YEARS 2010–14

Fiscal year	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015
Revenue income	64.44 (5,074.30)	72.99 (5,747.94)	88.43 (6,964.00)	101.24 (7,972.40)	115.71 (9,112.00)
Revenue expenditure	63.93 (5,034.30)	72.42 (5,703.07)	87.54 (6,893.56)	99.91 (7,867.60)	113.66 (8,951.00)
Profit/loss	0.57 (40.00)	0.57 (44.86)	0.89 (70.44)	1.33 (104.80)	2.03 (160.00)

Source: DWASA 2015a (converted from Bangladeshi Taka, 1 BDT = \$0.013).

ORGANIZATION, BUDGET, AND STAFF

DWASA is overseen by a board of 13 members from various professional organizations and government agencies (DWASA 2015b). The authority's managing director is supported by four deputy managing directors, each of whom heads a division: operation and maintenance (O&M); research, planning, and development (RP&D); finance; and administration. Functions relevant to flood-risk/drainage management are carried out under the first two. The DWASA service area is organized into 11 zones—10 in Dhaka and 1 in Narayanganj. O&M, revenue collection, and other functions are managed by these zonal offices.

DWASA is a profit-making agency, and its net profits increased between 2011 and 2015 (TABLE 4.2). In addition to sales, it receives budgetary allocations from the government and project funds from development partners. According to a DWASA official, funding requirements for new drainage projects are very high, and particularly challenging when it is requested to provide drainage after land is already developed by RAJUK.

CONFLICTING DRAINAGE MANDATES AND THE ISSUE OF MAINTENANCE

DWASA's storm-water network (FIGURE 4.3) comprises approximately 350 km of lines, 74 km of open canals, 10.5 km of box culverts, and pumping stations at Kallyanpur and Rampur. The storm-sewer lines grew from 275 to

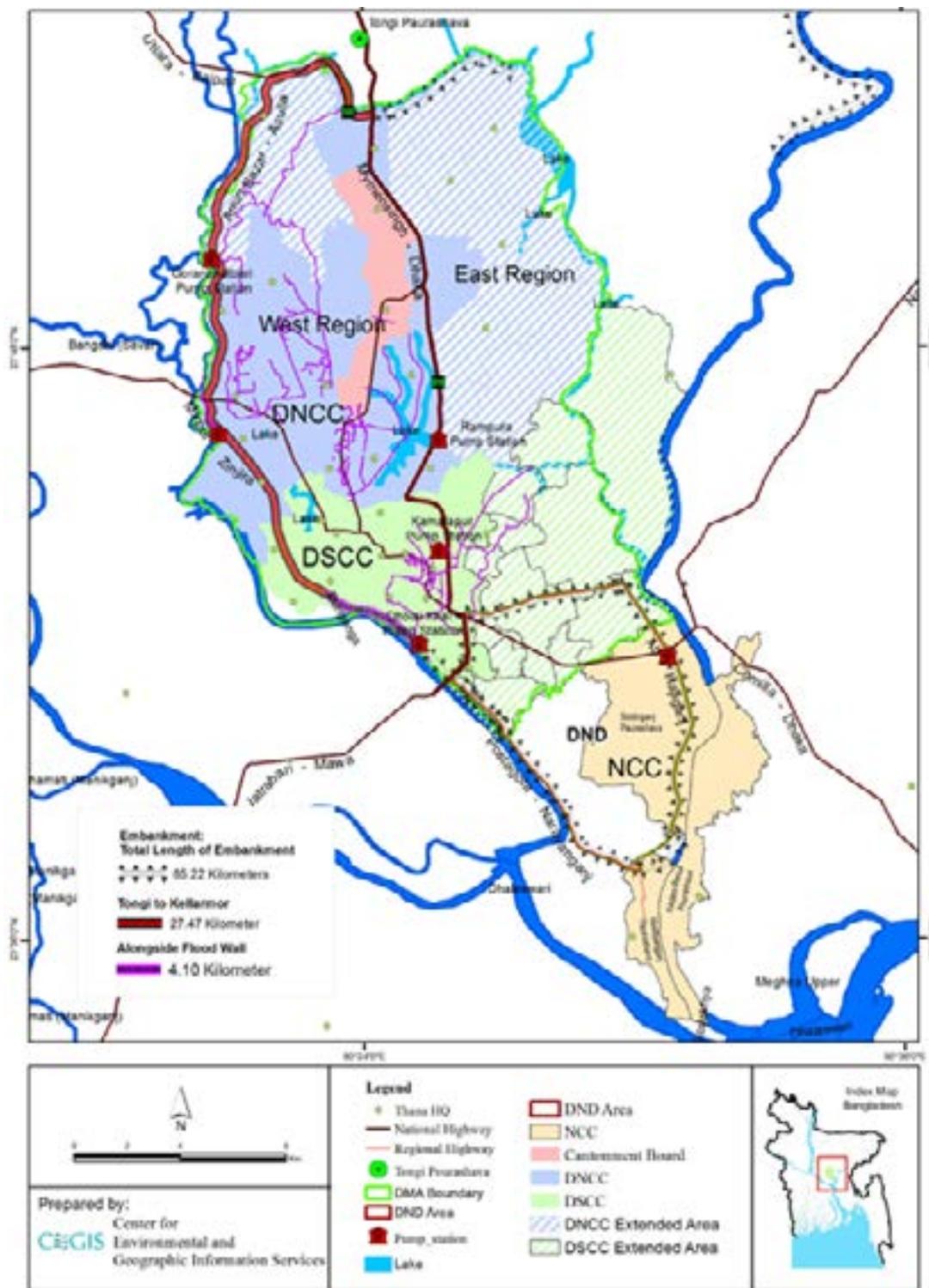
350 km between 2010 and 2015. The system is designed to drain flood waters through natural canals into the rivers surrounding the DMA. The storm-water network covers roughly 38 percent of the area of the DMA and about 14 percent of Greater Dhaka, as defined in the DAP (CEGIS analysis). In 2015, one sewage treatment plant received sewage from 926 km of sewer lines; about a quarter of the city has sewer coverage.⁴⁵

The spatial coverage of DWASA's drainage network includes only part of the area under the two city corporations and does not extend over the entire DMA or Greater Dhaka. The DND area and most of the fringe areas outside the DMA do not have a storm-water network (SEE FIGURE 4.4). DWASA also maintains the larger open canals within the DMA (DWASA 2013). In recent decades, the approach to drainage in the city has been to cordon off the city from the rivers and, when the city floods, to pump the flood water out. This approach has required significant investments in building, operating, and maintaining pumping stations.

Currently the mandate for drainage is split among several entities, among them DWASA, BWDB, and the two city corporations. Field research carried out for this report revealed a lack of clarity on which agency was responsi-

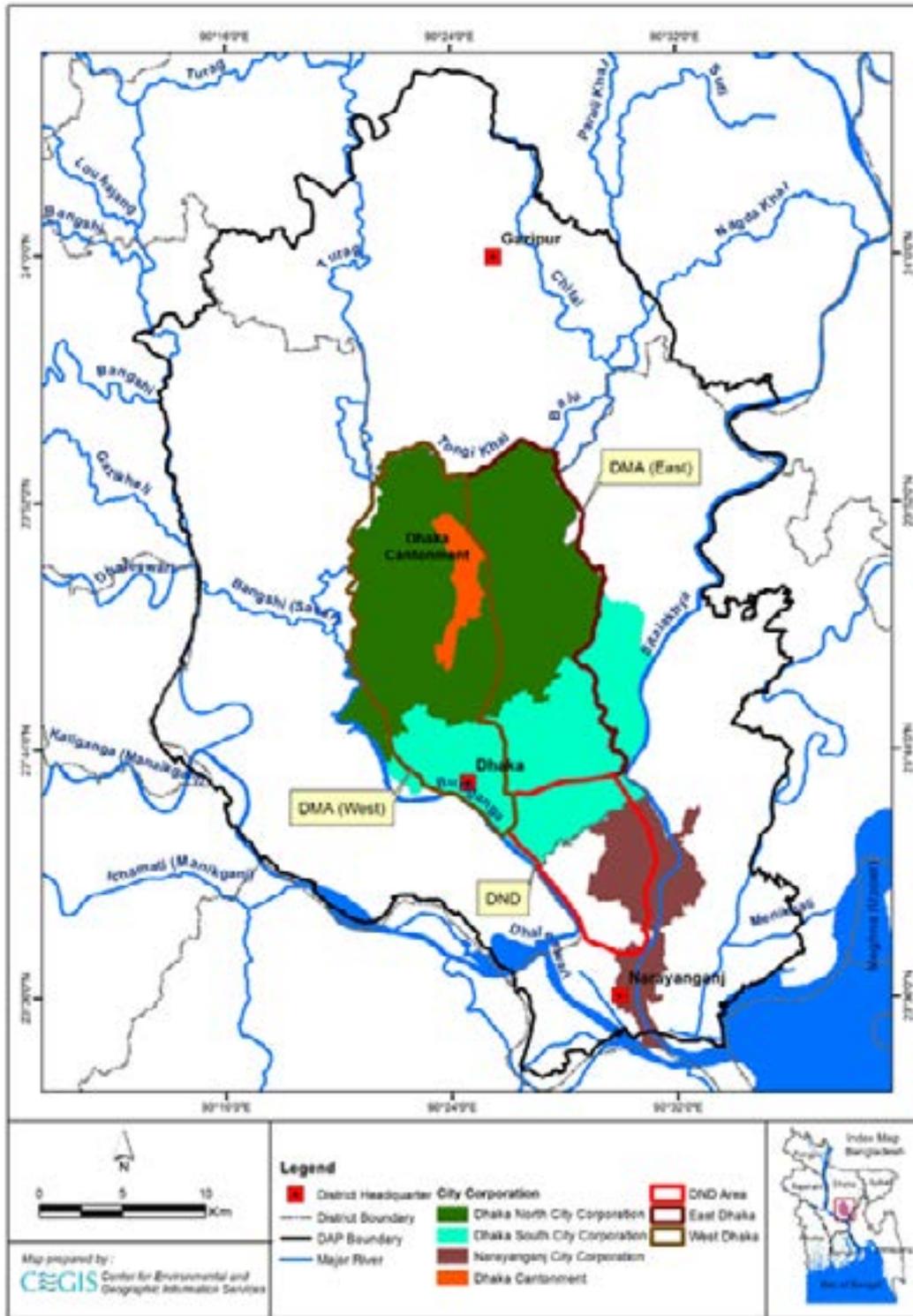
45. Consultation with DWASA officers.

FIGURE 4.4. DWASA'S DRAINAGE NETWORK IN THE DHAKA METROPOLITAN AREA



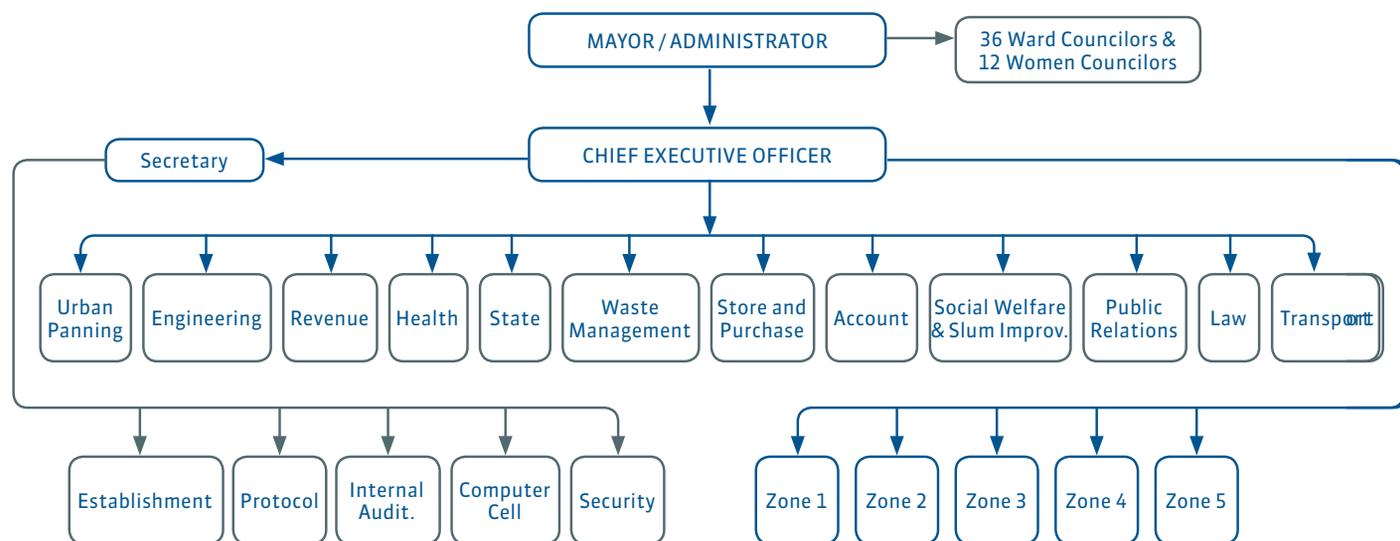
Source: Study team (based on DWASA information)

FIGURE 4.5. AREAS UNDER THE JURISDICTION OF THE TWO CITY CORPORATIONS SINCE MAY 2016



Source: CEGIS 2016.

FIGURE 4.6. ORGANIZATION OF DHAKA NORTH CITY CORPORATION



Source: DNCC 2016.

ble for maintaining the various drains within Dhaka. For example, DWASA officials suggested that DWASA maintains some of the *khals*, even though they are under the jurisdiction of the city corporations who are responsible for maintenance (but owned by the national Ministry of Land). While the city corporations are responsible for maintaining the city’s “surface-water” drains, DWASA is apparently responsible for maintaining its “storm-water” drains though, in practice, the difference is not always clear. Clearly, greater institutional clarity on the subject of drainage and maintenance is needed for any comprehensive and effective approach to urban development and flood risk management in Dhaka.

With World Bank support, DWASA has prepared a storm water drainage master plan. In 2015, DWASA had 3,242 staff (DWASA 2015a, 2015b). Most work on water supply and a smaller percentage work on drainage. While in old Dhaka the drainage and sewerage lines were combined, the newer network is mostly separate. Most of the storm water goes directly to rivers without treatment. This problem is exacerbated as

many industries in Dhaka do not have treatment plans for the effluent they generate, which goes untreated into the rivers.

DNCC and DSCC: Dhaka’s main city corporations

Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) were created in 2011 by dividing the earlier DCC (Local Government Act of 2009, Amendment 2011). DNCC and DSCC are both part of the MLGRDC. As municipal corporations, they are responsible for providing basic services—among them collecting solid waste, building and maintaining roads, street lighting, provision of public transportation and basic health facilities, and cleaning drains and sewerage lines.

Until recently, the jurisdiction of the two corporations was largely limited to Dhaka West (the western part of the DMA). In May 2016, 16 Union Parishads were brought under the jurisdiction of the DNCC and DSCC (FIGURE 4.5). (Union Parishads are the smallest

TABLE 4.3A. BUDGET FOR DHAKA NORTH CITY CORPORATION (BDT CRORES), FISCAL YEARS 2012–15

Fiscal year	2012–13	2013–14	2014–15	2015–16
Budget from central government	Not available	Not available	64.00	135.00
Revenue collection by DNCC	Not available	Not available	521.46	882.15
Development projects	Not available	Not available	140.38	476.00
Total			725.84	1,493.15
\$ million equivalent	-	-	\$9.2	\$189.8

TABLE 4.3B. BUDGET FOR DHAKA SOUTH CITY CORPORATION (BDT CRORES), FISCAL YEARS 2012–15

Fiscal year	2012–13	2013–14	2014–15	2015–16
Budget from central government	158.50	190.52	112.78	327.00
Revenue collection by DSCC	224.18	252.10	394.33	632.09
Development projects	275.51	156.29	304.35	1,635.48
Total	658.19	598.91	811.46	2,594.57
\$ million equivalent	\$83.7	\$76.1	\$103.1	\$329.8

Source: Data obtained from the city corporations.

administrative and local government units in Bangladesh.)

ORGANIZATION, BUDGET, AND STAFF

DNCC and DSCC have similar organizational structures (FIGURE 4.6).⁴⁶ Both are headed by mayors elected by the voters for a period of five years. Each mayor is supported by a chief executive officer.

Administrative and development functions are handled by the office of the chief executive officer. Each corporation has 15 departments—for urban planning, information and communication technology (ICT), engineering, revenue, solid waste management, and so on. The engineering departments are responsible for development and maintenance of roads, footpaths, and surface drains.

Both DNCC and DSCC are divided into smaller administrative areas known as wards and zones. Each ward is headed

by an elected ward councilor whose responsibilities include monitoring services at the ward level. Councilors may also submit ward-level development plans for inclusion into the corporation's development plans.

The DNCC and DSCC derive their funds from a variety of sources including taxes, markets, central government grants, and funding from development partners. In the last few years for which data are available, overall revenues of both DNCC and DSCC have increased (SEE TABLES 4.3A AND 4.3B).

The city corporations have highly limited capacity for urban planning. DNCC has about 200 staff in the solid waste division, including 3,500 support staff. About 50 staff work on drainage in the engineering division with support from 200 support staff. However, their planning division has only two technical staff, a town-planner and an architect, indicating the limited priority given to this division. Similarly, in DSCC, about 2,000 staff work on provision of solid waste while 40 staff work on drainage. Only six officials working in the planning division (including two urban planners, one geographer, one

46. <http://www.dncc.gov.bd/>.

BOX 4.2.

Solid-waste management in Dhaka

A sound system for managing the disposal of solid waste is a critical determinant of the success of any city's drainage system. However, in present-day Dhaka, the clogging of storm-water drains and manholes with uncollected waste is a primary cause of frequent, localized flooding. In Dhaka, responsibility for solid-waste disposal lies with two city corporations: Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC). The principal solid-waste activities of the corporations are street sweeping, unclogging of drains, collection of waste from designated points in neighborhoods, and conveyance of that waste to the landfill managed by the corporation. However, for both the DNCC and the DSCC, the extent of uncollected waste is substantial. According to DSCC officials, Dhaka South generates an estimated 3,300 tons of solid waste per day, only two-thirds of which (2,200 tons) is collected. Of the collected amount, 1,900 tons are processed in landfills, while the remaining 300 tons are recycled. The situation for DNCC is similar. The rapidly growing outskirts of Dhaka are not covered by the city corporations. Although authorities at the subdistrict level there (in entities known as *upazilas*) are nominally in charge of waste management, in most cases no formal solid-waste collection system has been established.

A national strategy for waste management (National 3R Strategy for Waste Management) has been developed by the Department of Environment in the Ministry of Environment and Forests. In 2005, a Solid Waste Master Plan for Dhaka was conceived to transform the municipal solid waste management system. It set out to develop a participatory waste-management program, build government capacity to collect and transport waste, modernize and expand disposal sites, and improve administrative and financial management.

To address the issue of solid waste management in Dhaka, the waste management departments of the DNCC and DSCC should adhere closely to the national strategy and the citywide master plan. There is also a need to develop a recycling strategy to reduce the need for primary and secondary solid waste collection.

sociologist, and two researchers) alongside three office assistants. Here too, relatively little importance is given to planning.

The urban planning divisions of the two city corporations focus on tasks such as ward-based GIS mapping; approval of multistoried (6, 10, and up) buildings; management of on-street car parking; road naming and name plate setup; representing DSCC in national exhibitions; site development schemes, including development of sites or erecting/re-erecting of a building or any plot of land covered by the master plan; city beautification; publishing DSCC's yearly reports; restrictions, regulations, and prohibitions on the development of sites and the erection/re-erection of buildings within the city; regulation of building controls; heritage and risky building identification and development; and the renaming of roads/infrastructures. The urban planning departments are not directly involved in flood-risk mitigation. The above indicates the limited attention to spatial planning placed by both urban planning divisions under the two city corporations.

Most important, it is unclear how planning undertaken by the two city corporations relates to the planning functions undertaken by RAJUK. Typically, the office of

planning is under the mayor's office. In Dhaka that is not the case and there is a disconnect between planning functions and municipal service delivery functions.

ACTIVITIES RELEVANT TO FLOOD RISK MANAGEMENT

The two corporations' major tasks related to flood risk management are (i) construction, improvement, and maintenance of surface drains within their jurisdiction (including slum areas); and (ii) solid waste management (box 4.2)—both of which are essential to relieving the drainage congestion that contributes to waterlogging in the city. DNCC's website states that the engineering department is also tasked with the development of low-lying areas, though it is unclear what this entails and how it relates to RAJUK's activities.

When the fieldwork for this study was conducted, the corporations were considering preparing drainage master plans for the city. At present, however, neither corporation has a long-term strategic plan for addressing flood-risk mitigation. Coordination of drainage management with DWASA's activities is also unclear.

FIGURE 4.7A. ONGOING FILLING OF LOWLANDS IN DHAKA EAST



Source: Study team (October 2016).

FIGURE 4.7B. SAND MINING FOR CONSTRUCTION ACTIVITIES IN DHAKA EAST



Source: Study team (October 2016).

BOX 4.3.

Hatirjheel Lake: A case study in interinstitutional cooperation

Despite the institutional fragmentation noted above, the Hatirjheel project in Dhaka stands out as a good example of institutional coordination. The estimated \$250 million Hatirjheel-Begunbari Integrated Development Project was initiated in 2007. The project aimed to enhance the capacity of the locale to retain storm water by transforming a wastewater canal into a freshwater lake with recreational facilities for city dwellers, while also connecting the northern and southern sides of the lake with roads, bridges, and viaducts. The concept for the project, which began in 2008 over an area of 122 hectares and is nearing completion, was based on a technical study commissioned by RAJUK and carried out by the Bureau of Research, Testing and Consultation of the Bangladesh University of Engineering and Technology.

Owing to its multisectoral nature, several agencies worked closely on the project. The Ministry of Housing and Public Works was the lead ministry. RAJUK was the main implementing agency. To facilitate interagency communication and cooperation, a steering committee of project directors from the partner agencies was established, chaired by the minister of Housing and Public Works. Participating agencies had clear mandates. RAJUK was responsible for acquiring the land (and for compensating the previous owners), excavating the site, and building waste disposal infrastructure. The local government's engineering department executed the designs for a two-lane road along the lake, a footpath, a bridge, overpasses, and landscaping. The Dhaka Water Supply and Sewerage Authority (DWASA) built the storm water and sanitary drainage system and water supply network. The Bangladesh Army provided overall supervision during project implementation (Hatirjheel Project Office 2015, personal communication).

It is important to note the role of local research in this context. The university provided the architectural and structural designs for the drainage systems, the traffic system, lowland excavations, and roads and walkways. Detailed studies were carried

out by the Bureau of Research, Testing and Consultation to estimate the retention capacity of Hatirjheel needed to protect adjoining areas from flooding and water-logging during the monsoon season. Detailed surveys were undertaken to identify private and government-owned land within the project area, and land acquisition proposals were prepared for the storm-water retention area. Plans were designed to excavate and remove sludge and to divert domestic and industrial sewage (pre-

viously discharged into the lake) through new sewers to be built along the periphery of Hatirjheel. These diversion structures and an associated sewage treatment plant will be constructed by the Bangladesh Army near the main inlet point.

Land acquisition was a major challenge. Of the total 122 hectares required, only about 32 hectares had been acquired prior to the project. Another 57 hectares were privately owned, and 33 hectares were so-called *Khas* land (land redistributed under earlier land reforms). Evic-

tion of illegal occupants of the land caused delays in implementation of the project.

One of the main lessons from the project is that cross-sectoral coordination is possible, given the high-level support at the ministerial level. In this case, a steering committee chaired by a senior minister and clear demarcation of responsibilities were instrumental in achieving coordination among agencies. Another lesson is that strong prior technical work and support from local universities were crucial in providing technical support to the project. Third, the case shows the importance of planning. Finally, strong monitoring (by the Army in the case of Hatirjheel) was also critical in the success of the project.

Source: Study team.



INSTITUTIONAL CHALLENGES

Analysis carried out for this report reveals multiple institutional issues that need to be addressed. First, there is overlap in mandates for urban planning and land use between RAJUK and the two city corporations. The city corporations can prepare master plans for the development, expansion, and improvement of any area within the city (Local Government Act of 2009). They can also prepare land-use plans, undertake site-development schemes, and regulate housing. These powers contradict and overlap RAJUK's mandate and need to be resolved. Second, current lines of reporting and vertical accountability are misaligned and create institutional inefficiencies. RAJUK reports to the Ministry of Housing and Public Works, whereas the two city corporations operate under the authority of the MLGRDC. Thus, even when it relates to local government/urban issues, RAJUK does not have to be accountable to the MLGRDC. It is also harder to resolve issues across ministries than within a ministry. This creates various institutional redundancies.

Third, there are discrepancies between planning zones and legal jurisdictions. While RAJUK makes land-use plans for the entire DAP area (that is, Greater Dhaka), DNCC and DSCC prepare plans and deliver services in jurisdictions that are subsets of that larger area. This has critical implications for the management and service delivery of the entire DAP region. Finally, as noted earlier, there is also *overlap between RAJUK and DWASA in drainage management*. Consultations carried out for this report revealed significant disagreement about which agency was responsible for the drainage system and its maintenance, typically done by a single municipal agency.

The Union Parishads, the DND area, and cantonment boards

THE UNION PARISHADS

A large part of Greater Dhaka falls outside of the jurisdiction of the DNCC and DSCC and is governed by approximately 77 Union Parishads, which are the smallest administrative and local government units in Bangladesh. Union Parishads cover more than 70 percent of the DAP area (CEGIS analysis). Under the Local Government Ordinance of 1997, Union Parishad members are publicly elected. Their functions include agricultural, industrial, community, and development activities. They do not manage flood risk or have any capacity for planning within their jurisdictions. This critical issue must be considered as the Greater Dhaka area is developed and urbanized.

THE DHAKA-NARAYANGANJ-DEMRA AREA

Although the formerly agricultural Dhaka-Narayanganj-Demra (DND) area falls within the DMA, until recently, it was not serviced by any city corporation but rather by *upazilas* (which are subunits of districts) and Union Parishads. In May 2016, some parts of the DND area came under the jurisdiction of the DSCC. It is too early to tell how service delivery may change as a result. The rest of the DND area continues to fall under the jurisdiction of Union Parishads. The area is now highly congested and bound on all sides by embankments topped by roads. Because of the embankments, even moderate rains result in waterlogging.

With rapid urbanization, the earlier institutional arrangements for the provision of basic services have ceased to work. At present, DSCC and the Narayanganj City Corporation (NCC) provide some basic civic services to parts of the DND area. DWASA is providing water supply and sewerage in the DND area to some extent. Management

of the pumps at Shimrail is undertaken by BWDB. The area urgently needs to be brought under and serviced by municipal administration.

CANTONMENT BOARDS

There are three cantonment areas in Greater Dhaka: Dhaka (SHOWN IN FIGURE 4.1), Gazipur, and Savar. Each is governed by a board. The cantonment boards began as a way of providing services to military families cantoned in the area. The Dhaka Cantonment Board, for example, began providing services in 1951. The boards have sole responsibility for a number of municipal services within their boundaries, such as operating schools and hospitals; providing streetlights; building and maintaining parks, roads, and mosques; and building and managing sewage and drainage facilities. They also work in tandem with the Defense Officers Housing Society, but their coordination with other agencies responsible for municipal services or flood control (RAJUK, DWASA, DNCC, DSCC) is limited. The boards have their own short-, medium-, and long-term plans that are generally not shared with the public or other agencies.

The cantonment boards are headed by executive officers, under whom branches operate for administration, taxes, water, electricity and so on. The engineering and civil works branches are responsible for spatial planning, facilities and structures, construction, and maintenance of the road and drainage networks. It was not possible to determine if they have any capacity for flood-risk assessment or take it into account in residential planning and housing development.

As statutory bodies akin to local governments, the boards must cover their own expenses. It was not possible to infer from available budget figures whether the boards had the ability to manage drainage.

Other institutions and the private sector

Other agencies have an indirect influence on flood risk management and preparedness in Dhaka (appendix B).

The Department of Disaster Management under the Ministry of Disaster Management and Relief is responsible for response and relief. The Bangladesh Inland Water Transport Authority under the Ministry of Shipping and Inland Water Transport is responsible for controlling inland water transport in the country including Dhaka.

The Local Government Engineering Department under the MLGRDC is mandated to develop, implement, and maintain small-scale water projects across Bangladesh. Its functions relate to the development and maintenance of urban infrastructure—such as sewerage, roads and footpaths, small flood-control embankments, sluice gates, culverts, rubber dams, and canals (LGED 2014)—with obvious implications for flood control.

Since the 1950s, the Ministry of Land (which has had different names at different times) is entrusted with land management for the country. Its objectives include settlement of state-owned lands (*khas* lands), *sairatmahals* (*jalmahal*, *shirmpmahal*, and so on), vested properties, and abandoned properties. The ministry has begun a national land-zoning project that will likely affect flood risk management in Dhaka and the rest of the country (MOL 2016).

The Department of Haor and Wetland Development under the Ministry of Water Resources is responsible for the integrated development of Bangladesh's wetlands.⁴⁷ However, it does not manage or oversee urban wetlands in the DMA or DAP area. Private developers play a very active

47. *Haor*: A bowl-shaped wetland ecosystem in the northeastern part of Bangladesh. Also known as a back swamp. *Baor*: An oxbow lake formed by dead arms of rivers; commonly identified as freshwater wetlands.





role in Dhaka's urbanization and thus shape the city's long-term flood risks. Amid rural-urban migration, demand for housing in Dhaka is high and rising. Because land is relatively cheap in Dhaka East, private land developers are purchasing low-lying lands and wetlands there and building housing (FIGURE 4.7A AND 4.7B). RAJUK does not appear to have exerted effective control over such purchases or the ensuing development activities. Recent field research for this study revealed that more than 300 housing projects were under way in the DMDP area—most located in flood-flow zones and in violation of the DMDP's flood-zone policies (Alam 2014). Many of the developers and projects are informal (Quium 2007).

In Greater Dhaka, housing on land that is six meters or above sea level tends to be protected from waterlogging. For this reason, developers tend to fill land to approximately that height. Survey results published in 2014 indicated that 41 percent of the housing projects in the DMDP area raised the height of land by 3 meters; in 21 percent of projects, lowlands had been raised by 7 meters (Alam 2014). Owners, too, may raise the elevation of their land after buying it from a developer. Despite these efforts, interviews with plot owners showed that the areas continued to experience waterlogging (Alam 2014).

All of these observations point to the need for improved enforcement of existing regulations governing wetlands and flood-flow zones.⁴⁸ Subdivisions on the urban periphery are an affordable housing solution for low- and middle-income groups. But urbanization has outpaced effective government regulation. Withholding official acknowledgment of newsubdivisions on the grounds that do not conform to planning regulations poses a dilemma for families who have acquired housing there and seek equal protection of the law. ■

48. <http://www.theguardianbd.com/land-use-of-dhaka-metropolitan-development-plan-area-past-and-present-scenario/>.



SUMMARY

- **The above analysis highlights that for Dhaka, there is no integrated flood risk management plan.** The Structure Plan (1995–2015) and the DAP (gazetted in 2010 and valid till 2016 with a one-year extension) have de facto been used to make decisions about land use, but without a comprehensive implementation plan or a coordinated approach to managing flood risk. The analysis further highlights the following key institutional issues that need to be addressed:
- **The Town Improvement Act that governs planning in Dhaka is outdated and needs to be revised on a priority basis.** The Town Improvement Act (1953) was prepared over 60 years ago and bestows enormous powers to RAJUK with little public accountability, and needs to be revised.
- **No overarching municipal agency is mandated to provide services within Greater Dhaka, resulting in institutional dysfunction and inadequate service delivery.** Until recently, the two city corporations DNCC and DSCC together had jurisdiction over only some of the DMA. Significant parts of the DMA, DND area, and Greater Dhaka (outside the DMA area) were, until recently, not under any municipal jurisdiction. Outer parts of Greater Dhaka and the DND area were and even now continue to be governed by Union Parishads. If indeed the plan is to develop the entire area under the Detailed Area Plan into an integrated urban area, it would make sense for the government to bring the entire area under one or more municipal corporations.
- **Disconnect between planning functions and service delivery.** Contrary to good practice, where planning offices and functions typically fall under the purview of



the mayor,⁴⁹ in Dhaka, planning is carried out by RAJUK with little contribution from the planning offices of the DNCC and DSCC. The two city corporations have planning departments but with limited human resources and technical skills needed for planning.

- **The chairman of RAJUK is not elected and hence not accountable to citizens.** The chairman of the very powerful agency RAJUK is appointed and not elected like a mayor and has little accountability to the public. Yet, RAJUK is in a position to undertake extremely important decisions about land use, water bodies, and housing that directly affect the citizenry on a regular basis. This leadership structure requires reform to enable greater public accountability.
- **The agencies involved in urban planning and municipal service delivery lie within different ministries and have different accountability structures.** RAJUK reports to the Ministry of Housing and Public Works. On the other hand DNCC, DSCC, DWASA, and the Union Parishads report to the MLGRDC. BWDB falls under the Ministry of Water Resources. Thus at a ministerial level, RAJUK has no accountability to the MLGRDC even though its activities directly affect municipal and local governance. This accountability structure needs to be reformed. Stronger mechanisms are also needed to ensure horizontal coordination between agencies in different ministries.
- **The boundaries—and service responsibilities—of the two city corporations have been expanded without adequate planning or additional resource allocations.** Since

49. One example of this is Washington, DC, where the DC office of planning is under the mayor.

May 2016, additional parts of Dhaka East and the DND area have come under the jurisdiction of the two city corporations. Neither city corporation has a long-term strategic plan for drainage or flood risk management. The capacity of both for planning, financing, and implementation will have to be enhanced if they are to meet their expanded mandates, notably in the area of drainage provision. The Unions Parishads that provide services in the rest of Greater Dhaka have very limited capacity for flood risk management.

- **Contradiction between RAJUK’s regulatory and development roles.** RAJUK issues licenses for land use and building construction to private land developers, but it also develops land for its own account with no clear oversight. Published research and consultations reveal that RAJUK has undertaken development activities in low-lying areas (for example, Purbachal, the Jhilmil Land Development Project) in violation of its own plans. The agency’s contradictory roles need to be addressed and clear and transparent accountability mechanisms need to be put in place.
- **Even though RAJUK is a profit-making organization, provision of housing for urban poor is not its priority.** RAJUK’s development activities primarily cater to the urban middle and upper class. Provision of affordable housing for the urban poor is a major gap.
- **Ad hoc incorporation of flood risk into implementation of the DAP.** In Dhaka, multiple agencies are involved in activities that have a bearing on flood risk management. However, there is no integrated flood risk management plan or any mechanism for coordination between RAJUK, DNCC, DSCC, BWDB, or DWASA. As such, the incorporation of flood risk concerns into the implementation of the DAP happens on an ad hoc basis. Any future infrastructure decisions, such as the Eastern Bypass, should be considered within the context of a flood risk management and urbanization strategy for the entire Greater Dhaka area.
- **Urban water bodies lack clear ownership; maintenance of natural canals and river systems has been neglected.** While DWASA maintains some khals and waterways that are part of its drainage network, it is unclear which agency is ultimately responsible for managing and protecting Dhaka’s lakes, water bodies, and canals; maintaining (and not just monitoring) water quality; and preventing encroachment and dumping. Regular maintenance is essential for these lakes to effectively function as retention areas and if water is to drain adequately during monsoon season. Likewise, regular dredging of the

surrounding river system, a BWDB mandate, is not given sufficient priority by the agency.

- **Responsibility for drainage is split across multiple agencies.** In Dhaka, some pumping stations are operated by DWASA, others by BWDB. Storm-water drainage is provided by DWASA, while DNCC and DSCC manage surface-water drains. However, there is little coordination between DWASA and the two city corporations on drainage maintenance. BWDB, DWASA, RAJUK, DNCC, and DSCC, and the Upazilas often implement their projects in isolation from the others. Overlapping development, with implications for drainage and waterlogging, creates disruptions particularly in the monsoon season.
- **Current drainage provided by DWASA covers only 38 percent of the DMA.** Although DWASA has a noteworthy task of providing water supply, sewerage, and drainage services, its drainage services cover only 38 percent of the DMA and are absent from most of Greater Dhaka and the DND area. Drainage coverage needs to be expanded, especially in Dhaka East, before further urbanization occurs. No overarching agency is presently responsible for the provision of drainage, sewerage, or wastewater treatment in those parts of Greater Dhaka where DWASA does not operate.
- **RAJUK lacks the information base to undertake proper land-use planning and zoning.** It does a poor job of engaging with the public and consulting with local governments and communities during plan preparation. Strengthening planning capacity and ensuring public participation will be essential in improving urban resilience in Dhaka.
- **Insufficient focus on urban weather early warning systems.** The Flood Forecasting and Warning Center (FFWC, under BWDB) is set up to assess river floods. But because Dhaka is also vulnerable to intense rainfall, BMD's capacity for forecasting needs to be strengthened, as does FFWC's capacity to undertake impact-based forecasting to help target communities at risk and help them prepare in advance for flood events.
- **Absence of constructive engagement and partnership with private developers.** At present, private developers are openly filling up land and developing low-lying areas. There is no coordinated mechanism for public sector agencies and private sector agencies and developers to address the problems of urbanization, including flooding. Such a mechanism needs to be developed.



5 · Conclusion and Recommendations





The complex institutional landscape shaping flood risk management has long-term implications for strengthening urban resilience in Dhaka. As chapter 2 shows, Dhaka is at high risk of flooding and this is expected to increase with climate change and variability. Urbanization in Dhaka has been accompanied by a significant decline in the city's wetlands and waterways. This affects the conveyance capacity, navigability, and water quality of its water bodies, with significant implications for flood risk management. It is unclear which agency owns the city's wetlands and waterways or is responsible for maintaining these. As chapter 3 shows, the public sector's response to managing flood risk has mainly been in the form of infrastructural investments. Further, these have been most often in reaction to extreme weather and flood events and not as a result of a comprehensive, integrated, and participatory urban planning or flood risk management process. To some extent, flood infrastructure in Dhaka has contributed to reshaping the nature of the city's hazards. While before the construction of the western embankment in the 1990s, the main hazard facing Dhaka West was flooding from high river water and heavy rain, now the hazard in Dhaka West is primarily urban flooding and waterlogging resulting from suboptimal drainage. Dhaka West continues to be at high risk due to intense rain and river flooding.

Flood infrastructure has also been an important driver of urbanization. For instance, in the Dhaka-Narayanganj-Demra (DND) area, it has helped transform what was a primarily agricultural area in the mid-20th century to a messy, congested urban area today. It enabled rural migrants to settle, leading to urbanization and densification, even though there was no systematic municipal governance or provision of urban services in the DND area. Due to institutional issues and limited investments in maintenance of urban water bodies, drainage canals, and infrastructure, parts of the internal waterways (particularly in the western and southern parts of the city) are also disconnected from the outer river

system. This connectivity between the internal natural drainage network and surrounding river system needs to be restored.

Disconnected from urban planning, flood management infrastructure has put Dhaka onto a path that needs significant adjustment. Infrastructure has been erected without a full understanding of its consequences, with comparatively little attention to planning, zoning, enforcement, forecasting, and early warning systems: critical "nonstructural" tools that can help the city manage people, land, and resources in a more balanced way. This scenario, where infrastructure investments are made to manage flooding before or in a manner disconnected from urban planning can be referred to as an "infrastructure trap" facing Dhaka city today.

Given this scenario, what are the options for managing flood risks as urban expansion continues unabated in Greater Dhaka? How can the city innovate? As the case of Singapore shows, transformative solutions are possible (SEE BOX 5.1).

For Dhaka, the answer lies in (i) undertaking difficult but priority institutional and organizational reforms; (ii) moving towards innovative approaches to managing flood risk using eco-engineering/nature based solutions, early warning systems, land use planning and zoning (discussed below), instead of relying mainly on infrastructure based approaches and (iii) shifting away from a reactive approach to addressing flood risk fully as part of an integrated and participatory urban planning process. These are summarized in TABLE 5.1 and further discussed below.

BOX 5.1.

Singapore's urban reform

The transformation of urban Singapore provides important insight into how cities in developing countries can transform themselves. In the 1960s, Singapore faced many of the problems that Dhaka faces today: a declining river system, increasing slum settlements, limited wastewater treatment, and poor waste collection.

The city's reform process took decades and involved a multitude of institutional, structural, and nonstructural measures. A planning committee was set up and chaired by the housing authority. An extensive planning exercise brought stakeholders together to consider possible options and strategies, after which an integrated planning system was put in place. An interagency committee on rivers was then set up and significant funding invested in cleaning up the rivers. A multiagency land-use plan was prepared, with the requirement that it be reviewed every five years by a steering committee.

These steps were accompanied by building design plans at the plot level. Strong emphasis was placed on water rationing and reuse. The city made a commitment to maintain its green cover, requiring every building to replace the green cover it eliminates. There is a strong emphasis on public transportation and bicycle paths.

The reform was accompanied by investments in public housing and strong support for home ownership. Financing mechanisms were also set up to support housing.

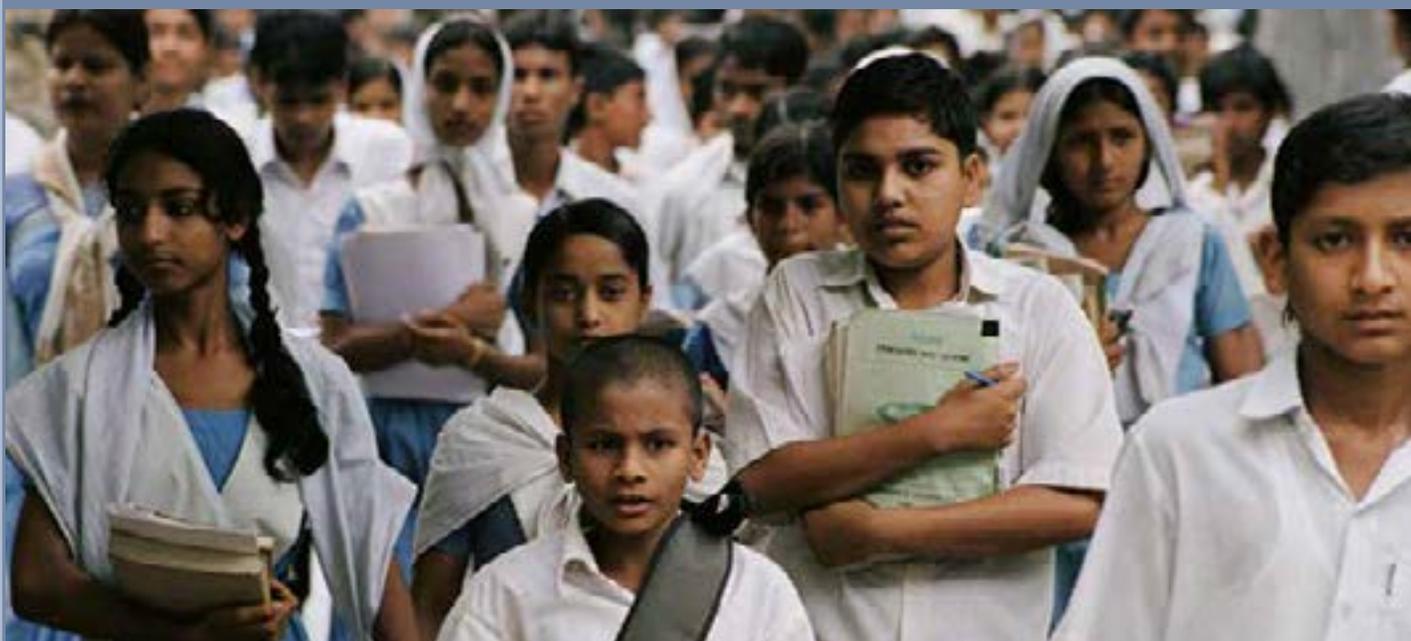


TABLE 5.1. SUMMARY OF KEY REFORMS AND INVESTMENTS

Policy and institutional reforms	Organizational strengthening	Enact Eco-Engineering measures in Greater Dhaka
<ul style="list-style-type: none"> • Bring DMA (including DND area) fully under municipal management • Revise outdated Town Improvement Act (1953); Resolve RAJUK's Development and Regulatory functions through policy reform • Clarify planning functions of RAJUK and City Corporations • Prepare zoning policy, laws and regulations • Clarify City Corporations' mandate for oversight of urban water bodies and waterways • Prepare updated DAP including zoning policies, regulations, and integrated flood risk management plan for DAP area • Consolidate drainage under DWASA 	<ul style="list-style-type: none"> • Establish interministerial steering committee on wetlands and rivers • Substantially improve planning capacity in City Corporations • Strengthen DNCC and DSCC capacity for monitoring and enforcement of development activities • Strengthen RAJUK's monitoring capacity 	<ul style="list-style-type: none"> • Revitalize <i>khals</i>, lakes, and water bodies • Dredge surrounding river system regularly (BWDB) to improve connectivity of urban wetlands and river system across DAP area • Strengthen early warning systems and flood management information systems • Modernize/improve design of flood infrastructure • Extend drainage to entire DMA • Improve solid waste management • Undertake eco-engineering investments in designing new infrastructure

Recommendations for institutional and organizational reform

INSTITUTIONAL AND POLICY REFORMS

Revise outdated Town Improvement Act (1953). One of the priority actions going forward is to reform the outdated Town Improvement Act (TIA). The TIA was approved over 60 years ago and should be revised to take into account the current realities, level of urbanization, institutional arrangements and challenges facing Dhaka. The revised Act should address the conflicting powers bestowed to RAJUK and similar planning agencies in other major urban areas in Bangladesh. Revision of this Act could also become a blueprint for addressing the disconnect between urban planning and municipal service delivery in other major cities in Bangladesh.

- **Reform RAJUK by clarifying planning functions and moving its monitoring and development functions to city corporations.** RAJUK presently plays the triple

role of planner, developer, and regulator—a built-in conflict of interest. Moreover, planning and city management functions are divorced. Planning is done by RAJUK, while municipal services are provided by DNCC and DSCC. To address this disconnect, it is recommended that RAJUK be mainly responsible for Structural Planning and zoning. The city corporations will be responsible for more detailed planning, zoning and enforcement within their areas of jurisdiction. Moreover, development and monitoring functions should be moved out of RAJUK and undertaken by the municipal corporations. Private entities can also be engaged in provision of housing. RAJUK's main mandate would be to undertake comprehensive planning for Greater Dhaka in an integrated way, in coordination with the city corporations, *upazilas*, and communities. The realigned RAJUK should also prepare a zoning policy for the Greater Dhaka area which currently does not exist. It would also be responsible for coordinating with the existing (and future) city corporations to ensure that all zoning laws prepared by the city corporations are consistent with the

overall plan for Greater Dhaka. RAJUK should become a hub of public information on land use and spatial plans, including databases, risk maps and maps of water bodies for the entire Detailed Area Plan.

- **Establish an interministerial committee on Dhaka's rivers, urban wetlands, waterways, and drainage.** One of the main challenges in land and flood management in Greater Dhaka is maintaining the urban wetlands, water bodies, *khals*, and drainage facilities within Dhaka, as well as the river system surrounding the city. To address this issue, an interministerial committee on rivers, urban wetlands, and waterways is recommended. The committee would provide oversight on the activities of relevant agencies. The BWDB would continue to be responsible for river dredging and DWASA for maintenance of canals and storm water drainage. The city corporations would be responsible for maintaining urban water bodies (notably lakes) through issuance of land-use plans and zoning ordinances. This committee would report to the prime minister's office and work closely with RAJUK and the city corporations. It would comprise representatives of BWDB; the city corporations; the Ministry of Housing and Public Works; MLGRDC; the Ministry of Water Resources; DWASA; the Department of Environment, and Upazila Parishads. It would meet on a quarterly basis and be responsible for ensuring that high priority and oversight be placed on the management of the urban river system, wetlands, and ecology, in support of sustainable urbanization.
- **Bring the DND area and Dhaka East under municipal management.** Until May 2016, Dhaka East and DND area were not under the jurisdiction of any municipal agency and were urbanizing haphazardly. Instead of an ad hoc approach to urbanization, East Dhaka and the DND area should be brought fully under municipal control to ensure systematic management of land, resources, and services.

- **Consolidate drainage under DWASA.** At present, the Dhaka Water Supply and Sewerage Authority (DWASA) provides drainage services to 38 percent of the DMA. This should be expanded to the entire DMA at a minimum and eventually to all of Greater Dhaka—that is, to the entire area covered by RAJUK's Detailed Area Plan. A basic drainage network should be in place as land is being prepared and serviced for housing construction. Responsibility for the construction and maintenance of drainage should be consolidated under DWASA, which has much more experience providing the services.
- **Legislation to task the city corporations with management and oversight of urban lakes, wetlands, and water bodies.** At present, no agency is clearly responsible for ownership, management, and maintenance of urban wetlands and waterways. Appropriate policy and legal measures need to be put in place to clearly assign this responsibility to the city corporations. Since the mayors are elected officials, it will enable greater commitment to this vital urban resource that can have numerous benefits for improving the quality of life beyond flood risk mitigation.

RECOMMENDATIONS FOR ORGANIZATIONAL REFORMS

- **Strengthen the human resource and planning capacity of the city corporations.** The capacity of the planning departments of the DNCC and DSCC should be strengthened. The city corporations should be responsible for preparing—and able to prepare—detailed land-use plans and zoning ordinances consistent with Greater Dhaka plans. To support this, staff capacity and resources allocated to the planning departments should be strengthened. The two departments should work in close collaboration in the interest of consistency. This approach would allow the city corporations to have more discretion

BOX 5.2.

Lessons from Case Studies

Case study analysis of eco-engineering approaches to flood risk mitigation in New Orleans, Portland, Rotterdam, Singapore, Beira and Ho Chi Minh City have important lessons to offer. They show that efforts to use eco-engineering based approaches were accompanied by important institutional reforms. In Singapore, for instance, they were part of an overall reform process to improve livability and sustainable urbanization that took decades to unfold and involved numerous legal and regulatory changes, strengthening planning, inter-agency coordination, and allocation of funds for major tasks such as cleaning rivers. In all cases, a change of thinking about how to address flood risks was involved and required strong political will.

The cases demonstrate the many benefits of eco-engineering beyond flood risk mitigation. In New Orleans, storm water drainage focusing on the principals of retaining and reusing water can help reduce the load on the drainage system, allow improved water circulation and also help improve water quality. In Portland, retrofitting streets through the Green Streets program has helped reduce sewer overflows and water pollution. Eco-engineering measures are context specific and involve important partnerships between public and private sector institutions and local communities. Even though the measures may be small (e.g. rain gardens, permeable paving, water harvesting), when applied over a large area can have significant benefits and be cost effective (see appendix A).



over planning and land use within their areas of jurisdiction. Monitoring of land development, oversight of water bodies, and monitoring of filling functions should also be placed under the city corporations, as they are best placed to monitor activities within their jurisdiction. Because mayors are elected officials, this option would introduce a significant measure of accountability into the planning and zoning system. Staff capacity for monitoring land use and water bodies in their areas of jurisdiction should also be enhanced.

- **Prepare new Detailed Area Plan based on a participatory process and accompanied by zoning policies and regulations.** RAJUK has prepared a Structure Plan, a draft of which is available. A new Detailed Area Plan (to succeed the earlier one) is apparently under preparation. Given past problems in implementation, and the time lag between the preparation of the Structure Plan and the past Detailed Area Plan, this process should be expedited. Further, the new Detailed Area Plan should be prepared for the entire area to be covered, and with public consultation and input. Moreover, the new plan should be accompanied by clear zoning policies and regulations.
- **Demarcate areas into zones and prepare local area plans and zoning regulations.** The entire area covered by the Detailed Area Plan should be divided into zones and the city corporations should prepare local area plans and zoning laws/ordinances for each zone based on a participatory process in accordance with the updated plan. In the past, even though the Detailed Area Plan was gazetted, RAJUK or the city corporations did not prepare a zoning policy or regulations. Without these, it was extremely challenging to implement or enforce the plan and manage densification, housing development, or urban growth. Going forward, this will be essential.
- **Enhance investments in early warning systems and develop systems that are tailored to the hazards facing specific areas of Dhaka.** Enhance investments in early warning systems and develop systems that are tailored to the hazards facing specific areas of Dhaka. Different areas of Dhaka face different types of hydro-meteorological hazards—Dhaka East and the fringe area are mainly exposed to river floods and rainfall; DND and Dhaka West are mainly vulnerable to rain-induced waterlogging. These require tailored early warning systems. The capacity of the Bangladesh Meteorology Department (BMD) to provide short duration rain alerts and early warnings should be strengthened through improving rainfall monitoring and radar systems.⁵⁰ This will particularly support users such as BWDB and DWASA and residents of the Dhaka West and DND areas. Further, BWDB's Hydrology Unit should set up a Flood Risk Information System for developers and the public.⁵¹ Flood risk maps can support preparation of flood zoning regulations for the entire area and help identify areas more or less prone to flooding. These flood maps should be made available to the public and to planning agencies in Dhaka to inform planning and zoning. The Hydrology Division of BWDB should strengthen its capacity for location specific forecasts for Dhaka, specifically Dhaka East, including impact-based forecasting. These measures would greatly help to manage flood risk in Dhaka.⁵²
- **Allocate sufficient funding to maintenance.** Extensive investments in infrastructure require proportionate long term but routine investments in maintenance. While it was difficult to determine the amounts

50. This is being underpinned by the World Bank-supported Weather and Climate Services Regional project.

51. For an example of such a system, see <http://fris.nc.gov/fris/Home.aspx?ST=NC>

52. A recently effective (May 2017) World Bank project is expected to support BMD's and BWDB's forecasting services for Dhaka.

allocated for maintenance by BWDB and the city corporations, it was evident that given the state of the river system in urban waterways, the investments in maintenance are not sufficient. This needs to be enhanced.

- **Strengthen engagement and partnership with private developers.** At present, private developers are openly filling up land and developing low-lying areas. There is no mechanism between public and private sector agencies and developers to address the problems of urbanization, including flooding. Such a mechanism needs to be developed.

Recommendations for eco-engineering approaches to flood risk mitigation

In many of the world's cities, flood risk mitigation has tended to rely on infrastructure-based solutions. There is a growing realization that while these are needed in many instances, they are not necessarily the optimal solution and may increase flood risk.⁵³ Among recent approaches to flood risk management, “eco-engineering,” “green defense,” or “green adaptation” stand out as some of the most innovative (see appendix A). Briefly, these concepts refer to the use of eco-system functions to provide protection from flooding, food and freshwater security, and sustainable livelihoods (Hulsman & Maarse 2010). They involve maintaining and restoring natural ecosystems and the services they provide; protecting vital functions such as water flow and quality; and reliance on natural barriers for flood protection (Hulsman & Maarse 2010). In the Netherlands, where they have been pioneered, they have guided initiatives such as the Room for the Rivers program.⁵⁴ Case study analysis (see box 5.2) shows that

they can be used in conjunction with hard engineering approaches to water management, can be cost effective compared to infrastructure approaches and are vital to climate resilience.

In Dhaka, as discussed in chapter 3, flood risk management has emphasized embankments, flood walls, pumps, box culverts, and sluice gates, despite which waterlogging remains a regular problem both in Dhaka West and the DND area. Further, the connectivity between the internal waterways and canals, wetlands, and river systems has been compromised and needs to be reestablished to manage flood risk.

Building on lessons from ongoing international efforts, the application of eco-engineering solutions in the context of Dhaka implies consideration of the overall connectivity of the hydrological system across the city's urban catchment, ensuring the connectivity of the internal waterways with the surrounding river system, and balancing structural and nonstructural interventions. The focus should be to revitalize the natural urban canals and water bodies, dredge the peripheral river system, expand the storm-water drainage network, promote innovative infrastructure design, prioritize maintenance, and maintain links between the internal waterways and peripheral river system. Within this broader framework, specific measures could be taken in major areas of Greater Dhaka, as described below.

MEASURES FOR DHAKA WEST

The western part of the DMA has developed as an unplanned urban area since the 1960s. Although flood-control infrastructure was constructed by BWDB after the catastrophic floods of 1987 and 1988, maintenance of that infrastructure has not been adequate. Many of the sluices are not functioning efficiently. Illegal encroachment of natural canals and wetlands and unplanned construction

53. <https://www.gfdr.org/sites/default/files/publication/role-of-flood-risk-management.pdf>.

54. <https://www.huduser.gov/portal/periodicals/em/winter15/>

[highlight3_sidebar.html](#).

of housing and industries have complicated maintenance of canals. The high price of land and the absence of a long-term vision, integrated planning, and coordination among relevant agencies have further exacerbated the problem of waterlogging.

The flood and drainage infrastructure maintained by BWDB, DWASA, and the two city corporations consists of embankments, flood walls, sluice gates, and a storm-water drainage network (box culverts, pipes, drains, and pumps). DWASA's drainage system covers only 38 percent of the DMA, not enough to meet the requirements of the area. The peripheral river system also plays an important role in draining storm water from the area, as these rivers are linked with the internal natural canals of the city and with the outer river system of Greater Dhaka. Connectivity of the waterways must be maintained and protected from encroachment if they are to drain the area properly at all times.

Within this overall framework, the following measures can be taken in Dhaka West:

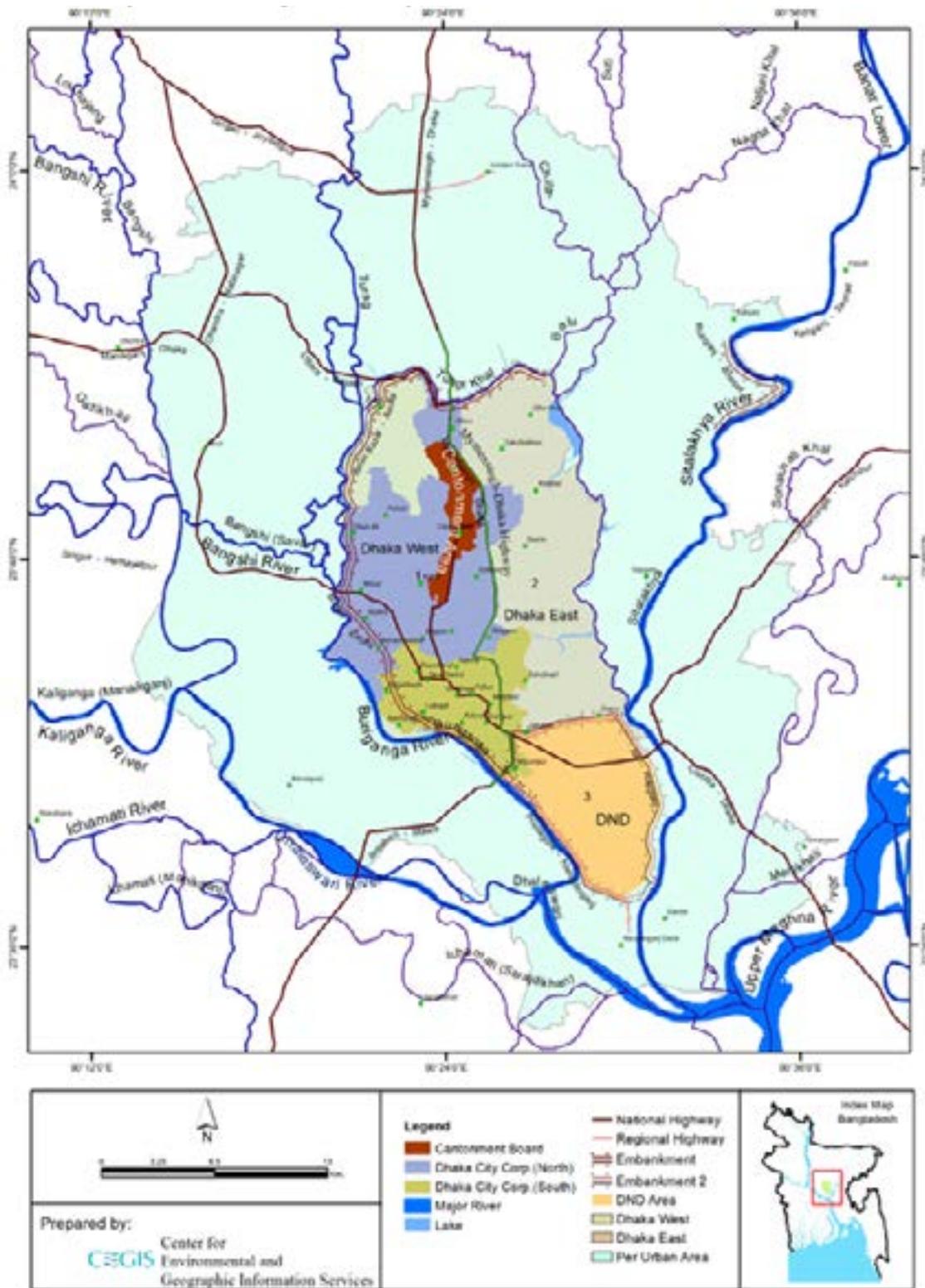
- **Revitalize silted up or encroached khals.** *Khals* that are crucial for proper drainage should be revitalized. These include at least the following *khals*: Katasur, Hazaribagh, Ibrahimpur, Kallyanpur, Abdullahpur, Ramchandrapur, Baunia, Digun, Diabari, Dholai, Rayerbazar, Baishteki, and Shahjahanpur (FIGURE 5.2). Highly degraded from dumped waste and illegal encroachment, these *khals* must be reexcavated.⁵⁵ Preliminary analysis based on results from a hydrodynamic model for the DAP area developed by CEGIS indicates the required minimum width of *khals* that will be needed to improve flow (APPENDIX B, TABLE B.1).
- **Introduce eco-engineering options on the canal network.** Both sides of the natural *khal* network should

be protected against encroachment through eco-engineering options, such as building perforated sidewalks and a 2–3 meter green strip on both sides of the canal. Eco-engineering can potentially help convince residents to use the sides of the canals for walking instead of encroaching upon them to build dwellings (as evident in the case of Hathirjheel). This can also enhance the recreational value of the *khals*.

- **Dredge peripheral rivers.** BWDB should undertake regular dredging of the surrounding rivers. The Buriganga, Turag, Balu, and Tongi Khal rivers must be dredged regularly to maintain their conveying capacity, environmental flow rates, and connectivity with *khals*. All peripheral river systems have to be revitalized because of the interconnected nature of rivers.
- **Create a buffer zone.** A buffer zone must be created to protect the Dhaleswari, Bangshi, Turag, Tongi Khal, and Buriganga rivers and so facilitate the smooth passage of flood flows. All of these rivers enter Greater Dhaka from both sides; many are connected to the Jamuna on the west. A minimum width for the buffer zone is proposed in APPENDIX B, TABLE B.2. The zone must be protected and preserved by a low embankment that would store flood water up to a certain limit and during the monsoon season. In the dry season, the floodplain inside the embankment could be used for recreational purposes.
- **Expand storm-water drainage.** All of Dhaka West should be covered by a properly maintained storm-water drainage network. Regular cleaning of the network will lessen congestion after high-intensity, short-duration rainfalls.
- **Preserve water retention areas for pumping stations.** Water retention areas for the pumping stations of Dhaka West should be preserved and converted into permanent wetlands, thus promoting eco-tourism and attenuating flood peaks during extreme events.

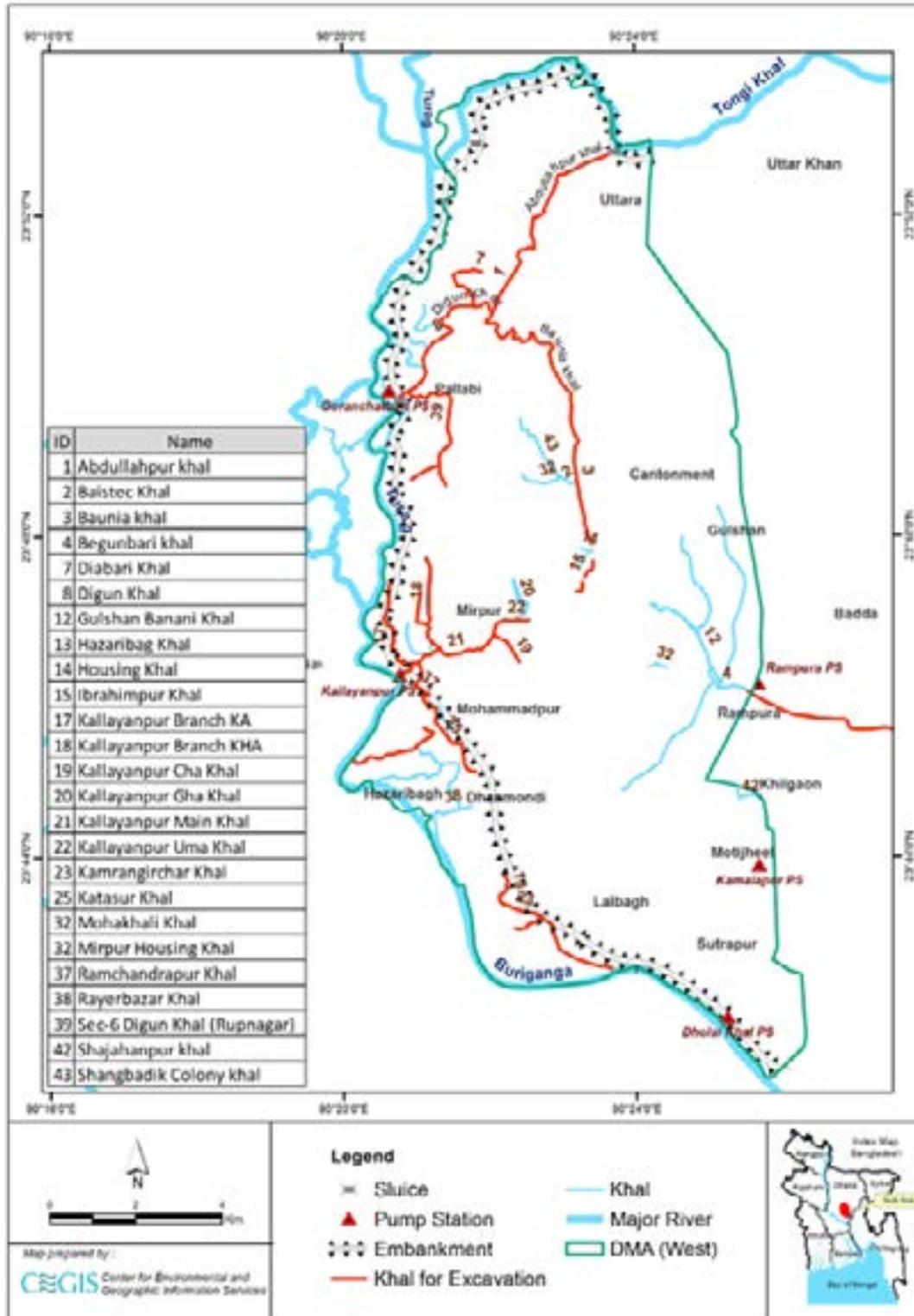
55. The depth and width would need to be determined through follow-up studies.

FIGURE 5.1. HYDROLOGY OF LAND COVERED BY THE DETAILED AREA PLAN



Source: Study team

FIGURE 5.2. PROPOSED KHALS TO BE EXCAVATED AND REVITALIZED IN DHAKA WEST



Source: Study team

- **Reclaim and revitalize lakes.** The artificial lakes of Dhanmondi, Banani, and Uttara must be cleaned under DWASA supervision to increase their retention capacity. Recreational facilities should be modernized to promote eco-tourism.
- **Establish a central, eco-friendly solid waste management system to convert waste into green fertilizer.** This measure would lessen waste dumping in natural canals and storm-water drains and reduce clogging and silting.
- **Undertake design improvements in flood infrastructure.** Design improvements in existing infrastructure are needed. For instance, 11 sluice gates (or regulators) currently operate in Dhaka West. Most are manual and very heavy to operate. Furthermore, their size is narrower than the natural canals, which limits the flow of water. Modernizing these sluices would enhance their efficiency. Improvements in the efficiency of pump operations also offer energy efficiency gains.
- **Clean box culverts.** All box culverts should be cleaned regularly by DWASA to maintain connectivity with natural canals and promote the smooth flow of water.

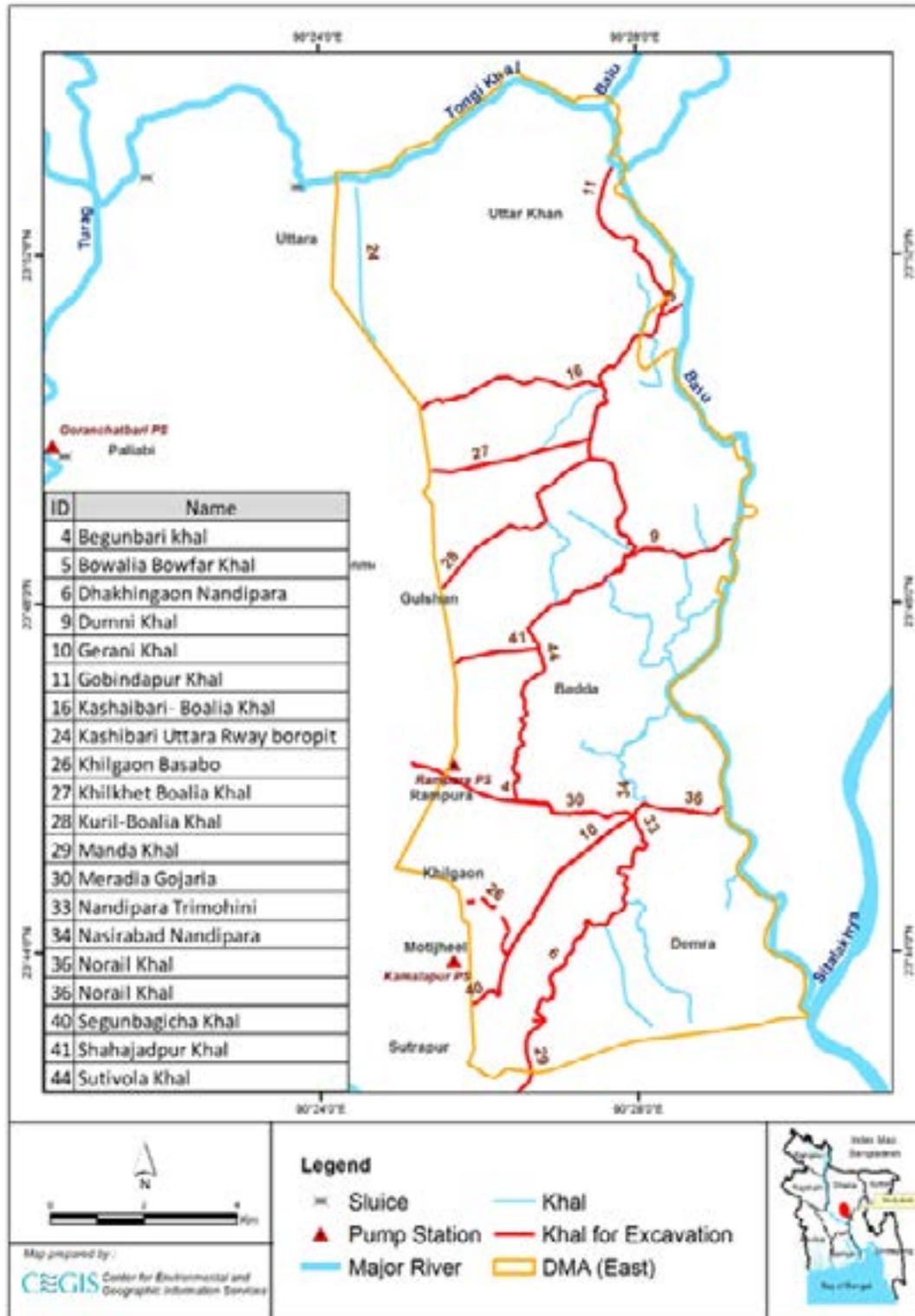
MEASURES FOR DHAKA EAST

At present, Dhaka East is very different from Dhaka West in terms of its hydrology, population density, institutional arrangements, and access to drainage and sewerage. This area is not yet controlled against river flooding, nor does it have a storm-water drainage system. It is primarily drained by isolated depressions, natural canals, and the river system. However, in the absence of any municipal organization to provide services to this area, limited land-use zoning, and limited oversight by RAJUK, the area is being used for haphazard landfilling and urbanization. This needs to be urgently addressed if Dhaka is to embark on a more sustainable development path.

As a first step, the area should be brought under full municipal oversight and administration so that it can be managed and serviced in a planned way. Land-use planning and zoning in Dhaka East should be compatible with planning for the entire DAP area. Drainage should be expanded in the area in accordance with land-use and zoning plans—that is, before the land has been developed and provided with roads, water, and other services. To maintain Dhaka East’s connectivity with the river system, the following measures can be undertaken.

- **Revitalize and protect natural canals.** Natural canals (FIGURE 5.3) must be revitalized and protected to maintain water flow and establish connectivity with the river system. The *khals* in question include the Zerani, Manda, Meradia-Gazaria, Koshai Bari, Shahjahanpur, Shahjadpur, Sutivola, Dumni, Boalia, Rampura, Govindapur, Segunbagicha, Norail, Begunbari, and Khilgaon-Basabo, which are degraded and should be reexcavated on a priority basis. Their estimated minimum width, based on modelling analysis carried out by CEGIS, is indicated in APPENDIX B, TABLE B.3.
- **Mark and protect canals through “green adaptation.”** These natural canals can be protected from encroachment by creating a 2–3 meter green strip that will increase the ecosystem value of the canals.
- **Create a buffer zone for the Balu and Lakhya rivers.** This zone should be protected and preserved using a low embankment to store flood water to a certain limit during the monsoon season and to prevent encroachment. In the dry season, the floodplain inside the embankment can be used for recreational purposes. FIGURE 5.4 is a cross-sectional view of a river section with a low embankment (doubling as a walkway) and buffer zone. The design section of the embankment should be fixed after further technical studies. Vegetation can be implanted over the embankment to provide living space for aquatic species during the monsoon. A strip of vegetation 4–5 meters

FIGURE 5.3. PROPOSED KHALS TO BE EXCAVATED AND REVITALIZED IN DHAKA EAST



Source: Study team.

wide can be planted on the outer side of the embankment.

- **Dredge peripheral rivers.** The rivers surrounding eastern Dhaka, specifically the Shitalakhya and Balu, should be dredged regularly to allow water to flow smoothly. Interconnection of peripheral rivers and tidal effects in the above-mentioned rivers partially control the flow of the peripheral river system, especially during the dry season. Therefore, regular maintenance dredging is necessary to maintain the dynamic of the river system.
- **Promote eco-tourism by protecting wetlands.** Wetlands and waterbodies retain water and serve as eco-tourism sites. Some wetlands preservation zones are shown in FIGURE 5.5.
- **Deploy innovative eco-engineering measures.** Eco-engineering measures such as planted drainage channels, plaza planters, rainwater harvesting, and permeable paving should be undertaken to enhance urban development in this area.
- **Integrate the installation of a storm-water drainage network with overall spatial planning.** The connectivity of the storm-drainage network with natural khals should be properly monitored and maintained. Regular cleaning is mandatory for proper functioning of the network.

MEASURES FOR THE DHAKA-NARAYANGANJ-DEMRA AREA

The low-lying DND area is one of the most vulnerable to flooding, at present and in the context of future climate scenarios (Dasgupta et al. 2015). It is situated between the Buriganga River to the west and Sitalakhya to the east, and lies in the flood plain of the Meghna River. Most of the former agricultural lands have become unplanned residential and industrial areas. The DND area is encircled by embank-

ments and floodwalls. Roads top the embankments. The pumping station at Shimrail drains water from the DND area into the Shitalakhya River.⁵⁶ The natural runoff to the canals has been disrupted by unplanned settlements, and the drainage canals built by BWDB to carry water toward the pumping station are badly dilapidated and clogged owing to unauthorized encroachment and solid waste.

Although some areas within the DND area have recently come under management of DSCC, most of the area does not enjoy any basic services. DWASA does not operate a storm water drainage network in the DND area. Consequently, drainage congestion has become a major problem that exacerbates flood risk in this area (Islam and Haque 2005). About 87 percent of the area becomes affected by waterlogging and inundation with a depth of 1–3 meters during moderate storms. It is also one of the areas most at risk of inundation owing to climate change (Dasgupta et al. 2015).

To address waterlogging issues, the DND area should come under municipal administration, with clear responsibilities for provision of basic services.

Within the framework of an integrated approach to land use and hydrology for Greater Dhaka, the following measures can be undertaken in the DND area (FIGURES 5.6 AND 5.7).⁵⁷

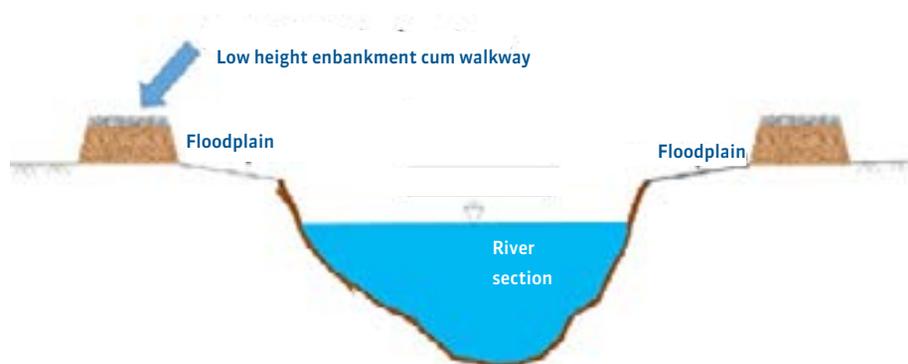
- **Reexcavate and maintain canals.** The BWDB should reexcavate the major drainage canals in Pagla, Fatulla, and Shampur, as well as other primary and secondary drainage canals and protect them against encroachment along their full length of 45.4 kilometers. The

56. The pump was originally constructed for irrigation purposes. It used to allow access to water from the river system to irrigate land. Its operation was reversed to drain out water and is used for flood management purposes.

57. Some of these measures have also been proposed by feasibility studies carried out by CEGIS, RRI, and Development Design Consultants (DDC) under the Drainage Improvement of DND project (BWDB 2010).

FIGURE 5.4. USING A LOW EMBANKMENT AS A BUFFER ZONE ALONG RIVERS

Source: Study team.



canals should be regularly maintained. The regulatory authorities should protect the canals from illegal encroachment.

- **Build green strips and fencing.** Two to three meter green strips with green fencing could be developed on both sides of the canals to infiltrate water into the ground. The strips would prevent erosion, dissipate wave energy, and discourage encroachment. They could also be used for recreational purposes.
- **Practice land-use zoning and enforcement.** The area should be divided into zones depending on their vulnerabilities (for example, high risk of waterlogging) or essential uses (for example, water retention). Some very low-lying parts of the DND area are still free of housing or other infrastructure and are submerged throughout the year. Any future development of these areas should be subject to risk zoning and enforcement.
- **Ensure preservation of a minimum wetland area.** At least 20 percent of the area should be declared by RAJUK as permanent wetland for water-retention purposes.

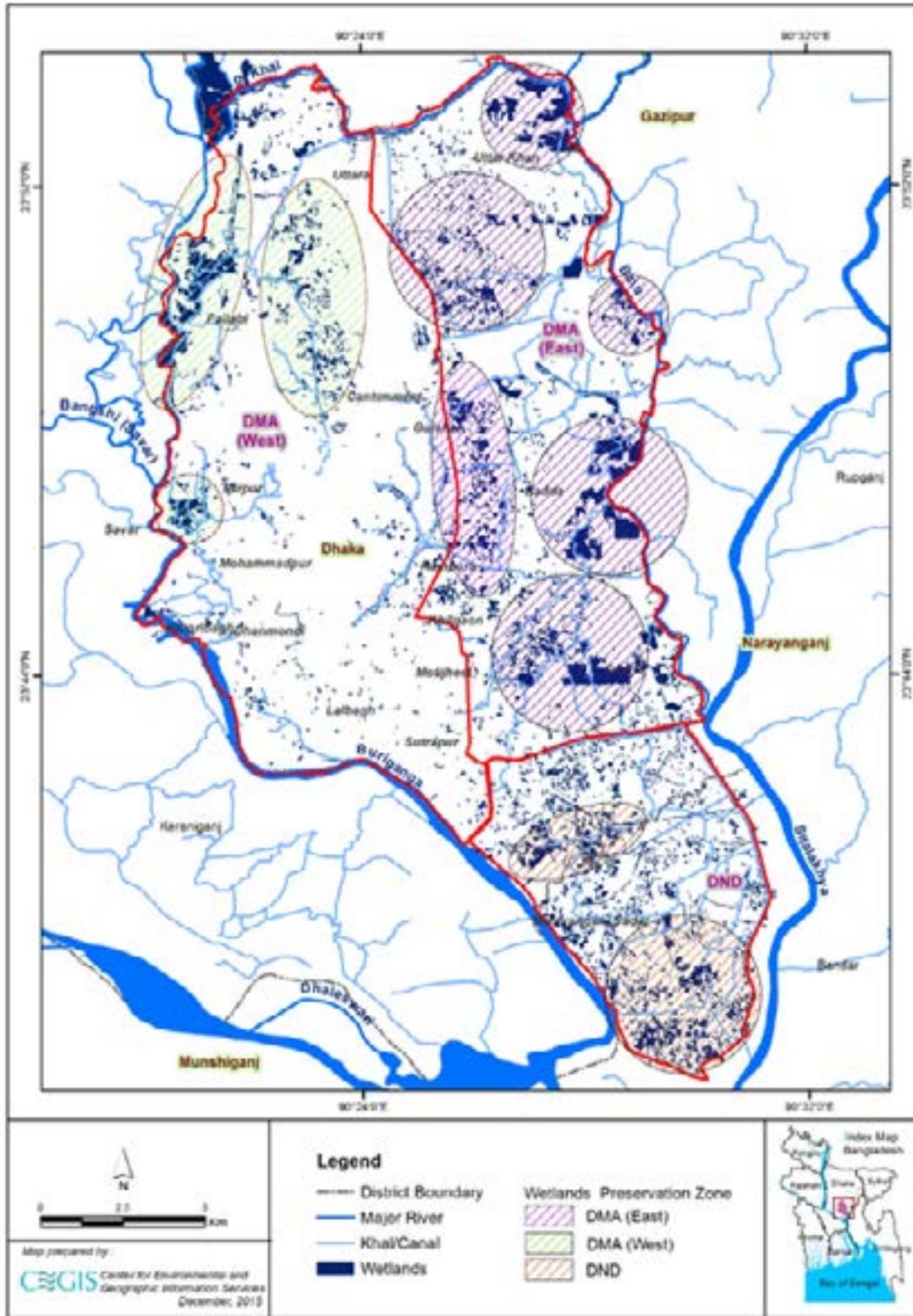
This should be done in full compliance with the recently developed Structural Plan.⁵⁸

- **Provide for storm-water drainage.** A piped storm-water drainage network should be established to handle storm water for the entire area. DWASA should be made responsible for maintaining and cleaning this drainage network.⁵⁹
- **Increase pumping capacity and efficiency.** The present pumping station at Shimrail (four pumps with a total pumping capacity of 14.52 cumecs) is not sufficient to evacuate excess water from the area. The capacity and efficiency of the station should be increased and additional stations installed at other locations (for example, Adamjinagar, Pagla, Fatulla).
- **Maintain the existing embankment.** The existing 31 kilometers of embankment (topped by a road) should

58. https://www.rajukdhaka.gov.bd/rajuk/image/slideshow/Dhaka_Structural_Plan.html.

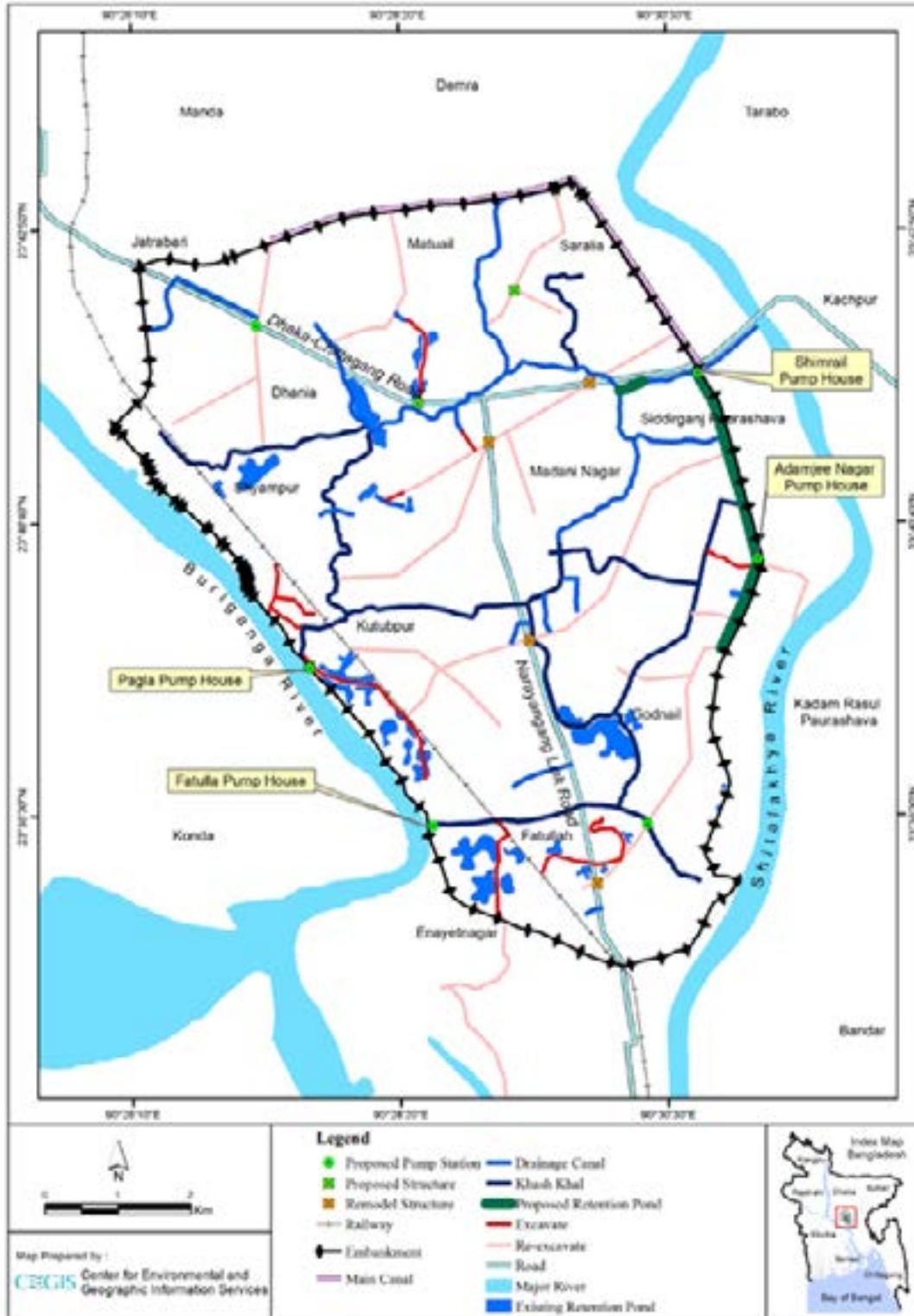
59. This could be done building on existing design studies.

FIGURE 5.5. PROPOSED WETLAND PRESERVATION ZONES



Source: Study team 2016.

FIGURE 5.6. PROPOSED MEASURES FOR THE DHAKA-NARAYANGANJ-DEMRA AREA



Source: Study team 2016.

be strengthened to protect the entire DND area from river flooding. The embankment should be maintained by BWDB.

- **Improve the design of existing infrastructure.**

Existing hydraulic structures should be remodeled and renovated using an eco-engineering approach. For example, eco-concrete (with rough surfaces that become overgrown with algae) could replace ordinary concrete in new hydraulic structures, providing space for fish and other aquatic species while enhancing the filtration capacity of water. Regulators and sluices should be automated to increase their efficiency.

- **Create buffer zones.** On both sides of the Lakhya River, buffer zones could be established to increase carrying capacity and discourage encroachment of the riverbank.

MEASURES FOR AREAS COVERED BY THE DETAILED AREA PLAN BUT OUTSIDE THE DHAKA METROPOLITAN AREA

The lands covered by the DAP but outside the DMA extend over 1,130 square kilometers, most of them suburban and semi-developed but also including

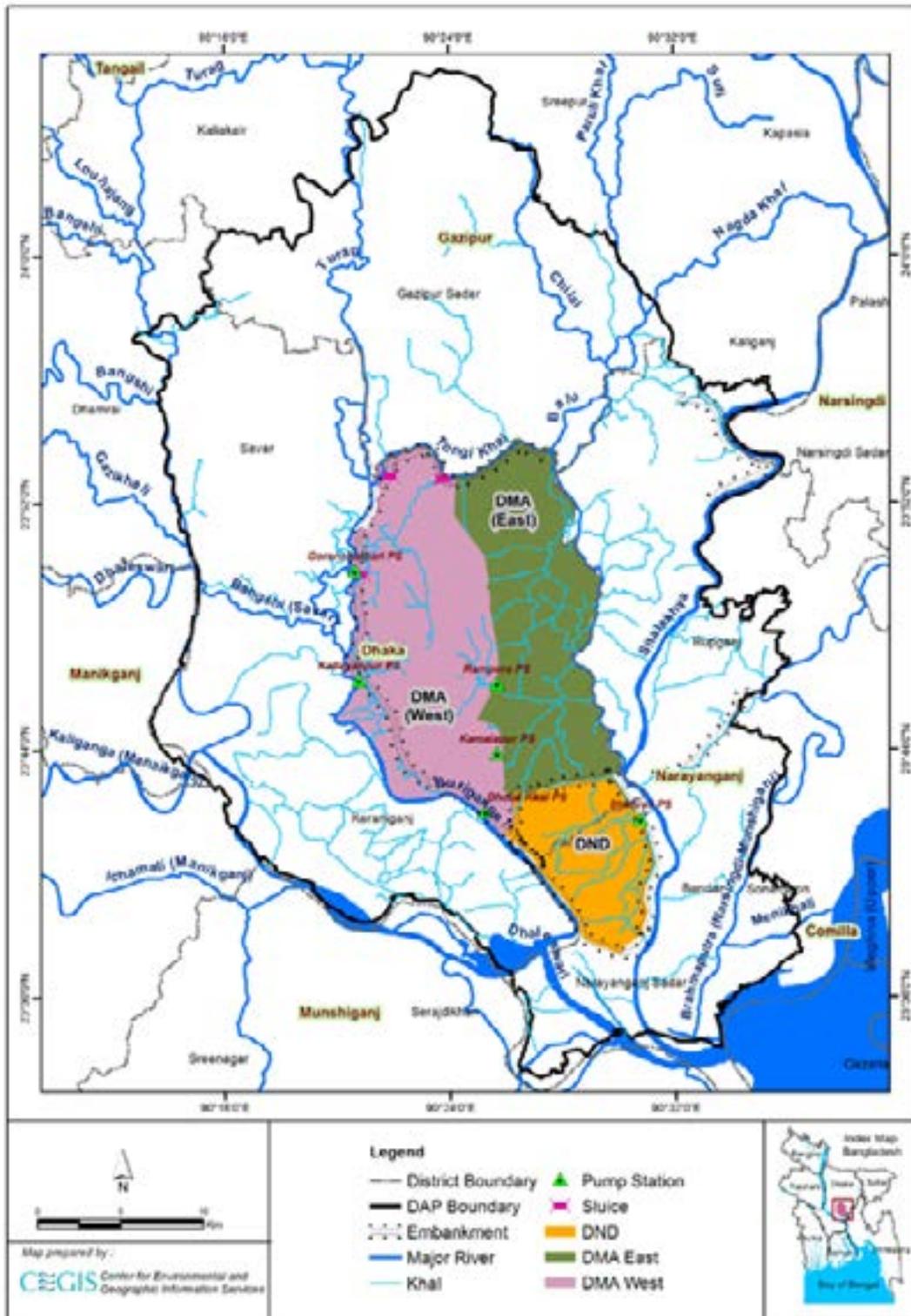
lowlands, rivers, floodplains, and agricultural lands.

Flooding of the area is still controlled by the major rivers (Old Brahmaputra, Jamuna, Bangshi, Dhaleswari, Kaliganga, Gazikhali, Ichamati, Chilai, Suti, Sitalakhya) and their many tributaries. No storm water drainage network exists in this area; it is drained by wetlands, natural depressions, and canals. Expansion of Dhaka to accommodate a growing population will pose immense pressure on this area. To ensure that urbanization is not unplanned and self-defeating, the following eco-engineering measures should be taken (FIGURE 5.7):

- **Dredge peripheral rivers.** The area's peripheral rivers (Bangshi, Dhaleswari, Kaliganga, Ichamati, Chilai, Sitalakhya) should be dredged regularly by BWDB and their connectivity maintained.⁶⁰
- **Maintain the existing canals.** Existing natural canals should be protected from illegal encroachment brought on by unplanned urbanization. Provision should be made for green strips 2–3 meters wide along both sides of the canal to prevent encroachment and increase the canals' ecological value.
- **Protect and preserve the area's wetlands.** The municipal corporations should acquire enough land to preserve and protect these wetlands from encroachment. ■

60. Studies carried out by CEGIS estimate dimensions of buffer area for Bangshi, Dhaleswari, and Lakhya.

FIGURE 5.7. PROPOSED BUFFER ZONE FOR MAJOR RIVERS OF GREATER DHAKA



Source: Study team 2016.



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APPENDIX A. ECO-ENGINEERING FOR FLOOD RISK MANAGEMENT: PROFILE OF SELECTED CASE STUDIES

The eco-engineering approach to water management in delta regions

Flood mitigation is one of the greatest challenges for delta areas such as Dhaka. To meet those challenges, flood-prone cities around the world are turning to integrated, sustainable, and adaptive solutions. These include variations of the Green Water Defense approach to adaptive water management in delta regions. This appendix briefly describes the underlying approach to eco-engineering and profiles six cities that are translating this approach into action.⁶¹

A number of terms are used to suggest the integral, sustainable, and adaptive approach to water management. All stress the importance of working with nature and making use of natural functions in human interventions for the benefit of both the human and the natural systems (BOX A.1).

In the eco-engineering or Green Water Defense approach, used interchangeably in this report, structural measures move beyond hard-engineered structures such as flood defenses and drainage channels to include more natural and sustainable measures such as wetlands and natural buffers. The “nonstructural” measures aim to protect

people from flooding through better planning and water management.

Case studies

The Green Water Defense or eco-engineering concept has been demonstrated in a wide range of applications, six of which are profiled in the case studies below. These experiences have shown that Green Water Defense can be cheaper than traditional solutions and often are more cost-efficient because they serve multiple purposes.

NEW ORLEANS: GREATER NEW ORLEANS (GNO) URBAN WATER PLAN

The U.S. government pledged more than \$100 billion to rebuild the city of New Orleans after it was struck by Hurricane Katrina, possibly the largest natural disaster in the history of the United States (Costanza et al. 2006). Rebuilding the city provided an opportunity to reconsider flood-risk mitigation. The traditional approach to storm-water management—a forced drainage system with levees—is resource-intensive, inflexible, and insufficient (GNO Urban Water Plan 2013). The system’s three main defects were found to be (i) insufficient capacity (leading to overflows); (ii) subsidence caused by pumping; and (iii) exclusion of water from public spaces by levee walls, which diminished the value of the area’s waterways and water bodies as public assets (GNO Urban Water Plan 2013). Indeed, forced drainage is considered the primary cause of subsidence in the region which, in combination with a rise in sea level, increases the vulnerability of the urban area.

61. A detailed review of eco-engineering approaches to flood risk mitigation was undertaken as part of this study. An abbreviated version is presented in this appendix and the detailed review is available upon request.

BOX A.1.

Defining eco-engineering approaches to water management

Eco-engineering: The design of sustainable ecosystems that integrate human society with its natural environment to stimulate both (Mitsch & Jorgensen 2003).

Green adaptation: Adapting to climate change by embedding natural functions in land and water use planning in order to not only strengthen livelihoods and support development, but also to enhance ecosystem health (Hulsman et al. 2011).

Green infrastructure: Green infrastructure is the strategically planned network of high-quality green spaces (EU 2012). The Environmental Protection Agency in the United States uses the term green infrastructure for its approach to using vegetation and soil for managing storm water runoff on the spot in local communities (EPA 2013).

Green Water Defense refers to the use of ecosystem-based measures in an integrated, holistic approach to flood-risk reduction (Marchand et al. 2012). As promoted by the World Bank, the United Nations Environment Programme, and other institutions and organizations, Green Water Defense is based on the concept of “green growth” as an alternative to traditional methods of flood protection.



Developed by a consortium of American and Dutch partners, the GNO Urban Water Plan addresses all three defects through an approach that focuses on adapting to water rather than defending from and excluding it, retaining water rather than draining it as fast as possible, and making water visible. It is based on a series of hydrological, ecological, and social principles that include “when it rains, slow and store”; “when it’s dry, circulate and recharge”; “live with water”; “work with nature”; “work together”; and “design for adaptation.”

The three principles on which the approach is based can be stated as follows: (i) slow down the water as much as possible by capturing and infiltrating rain locally in order to reduce the speed and the amount of storm-water runoff; (ii) store water in the landscape in canals and ponds and use as much as possible; (iii) drain only when necessary and as little as possible.

Strategies for slowing down water are based on the eco-engineering principles of bio retention and infiltration that make use of green infrastructure (GNO Urban Water Plan 2013). The measures involved are relatively small in scale but, when applied over a large area, have a significant effect. They include rain gardens and bio-swales, permeable paving, green roofs, and water harvesting.

The store-and-use strategies enhance water storage by retrofitting or improving existing storage areas such as canals and ponds, as well as introducing new measures that include basins, constructed wetlands, and underground storage, as well as retrofitting and constructing canals to increase their storage capacity. In addition to reducing flood risk, these measures also reduce the risk of subsidence through infiltration of ground water.

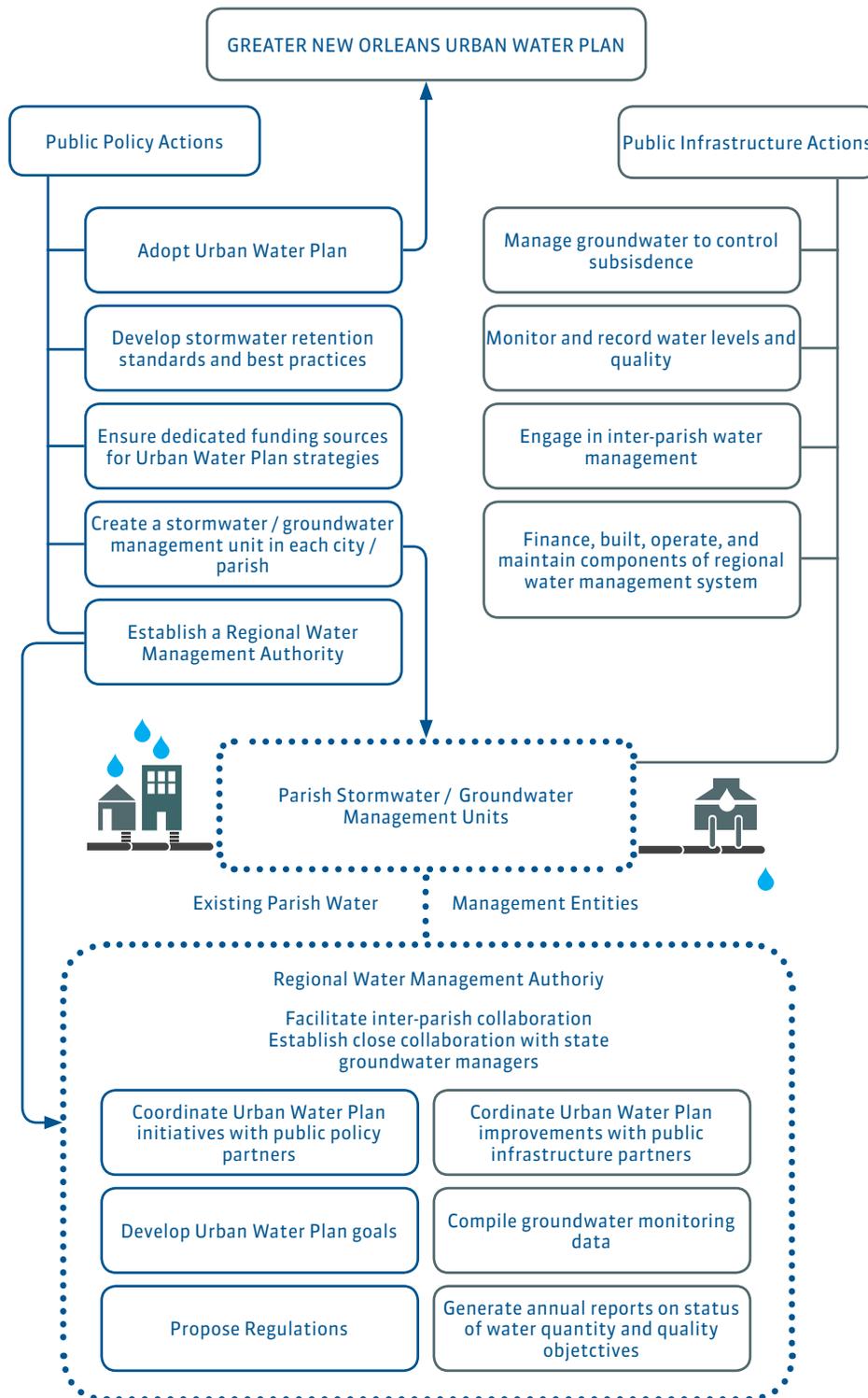
Strategies that infiltrate and store water locally can significantly reduce the load on the drainage system. Water that cannot be infiltrated, stored, and used is drained as efficiently as possible. The proposed drainage system allows for the circulation of water through

so-called blue-green infrastructure to improve water quality and prevent mosquito breeding. It also encourages infiltration into the ground water to further prevent subsidence.

In the GNO Urban Water Plan, the foregoing strategies and general measures are combined into seven types of interventions or facilities that improve urban water management while also increasing environmental and spatial quality, providing recreational facilities, and increasing land value. The seven types are described below.

- **Small-scale retrofits** slow, store, and infiltrate storm water locally in public spaces (streets, parks, squares) and on private property.
- **Circulating canals** contribute to water storage capacity and drain excess water; they also recharge groundwater and support local habitats.
- **Strategic parklands** provide large-scale water storage capacity while increasing the quality of open space and providing recreational facilities.
- **Integrated wetlands** contribute to water-storage capacity and increase infiltration.
- **Integrated waterworks** consist of all infrastructural elements that contain, guide, and filter storm water, surface water, groundwater, drinking water, sewage, and industrial wastewater. They include water-treatment plants, drainage pumps, sluices, weirs and gates.
- **Regional monitoring networks** provide real-time data on quality and quantity of both surface water and groundwater to address short-term drainage needs and long-term trends.
- **Waterfront development zones** encourage multifunctional urban development around waterways and parklands.

FIGURE A.1. RECOMMENDED PUBLIC POLICY AND INFRASTRUCTURE ACTIONS, NEW ORLEANS WATER PLAN



The structural measures of the GNO Urban Water Plan are accompanied by nonstructural (policy) measures. FIGURE A.1 provides an overview of the integration between infrastructural measures and policy recommendations proposed in the Urban Water Plan.

The GNO Urban Water Plan is in the early stages of implementation as funding is being sourced. Total costs are estimated at \$6.2 billion. Demonstration projects are important steps in the implementation effort. The plan is expected to save the area more than \$10.8 billion in avoidable flooding, subsidence, and insurance costs over a period of 50 years. The direct and indirect impact on the regional economy is estimated at \$11.3 billion. Employment is expected to increase by up to a 100,000 jobs, and property values are projected to rise by \$183 million. In total, estimated benefits are expected to reach \$22.3 billion, three times the investment, over the 50-year period.

SINGAPORE: ABC WATERS PROGRAM

Singapore, a densely populated city-state of 5.4 million people living on 700 square kilometers of land (World Economic Forum 2014), receives 2,400 mm of rainfall annually and has a catchment area that stretches across two-thirds of the nation's surface area (PUB 2011). Rainwater is collected and stored in 17 reservoirs, 32 major rivers, and more than 7,000 km of canals and drains (PUB 2011). This catchment system forms part of a sustainable water-management system that ensures not only sufficient water supply but also efficient storm-water management for a rapidly growing city with limited space for expansion.

The Singapore government has decided to combine the two objectives of flood-risk reduction and ensuring fresh water supply by integrating flood prevention and harvesting of rainwater. The many reservoirs, rivers, and canals play an important role.

ABC Waters, launched in 2006, advocates an integration of the environment, water bodies, and community to create a sustainable urban environment and transform Singapore's water bodies from mono-functional elements to more integrated, multifunctional elements. Storm water is detained and treated on site using plants and soil media before being allowed to flow into waterways and reservoirs. This practice reduces runoff and the risk of local flooding, while also facilitating improvements in water quality (vital for ensuring a sustainable water supply for the city-state) and increasing biodiversity.

The ABC Waters master plan, developed in 2007, encompasses more than a hundred projects that contribute to the development of this sustainable system. To be developed in phases by 2030, the plan has three guiding principles (Tan, Lee, and Tan 2009, cited in UNESCAP and UNECLAC 2009).

- **Active.** The plan provides new community spaces and brings people closer to water through recreational activities. With more opportunities for interaction, people will connect with the water, developing a sense of ownership and valuing it more.
- **Beautiful.** The plan develops reservoirs and waterways into vibrant and aesthetically pleasing lifestyle attractions that integrate with parks, estates, and even commercial developments.
- **Clean.** The plan provides for improved water quality by incorporating features such as aquatic plants, retention ponds, fountains, and recirculation to help remove nutrients. The aim is also to minimize pollution in the waterways through public education and by promoting a sense of responsibility for water quality.

The ABC Waters Program distinguishes between measures that contribute to water catchment, water treatment, and water conveyance water storage. Each category is described below.

Catchment. Measures to expand the catchment area of the city range from large-scale planning strategies to measures affecting individual buildings such as roof gardens or terraces, balconies, planter boxes, ground-level greenery, and vertical greenery.

Traditionally, storm-water catchment in roads and walkways in Singapore occurs through chambers that channel runoff into drains and culverts, which in turn convey it to main storm-water canals. ABC Waters proposes to incorporate bioretention swales and basins into this layout, contributing not only to water retention but also allowing storm water to be treated before being discharged into the waterways (FIGURE A.2).

Treatment. The water-treatment features of ABC Waters slow, retain, and clean storm-water runoff, simultaneously reducing the load on the drainage system and improving the water quality. Natural systems of plants and soils are a cost-effective, sustainable and environmentally friendly approach to improving urban water quality.

Conveyance and storage. Singapore's existing storm-water drainage system consists mainly of trapezoidal or U-shaped concrete canals. These canals can drain storm water only at a high rate; they contribute nothing to other water-management objectives such as infiltration or treatment. In addition, they have little impact on increasing spatial quality, biodiversity, or recreational opportunities. Creeping plants and gabions can enhance the appearance and biodiversity of such waterways (FIGURE A.3).

The use of natural materials as structural elements in the design of waterways (a technique known as bioengineering stabilization) goes beyond aesthetics and biodiversity to stabilize river banks and reduce erosion, reduce the velocity of water flow, facilitate the settlement and deposition of sand and silt to protect water quality downstream, and increase soil integrity through root networks. FIGURE A.4 illustrates the design of a construction tech-

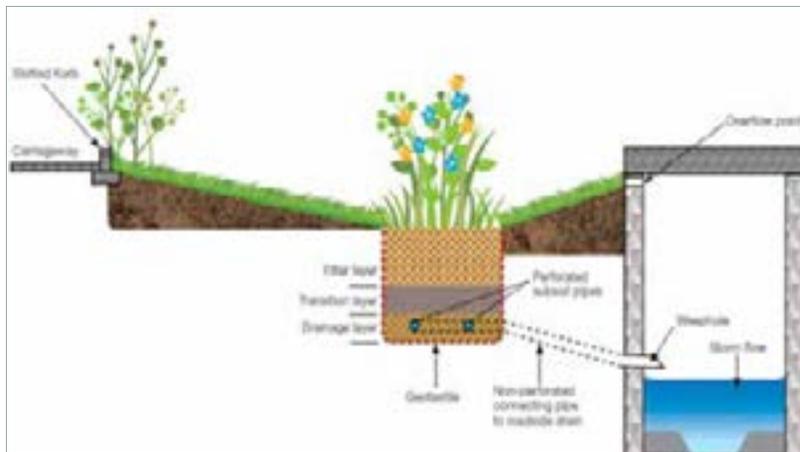
nique that makes use of gabions and wood crib walls on either side of the waterway.

ABC Waters has a large-scale public outreach program to increase community awareness. The program includes educational activities around water bodies throughout Singapore, as well as signage and information boards at project sites. A demonstration project engaged the community and increased awareness of the program. The Kolam Ayer ABC Waterfront, completed in 2008, consisted of a 200-meter make-over of the Kallang River. The Public Utilities Board in Singapore involved community organizations, schools, and residents early in the design process. In addition to community participation and awareness, the program deploys depth markers and early warning systems to warn the public of rising water levels.

Bishan Park and Sengkang Riverside Park showcase the concepts underlying ABC Waters, the design features of which have been implemented throughout Singapore. Bishan-Ang Mo Kio Park is a result of a collaboration between two of Singapore's governmental agencies: the National Parks Board and the Public Utilities Board. The park, completed in 2011, makes use of a cleansing biotope located in part of the park, the Pond Gardens, to maintain water quality without chemical treatment. In addition, the Kallang River, a previously canalized concrete stream running through the park, has been restored to a meandering river with bioengineered river banks.

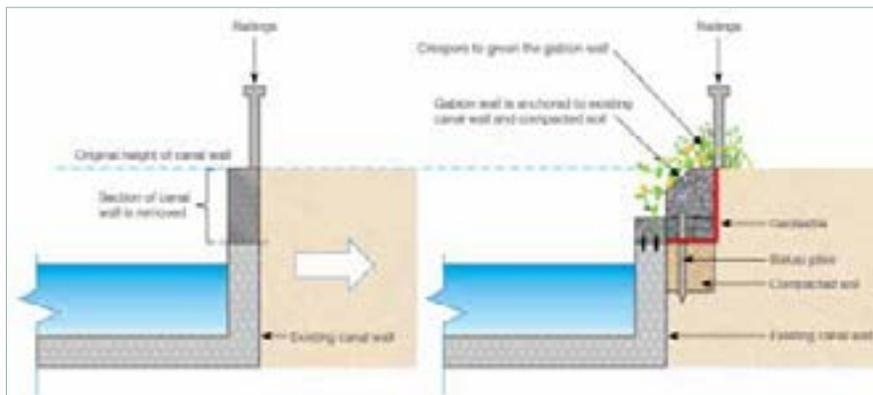
Sengkang Riverside Park, constructed in 2009 by Singapore's National Parks Board, center on a pond and constructed wetland that act as a buffer during heavy rainfall. Excessive rainfall is collected in the pond and released later through special outlets. The constructed wetland, with a surface area of approximately 2,500 square meters, treats storm-water runoff and natural sewage from a surface area that amounts to more than 40 percent of the park area. The open pond into which the water eventually flows is used to irrigate the park. At the same time, the pond and constructed wetland, located in

FIGURE A.2. SECTION OF DESIGN FOR BIORETENTION SWALES IN WALKWAYS



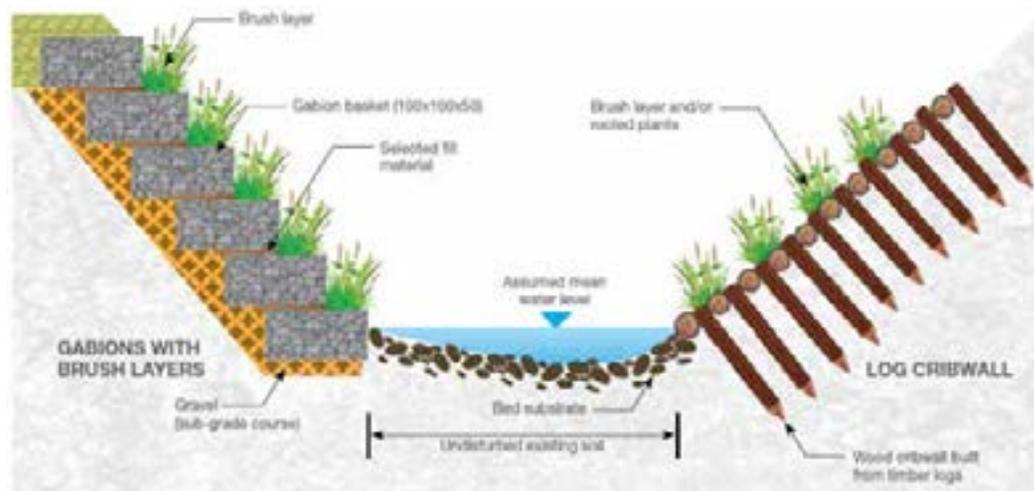
Source: PUB 2011.

FIGURE A.3. TWO SECTIONS SHOWING AN EXISTING CANAL WALL (LEFT) AND PROPOSED CANAL WALL WITH GABIONS (RIGHT)



Source: PUB 2011.

FIGURE A.4. A BIOENGINEERING STABILIZATION TECHNIQUE APPLIED IN THE KALLANG RIVER IN SINGAPORE



Source: PUB 2011.

FIGURE A1.5. OLD SEWERAGE SYSTEM (LEFT) AND SEPARATED SEWERAGE SYSTEM (RIGHT)

a wider reservoir area, have a recreational and educational value, while also increasing biodiversity.

WATERPLAN 2 ROTTERDAM

Although the harbor city of Rotterdam (600,000 inhabitants) owes much of its prosperity to its strategic position in the delta of the Rhine, water can also threaten its existence. Water threatens the city from at least three different directions: from the River Rhine, from the North Sea, and from above.

The Maesland Barrier (built in 1997) solved much of the flood risk posed by the sea. But the problems associated with high river discharge and heavy rainfall linger. At present the city is inadequately prepared for the drainage of water during a heavy downpour, a challenged compounded by a combined sewerage system that is not up to its task. It has been calculated that to effectively cope with a once in hundred years rainfall event, the city would need additional storage capacity of 500,000 to 600,000 cubic meters, the equivalent of 50 to 60 hectares of land covered by water a meter deep. In densely populated Rotterdam this space is simply not available, so alternative solutions need to be found to meet the challenge. With anticipated climate change, the needed storage capacity could approach 750,000 cubic meters.

Waterplan 2 Rotterdam, an ambitious effort to cope with present and future water risks, is a unique cooperative effort between the municipality and three water boards to integrate urban development and spatial planning with better water management. The underlying theme is that these components can reinforce one another by exploiting the synergies between land, water, and environmental management. Waterplan 2 proposes interventions to accommodate volumes of water by increasing storage capacity (on the surface and underground) and to improve water quality using a separated sewerage system.

Museumpark is an example of a multifunctional use solution for underground water storage. Utilizing special design techniques, the parking garage can store 10,000 cubic meters of water during heavy and prolonged precipitation while maintaining its normal function as a car park. When the heavy rainfall ends, the stored water can be discharged into the city's drainage system.

But progress in meeting the initial target for storage capacity has been slow. Going forward, emphasis will be placed on encouraging more participation from the private sector, namely, real estate developers and housing corporations.

From 2008 to 2011, about 50,000 square meters of green roofs were created in Rotterdam to retard run-off, thus

attenuating the peak flow and extending run-off over a longer. In 2011 Waterplan 2 established an annual target of an additional 40,000 square meters per year. Achieving that goal will require the cooperation and support of the municipality, the water boards, and the general public.

A separated sewerage system reduces the risk of spill-over of untreated sewage water into surface water during high-intensity precipitation. As sewage pipes reach their useful life of about fifty years, the old combined system can be replaced by a separated system, where technically and financially feasible. (FIGURE A 1.5).

Total investments for the Waterplan in the years 2007–12 were approximately USD 93.3 million⁶² (€82 million). More than half was provided by the water boards, the rest by the municipality. The concept is “the task holder pays” whereby water boards are responsible for measures that contribute to the water quality and water quantity goals, and the municipality pays for measures dealing with sewerage, open space, and recreational facilities. The municipality provides land free of charge, as required.

CLIMATE ADAPTATION STRATEGY: HO CHI MINH CITY, VIETNAM

Ho Chi Minh City lies on the Saigon River. The population of 7 million is growing, spurred on by a vibrant economy. With unplanned urbanization, the city has expanded into poorly drained flood-prone areas along the seacoast. Presently, a third of the urban area is vulnerable to regular flooding from the sea, rainfall, and the river (VCAPS Consortium 2013). The problems of flooding and poor drainage are likely to worsen with climate change. Other problems exist as well. Over-extraction of groundwater has increased subsidence.

62. Conversion rate of €1 = USD 1.14 (June 28, 2017)

Water and sanitation systems are inadequate (VCAPS Consortium 2013).

A draft master plan through 2025 does not address these issues sufficiently. Climate change, flood protection, and water supply get particularly short shrift (VCAPS Consortium 2013).

The Ho Chi Minh City Climate Adaptation Strategy introduces an adaptive delta management approach that builds on the principles of eco-engineering and takes into account likely climate change and future uncertainties inherent to long-term planning. The strategy is the result of a strategic partnership between the Vietnamese and Dutch governments and the city of Rotterdam, funded by the Dutch Global Water Program. Developed in 2013 by a multi-disciplinary team of Vietnamese and Dutch experts, the objective is to enhance the sustainable socioeconomic development of Ho Chi Minh City.

Important elements of the strategy are integration of short-term actions and long-term developments; cost-effective, flexible interventions for adapting to changing circumstances (climate change or socioeconomic developments); sectoral integration (urban planning, flood-risk management, water and sanitation, environmental science); and links with ongoing projects and initiatives (VCAPS Consortium 2013).

These elements are incorporated into six strategic directions to increase the resilience of Ho Chi Minh City over the short term (through 2025), the medium term (2025–50), and the long term (2050–2100).

Strategic direction 1: Development sensitive to base conditions. Development should take place in accordance with elevation, soil and water conditions, and exposure to sea-level rise. Low-lying, flood-prone areas should be avoided for dense urban development; any development planned for these areas must incorporate adaptive measures to mitigate flood risk.

Strategic direction 2: A stepwise approach to flood protection. To ensure flood protection on a larger scale, a range of flood-control measures is required. These include large infrastructure, community-based measures, and nonstructural measures such as the development of flood-protection standards, strengthening of emergency response capacity, and adequate reservoir management.

Strategic direction 3: Increased capacity for water storage and drainage. This direction focuses on localized floods resulting from high tides and heavy rainfall and caused by (i) insufficient storage capacity in built-up areas, (ii) low elevation aggravated by land subsidence, and (iii) insufficient or inadequately maintained sewage and drainage systems. All of these conditions are expected to worsen in the near future. A series of measures aims to increase water retention and discharge through:

- Retention ponds
- Minimization of impermeable surface area
- Above-ground storage basins and underground water storage
- Water retention on roofs
- Increased evapotranspiration through vegetation
- Land-use regulation

In addition to these interventions, storage and drainage standards must be reviewed and made consistent with the estimated effects of climate change. Procedures to enforce the new standards must be developed, and ongoing or planned development and maintenance works must reflect them. Compliance and enforcement can be encouraged by raising water awareness and building capacity among urban planners. Enforcement can also be encouraged through juridical procedures and economic

incentives. Physical improvements to the existing system are required.

Strategic direction 4: Coping with salinization. Direction 4 proposes to prevent salinization through structural flood-protection measures, smart dredging, and flushing the urban water system. Adaptive measures such as moving drinking-water intakes upstream and converting to salt-tolerant vegetation in those areas susceptible to flooding are proposed.

Strategic direction 5: Alternatives for groundwater use. In order to retain a sustainable groundwater table and reduce subsidence, abstraction should be reduced substantially. This can be achieved by improving surface water quality as an alternative water supply in combination with enforcement of regulations on groundwater abstraction.

Strategic direction 6: A stronger blue-green network and “urban ventilation.” Direction 6 aims to reduce heat stress in the city through a variety of measures, including reinforcement of the city’s network of blue and green spaces, implementation of green building codes, and planning for natural ventilation (VCAPS Consortium 2013).

Some of the main measures proposed in the Climate Adaptation Strategy are nonstructural, particularly under strategic direction 1. Careful consideration of land conditions in land-use planning and zoning are proposed in order to promote climate adaptive planning. In addition, the strategy highlights the importance of enforcing regulations against encroachment of waterways, as well as the development and application of procedures to enforce storage and drainage standards. It also proposes a review of these standards. Finally, it proposes the strengthening of emergency response capacity and mechanisms as an important nonstructural measure.

The Climate Adaptation Strategy is an ambitious program in the early stages of implementation. Although it is diffi-

cult at this stage to develop a definitive cost estimate, the initial cost range is \$110–130 million. Avoided flood damage is estimated at \$1.4 billion (VCAPS Consortium 2013).

GREENINFRA4BEIRA: BEIRA, MOZAMBIQUE

The city of Beira sits just a few meters above sea level. Poor storm-water management results in regular flooding of the city and peri-urban area. Natural depressions in the Beira floodplain retain water for long periods of time, leading to extended inundations. In addition, Beira is confronted with other water-related challenges such as providing drinking water, managing wastewater, and ensuring adequate sanitation. The threats of climate change, rising sea level, and land subsidence call for an integrated approach to water management. Growing demand for space in the delta area, coupled with illegal construction and a lack of capacity for planning, inspection, and enforcement, add to the challenge.

The GreenInfra4Beira project being developed by a consortium of Dutch organizations including Deltares, Witteveen+Bos, and Wageningen University will deploy green infrastructure and adaptation to address these issues. The project will examine the feasibility, costs, and benefits of water-management and prevention measures that make use of ecosystems such as wetlands and the coastal environment to naturally mitigate storm water. Essential to the approach is local execution by key Beira stakeholders. The project is a follow-on to the Masterplan Beira 2035 project, which began in 2012.

The approach is based on three key principles (Brils et al. 2013):

- **Be well informed.** This point includes an understanding of the functioning of the Beira ecosystem and its relationships to the Beira social system;

a striving for “integrated system solutions”; and using all readily available knowledge, including local knowledge.

- **Be adaptive.** The approach is iterative: plan > do > learn > improve > do.
- **Pursue a participatory approach.** Beira stakeholders will be involved throughout the different phases of the project.

The main deliverable is a detailed plan for implementing green infrastructure in the pilot area, including water retention areas and drains to address the storm-water problem. The plan will be developed to the point where it can be presented to local decision makers for consideration and implementation. Thus it will include an infrastructure financing strategy, as well as a proposal for an appropriate governance structure for developing the infrastructure and ensuring subsequent operations and maintenance. Furthermore, GreenInfra4Beira will be a demonstration case and thus a catalyst for future developments in Mozambique and abroad.

A detailed green infrastructure plan will be developed for a demonstration project in the Chota neighborhood with the objective of obtaining stakeholder support for an ecosystem approach to storm water management. Emphasis will be placed on the combined use of innovative tools and approaches. Situated in an alluvial zone, the Chota area is one of the lowest urbanized areas of Beira (1–2 meters above mean sea level). Most settlements are built on landfills along the sides of roads and paths.

The green infrastructure strategy for the Chota area envisions the following measures:

- Creation of a lagoon to serve as retention basin along the eastern coast. This will require deepening a former lagoon, which has become silted from sediment depositions.

- Creation of a drainage channel from the newly designed Maraza retention basin to the new lagoon.
- Rehabilitation of the current A3 drainage channel and its connection to the lagoon.
- Creation of smaller retention basins within Chota area.

Although the initial strategy has focused on structural measures, nonstructural and capacity building measures are on the agenda. The project will include capacity building of staff, a communication and awareness program, and recommendations for legislation and regulated urban planning.

PORTLAND, OREGON, USA

Portland has a long-standing history of green infrastructure projects, initiatives, and programs. Since the early 1990s, the city's Bureau of Environmental Services has had a multi-faceted and largely successful Stormwater Management Program that addresses multiple goals and includes education, outreach, and community initiatives. The program was developed in response to an inadequate drainage and sewerage system (partly separated and partly combined depending on the location within the city) that was insufficient to discharge the heavy rains that fall on the city.

The average annual precipitation in the Portland area is 970 mm, leading to about 10 billion gallons of storm water runoff per year over streets, parking lots, buildings, and other hard surfaces. In addition to carrying pollutants to rivers and streams, the volume and speed of the runoff can cause flooding and erosion, destroy natural habitat, and contribute to combined sewer overflows. Together with property owners, architects, engineers, and developers, the city has been exploring ways to better manage onsite surface storm water.

Important eco-engineering aspects in the current approach to storm-water management are to retain as much run-off as possible through green infrastructure; to introduce measures ranging from the local to the city-scale; and to combine structural with nonstructural measures.

The structural measures that have been introduced include so-called Green Streets as well as measures to retrofit existing buildings and to impose energy and environmental design requirements on new structures. All measures address storm water on site by retaining and infiltrating water as much as possible.

Open-space measures. Green Streets intercept and infiltrate storm water through a combination of landscaped curb extensions, swales, planter strips, pervious pavement and trees. Streets account for 35 percent of the city's impervious surface area, so street runoff contributes significantly to storm-water volumes. By retrofitting streets, both in public and private developments, with interception and infiltration measures, the city reduces combined sewer overflows and water pollution (WERF 2009). More than 1,400 streets in Portland have been retrofitted according to the Green Streets approach, and several more are in the pipeline (Kurtz 2014).

The award-winning Southwest 12th Ave Green Street Planters project on the Portland State University campus, completed in 2005, is a prime example of the Green Streets principle. Four sequential storm water planters were introduced to capture and treat runoff from 8,000 square feet of street surface. WERF (2009) described the concept as follows:

Water flows along the curb and enters the first planter via a channel cut into the curb. Depending on flows, water will pond to a depth of 6 inches, promoting infiltration and biological uptake of pollutants. If flows exceed this capacity, water will exit the first planter through a second curb cut and be routed into the subsequent planters, either infiltrating to ground-

water or, during intense storms, eventually entering the storm drain system. The planters themselves are designed to be long and narrow to fit into the existing sidewalk space, and they contain a mix of rushes, trees, and shrubs that provide attractive landscaping year-round.

Building-scale measures. Existing buildings are retrofitted with eco-roofs that significantly decrease storm-water runoff, reduce energy use, reduce water pollution and erosion, improve air quality, improve biodiversity, and reduce the urban-heat-island effect (BES 2014). Approximately 420 eco-roofs have been constructed (Kurtz 2014).

For publicly funded new developments, the city imposes energy and environmental design requirements, incorporation of Green Streets, and consideration of eco-roofs. For new private developments, partnerships are established with property owners to implement storm-water retrofit projects. These structural measures are complimented by policies, building codes and other nonstructural measures. In addition to incentives, several policies encourage the application of sustainable storm-water practices. The requirements for new development and redevelopment, both public and private, are set forth in the Stormwater Management Manual (1999).

Demonstration projects throughout the city are closely monitored. The monitoring and reporting of these measures is an important contribution to the success of the program, as the data collected are used to quantify the benefits of these measures, to improve their design and functioning, and to reduce maintenance costs by tracking performance and addressing maintenance needs as they arise (WERF 2009).

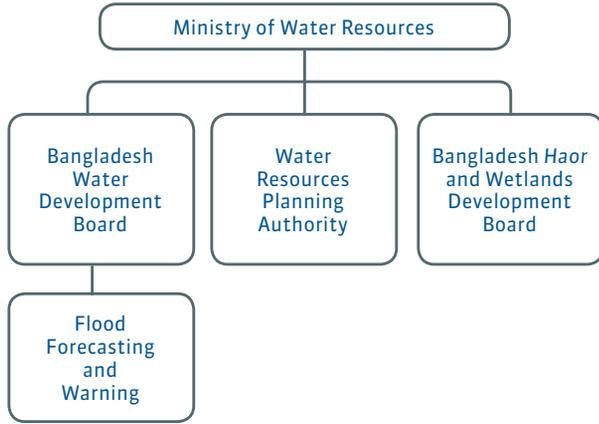
Finally, the city created a Stormwater Policy Advisory Committee (1996), which included a diverse group of stakeholders—architects and landscape architects, engineers, institutional organizations, and the storm-water treatment industry—to advise the city. The advisory com-

mittee was complemented by a Sustainable Stormwater Management Division (2002), a multidisciplinary group of professionals responsible for planning, technical assistance, outreach and monitoring.

With a quarter century of experience with eco-engineering and green solutions, Portland has demonstrated what is possible. The city's Stormwater Management Program has significantly reduced storm-water runoff, improved water quality, reduced heat stress, promoted biodiversity, enhanced neighborhoods, and raised property values. More importantly, Portland has demonstrated that green eco-engineering principles are more cost-effective than the traditional approach (Kurtz 2014).

Portland's program uses governmental grants, taxes, and development incentives. Incentives can be important in forging public-private partnerships. Normally, developers must comply with a certain floor-to-area ratio in urban areas. However, as an incentive, developers who place a green roof on their building are entitled to a higher ratio. These partnerships offer a win-win situation for both government and private developers. ■

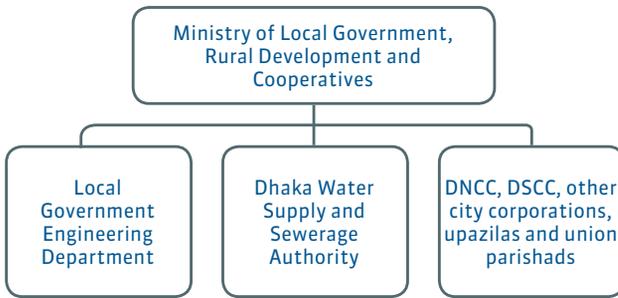
APPENDIX B. ORGANOGRAM OF KEY AGENCIES



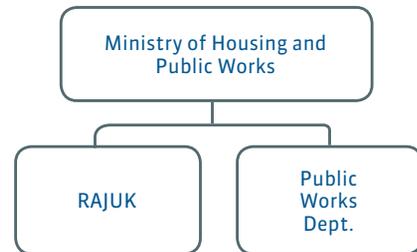
(a) Relevant agencies under the Ministry of Water Resources



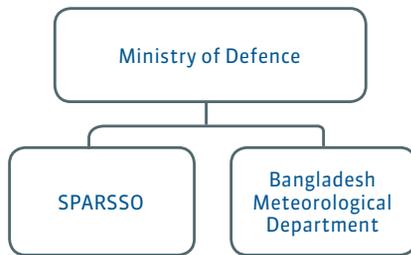
(b) Agencies under the Ministry of Disaster Management and Relief



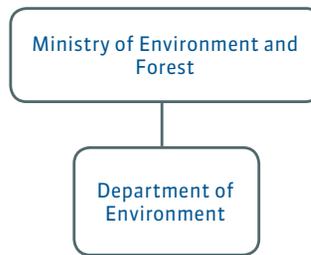
(c) Agencies under the Ministry of Local Government, Rural Development and Cooperatives



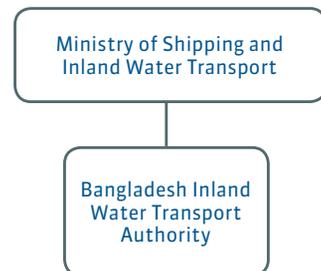
(d) Agencies under the Ministry of Housing and Public Works



(f) Agencies under the Ministry of Defence



(g) Agency under the Ministry of Environment and Forest



(h) Agency under the Ministry of Shipping and Inland Water Transport

APPENDIX C. EXCAVATION OF KHALS

TABLE C.1. REQUIRED MINIMUM WIDTH OF PROPOSED NATURAL KHALS TO BE REEXCAVATED IN DHAKA WEST

Name	Length (km)	Minimum width (m)
Katasur	2.60	15
Baunia	7.60	25
Abdullahpur	5.50	15
Digun (main)	4.20	30
Kallayanpur Uma	1.10	12
Kallayanpur Cha	.95	14
Kallayanpur Kha	3.30	10
Ramchandrapur	1.40	12
Kallayanpur Ka	2.70	8
Kallayanpur main	3.00	25
Dholai	.40	12
Hazaribagh	.42	25
Ibrahimpur	.85	20
Shahjahanpur	.80	8

Source: Data obtained from the city corporations.

TABLE C.2. REQUIRED MINIMUM WIDTH OF BUFFER ZONE FOR PERIPHERAL RIVERS OF DHAKA

River name	Buffer width on each side (m)
Turag	50–225
Dhaleswari	500
Buriganga	100
Bangshi	50
Tongi Khal	75
Balu	50
Sitalakhya	25
Chilai	50

Source: CEGIS 2016

TABLE C.3. ESTIMATED MINIMUM WIDTH OF NATURAL KHALS TO BE REEXCAVATED IN DHAKA EAST

Name	Length (km)	Minimum width (m)
Zerani	5.00	20
Meradia-Gazaria	2.60	25
Manda	5.00	8
Khilgaon-Basabo	3.20	15
Sutivola	7.40	25
Kosaibari-Boalia	5.60	10
Shahjadpur	7.80	5
Dumni	3.50	35
Boalia	1.90	30
Gobindapur	3.70	25
Segunbagicha	.85	16
Norail	2.20	22
Begunbari	2.00	55

Source: CEGIS 2016



EUROPEAN UNION



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SWEDEN

