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Integrated Drainage Water Management for Environmental Improvement in Kolkata, India

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Kolkata city situated beside Hugli (Ganges) river in West Bengal has perennial problem of water logging during monsoon. The city proper has a combined sewer disposal system, and some parts of the added areas have only recently central drainage collection system. Major works have been done by various government organizations for augmentation and management of drainage and sewerage system in the city. Yet, inundation problem at many parts in the city imparting inconvenience to people is still observed. Pressure from tremendous urbanization in and around the city and lack of matching infrastructure development have resulted multiple environmental problems from urban flooding to groundwater depletion to air pollution. This paper addresses the drainage and environmental problems in the city, recent measures taken to mitigate the problems, and author's proposal for integrated drainage water management for environmental improvement in Kolkata.

Key words : *Monsoon climate in Kolkata, urban flooding, environmental problems, recent measures taken, proposal for environmental improvement*

Introduction

Kolkata (earlier 'Calcutta'), the capital city of the State West Bengal, is a linear city grown along the eastern bank of river Hugli (Ganges). The area under Kolkata Municipal Corporation (KMC) presently consists of 141 wards in an area of 185 sq km. In 2001, the population of the municipal area was 4580544 and population density was 24760 per sq km (Census of India, 2001)[1]. In 1950s, the World Health Organization (WHO) reviewed the sanitation conditions of Calcutta Metropolitan area and recommended for development and management of water supply and drainage, and the disposal of sewage and garbage in its report. The Calcutta Metropolitan Planning Organisation (CMPO) of the Government of West Bengal published a Master Plan titled 'The Basic Development Plan' (BDP) for the Calcutta Metropolitan District 1966-1986 with the help of Ford Foundation of U.S.A. for metropolitan water supply, sewage and drainage (CMPO, 1966)[2]. Only 54% of the Calcutta Corporation area had sewerage facility in 1961 (CMPO, 1966)[2]. Since 1970s, Calcutta Metropolitan Development Authority (CMDA, now KMDA) has undertaken several works like construction of relief storm-drains and sewers, construction and augmentation of pumping stations, silt removal, etc., during decades. Under the Central Government funded 'Ganges Action Plan' (GAP) which started in 1980s with the objective of purification of water of river Ganges by stopping of disposal of drainage and sewage and industrial waste into it, three lifting stations and three sewage treatment plants have been constructed and operational in south of Kolkata that contributed some relief in the drainage management system. However, to understand the present magnitude of urban development and the possible load on drainage and sewerage, a survey conducted by the author on the rate of construction of new buildings in the municipal area during April 2005 to March 2010 revealed that average total number of Building Proposals sanctioned by the KMC was 3564 per year and average total floor area sanctioned for construction per year was 1.892 million sqm (Bose & Banerjee, 2010)[3-4]. Hence, surface run-off area has increased manifold and there was no regulation for recycling of water from built-surfaces or from roofs of buildings until 2003-2004. Adequate drainage infrastructure matching demand from rapid development could not be made in the city. Meanwhile, a recent township called "Rajarhat – New Town" with large buildings has been set up in east Kolkata area.

Climate, soil, topography and geomorphology in Kolkata

Kolkata has a tropical monsoon climate with excess of humidity. Annual maximum and minimum temperatures in summer and winter are generally 39°C and 9°C. Kolkata has an annual average rainfall of around 1651 mm (India Meteorological Department, 2010)[5], based on 100 years' (1901-2000) data, with irregular distribution. More than 80% of the annual rainfall occurs during 15th June to 15th September in monsoon season (Das Gupta, 1991)[6]. The high rainfall intensity during monsoon period produces very large run-off. Many areas of Kolkata have a thick fine silty clay layer in the ground top soil that retards quick absorption of rainwater into the ground. Other areas have top soil with sandy river-belt deposit, which has greater absorption quality of rainwater into the ground. The natural slope of the ground of the city is from west (river bank of Hugli) to east (fringe area with wetlands). Though apparently having a flat basin, the city has land

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undulations and saucer-like depressions in various areas. Within the Municipal area, there exist numerous water bodies (3500), wetlands, water channels and canals (11) (KMC, 2006)[7].

Drainage systems in Kolkata

Drainage system in city and fringe areas

The city proper has a combined sewer disposal system laid in west to east direction following natural slope. Underground sewers carry drainage load to pumping stations, which further discharge the load to channels and canals. The channels and canals dispose drainage partly to eastern wetland system and the rest to river Kulti, flowing southern over rural areas carries the discharge to Bay of Bengal (**Fig. 1**). The fringe areas do not have centralized sewer collection system. There, sanitary sewage is stored in individual septic tanks and the storm water (with sullage) is separately drained through municipal conduits or surface drains falling to nearby channels and canals (Chakravarti & Chowdhury, 2006)[8-9]. The KMC area generates everyday more than 600 million litres o sewage and wastewater and about 4000 metric tons of solic waste (KMC, 2006 & 2011)[7]. Huge quantity garbage i deposited at Dhapa Dumping Ground at eastern fringe.

East Kolkata wetland ecosystem

The east Kolkata wetland ecosystem, included in the 'Ramsar List' in 2002, is spread over 12,500 hectares (with 5850 hectares of water body). It has 254 sewage-fed fisheries (being inter-distributing swamps with embankments and having depth varying between 0.5-1.5m). Approximately 250 million litres of sewage is flown into it everyday. Here, the organic compounds are biodegraded and nutrients of the sewage and wastewater are biologically absorbed by planktor population in the shallow ponds through photosynthesis by solar radiation, and planktons are consumed by fish in the water. This way, the sewage is treated naturally and the nutrients are processed and stored in fish for human consumption (**Fig. 2**). Annually about 11,000 metric tonnes of

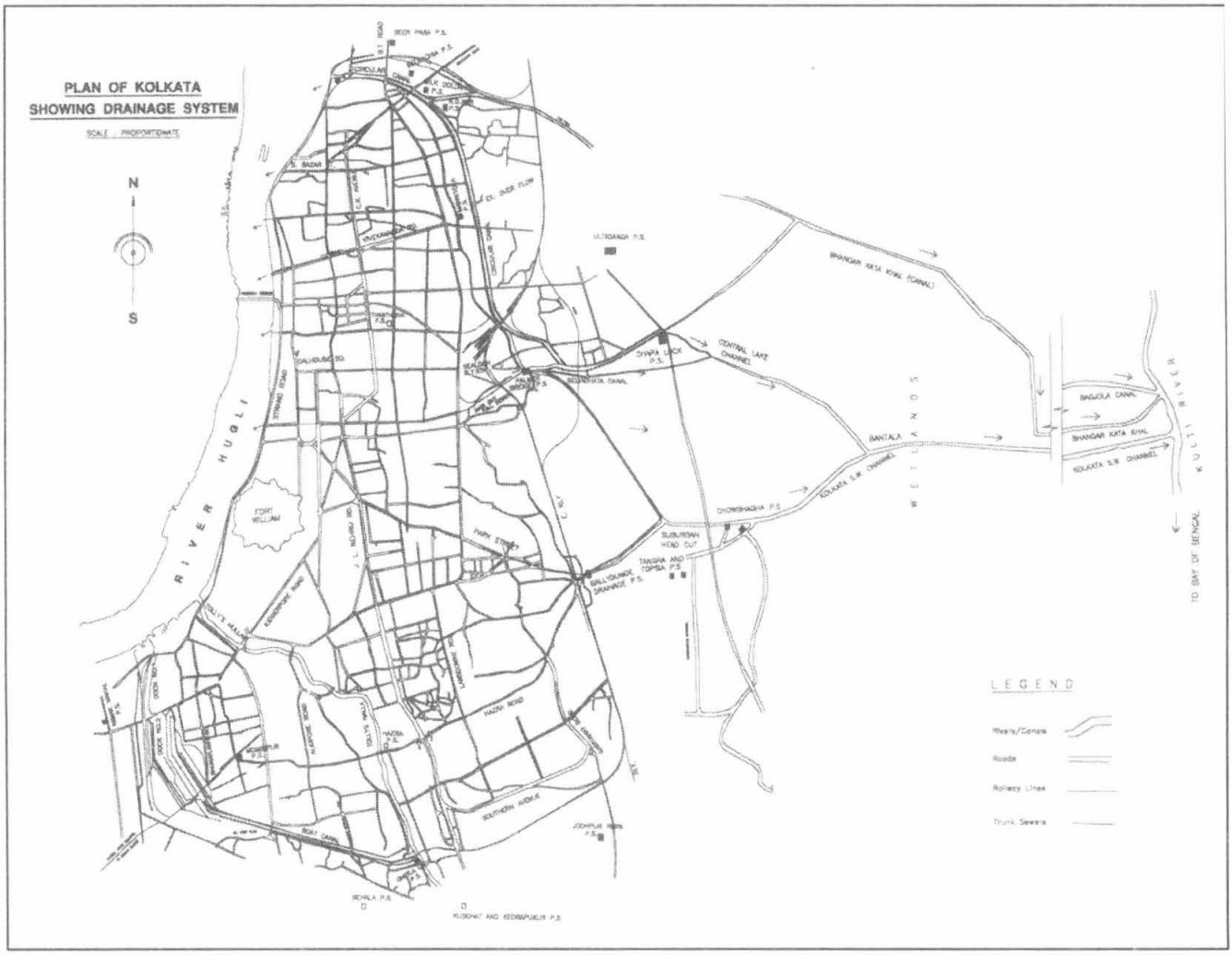

Fig. 1 : Map of Kolkata showing drainage system (Source: Bose, 2009)[12]

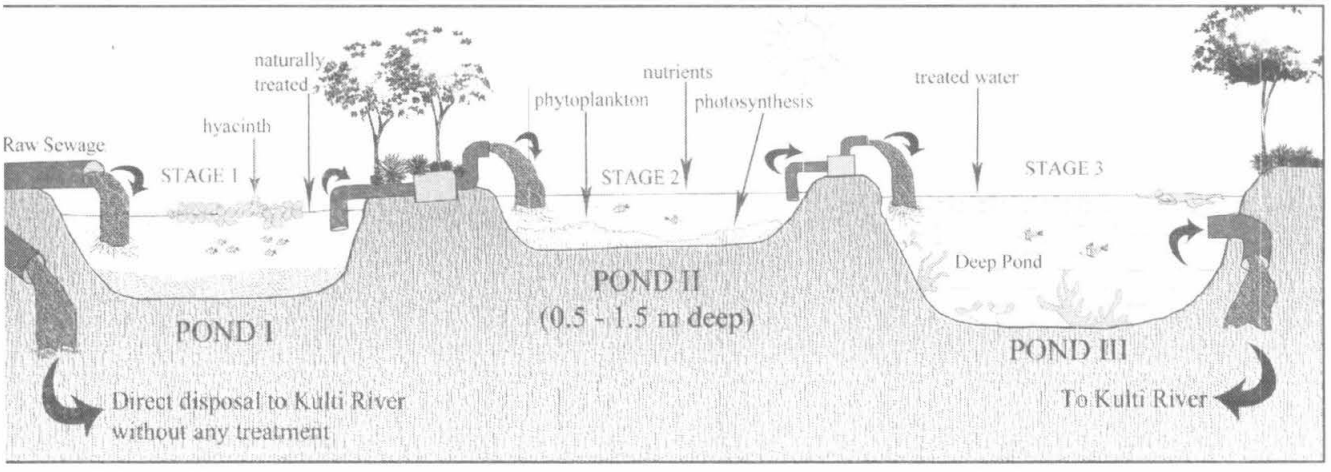

Fig. 2 : A schematic diagram explaining East-Kolkata wetland ecosystem (Source: Bose, 2011)[14]

lible fish and daily 150 metric tonnes of vegetable are oduced from the wetland system (Bose, 2009)[10]. This is a nique example of treatment of nearly 42% of sewage and ainage of the city naturally and integration of drainage anagement with ecosystem and environmental flow.

rainage and environmental problems

Even after various measures taken for augmentation drainage systems, and total area under water logging being inimised greatly in recent years, urban flooding still happens various parts in Kolkata during monsoon (**Fig. 3a & 3b, 4, 6, 7**). It has been observed by the Indian Institute of Tropical eteorology, Pune and the India Meteorological Department overnment of India) that character of monsoon has been anging during some years. Heavy shower has become equent occurrence during monsoon in Kolkata (Jayan & udur, 2007)[11]. It has been declared by the Kolkata Municipal orporation that according to the drainage management pacity of the municipal system, no water stagnation will ppen in any part in Kolkata if the rainfall is within 6mm per ur (KMC, 2004)[7]. Every year during monsoon period, many nes the rainfall per hour exceeds the mark of even 15mm and becomes beyond the draining capacity of the KMC.

The problems related to inundation are from sruption in traffic and transportation, disturbance in public tivity, distress and disease in human life with malaria and ngue from mosquito, other diseases from dampness, mages to buildings and properties, possibility of death of ople by accident and electrical short circuit, and gross vironmental pollution and degradation. In Kolkata, pulation is ever increasing and population influx from rrounding region is high. Only 6% of Kolkata's municipal ea is the total area of roads. Parks and open spaces are also ry inadequate, about 2.5% of the municipal area of the city. ie city is in the process of metamorphosis in somewhat ontaneous way. Imposition of strict control over development may adversely affect the much desired economic development within the city and region. Meanwhile, upgrade and capacity increment of drainage system (infrastructure) could not have been done at par the pace of unprecedented urbanization which results in failure of drainage system during monsoon in the city. There is lack of periodic maintenance of the old-existing and recently completed drainage network. Some of the old and major underground brick sewer lines of the city are dilapidated and require immediate repair and restoration (Chakravarti, 2006; Ghosh, 2007)[8-12]. In road-repairing work, the municipality commonly lays a new macadam layer over the existing top layer, thus increasing the level of the road after repair work. By this, especially at the historic part of the city, the ground levels of the old buildings are rendered lower than the top-up road. This causes inundation of the premises and area. Many people throw garbage in plastic packets in the surface drains, road gutters, channels and canals. Road side shops, market places and slums add congestion of drains by putting garbage and plastic in gutters. Plastic element in drainage system creates choking of drainage system resulting inundation (KMC, 2006)[7]. During heavy shower, the garbage dumped locally and temporarily across the city before being deported at Dhapa enters into the drainage system and chokes the conduits. The trunk-drains, the outfall channels and canals all carrying sewage and drainage discharge have been silted up. The State Irrigation Department responsible for dredging of canals has not done substantial work in this account. The river Kulti which finally carries the load to the Bay of Bengal through Sunderbans also needs dredging. The State Environment Department has examined satellite images and conferred that wetlands have shrunk from 6100 hectares in 1992 to 5850 hectares in 2004, only 4400 hectares are 'active wetlands' and the rest is degraded and silted (Kamboj, 2004)[13]. 250 hectares of water bodies have been filled up illegally. Many water bodies across the city have been filled up illegally for construction of residential buildings, and by local garbage deposition. Construction of major roads like Eastern

Metropolitan Bypass in the eastern region has formed physical barriers and impedes natural drainage of the city. Moreover, in the eastern fringe areas, large numbers of low-rise-high-density dwellings and high-rise buildings built on previously rural/ agricultural lands in unscientific ways of plot divisions ha blocked natural drainage path (Chakravarti & Ghosh, 2004 Recent work for the south-eastern extension of the Me Railway over the Tolly's Nullah (an offshoot canal of ri

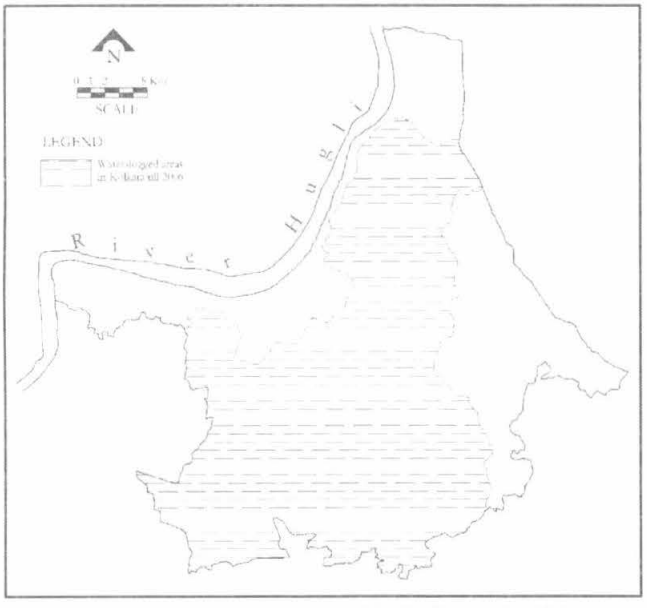

Fig. 3a :Water logging area in Kolkata till 2006

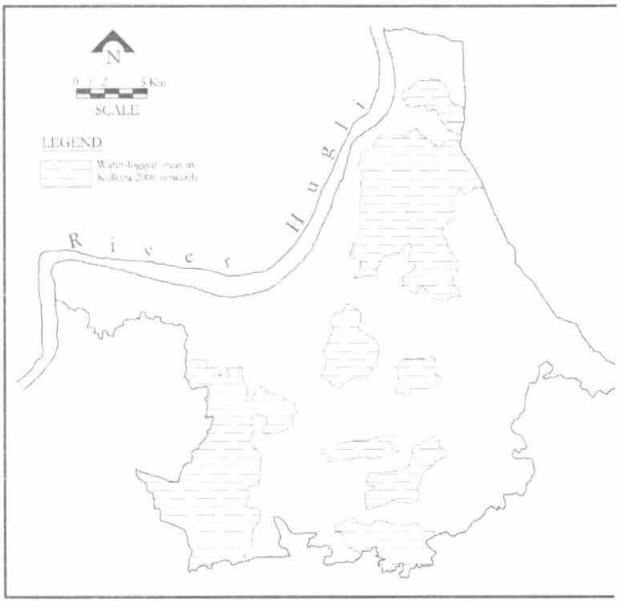

Fig. 3b : Water logging area in Kolkata in 2010

Fig. 4 : Water logging at Dalhousie in 1966

Fig. 5 : Water logging at Ballygunge in 2006

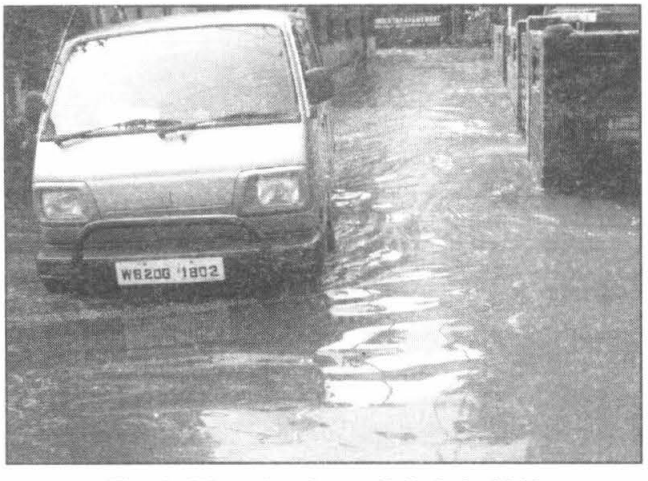

Fig. 6 : Water logging at Behala in 2010

Fig. 7 : Water logging at Alipore in 2011

(Sources : Fig. 3a & 3b – Bose, 2011[3]; Fig.4 – CMPO Traffic & Transportation Plan, 1967[17]; Fig. 5 – Bose, 2006[3]; Fig. 6 – Ray, 2010[18]; Fig. 7 – Datta, 2011[19])

ıgli) has rendered the canal into a dead one adding vironmental hazard. Urban development projects are under fferent departments of the Central, State and Local overnments and various joint sector and private ganizations among which, problem in coordination produces desired results (Chakravarti & Ghosh, 2004)[14]. A related vironmental problem is that the groundwater (aquifer) level the city has been depleted by 7m to 11m in last 45 years om 1958 to 2003 (KMC & CGWB, 2009)[15]. Construction of ge buildings in the city and indiscriminate boring of deep pe wells for extraction of groundwater is the reason for this. ıe quantity of extraction of groundwater everyday in Kolkata ınicipal area has been estimated to be as around 868.9 million er. Only a little quantity of rainwater reaches up to the aquifer. ıe groundwater depletion has been resulting in the city's bsidence and contamination of Arsenic with groundwater eating severe health problem to hundreds of thousands of ople. The environment management department of Indian stitute of Social Welfare and Business Management in olkata revealed that the water level in around 30% of the city ea has shrunk to the extent of triggering subsidence" anguly & Basu, 2009)[16]. The Government has not been able increase the supply of filtered water from the river.

ecent measures taken

As monsoon flooding affects the whole society in olkata and challenges the quality of urban governance, anning and management, hence the state government and e municipality always put various efforts to mitigate this oblem. Measures taken in this regard during the last eight ars are categorically stated below.

irective of the West Bengal State Pollution Control Board

The West Bengal Pollution Control Board empowered enforce the Water (Prevention & Control of Pollution) Act, 974 has directed (in 2004) all Municipal Corporations to ensure hile granting permission for construction of any housing mplex within their jurisdiction having around 100 flats or ore, or covering a super-built up area of around 6000sqm or ore, that the wastewater from the housing complex be treated rough its own 'treatment system' before discharging into ıe road sewer main of the Municipality (WBPCB & howdhury, 2006)[20,9].

irective of Kolkata Municipal Corporation for in-house wage treatment and rainwater harvesting

It has become mandatory by the directive of the KMC ıat all large housing, commercial and other development ojects in Kolkata have to treat wastewater (except storm ater from roofs of the buildings) in the in-house Sewage reatment Plants (STP), and the treated water can either be ilized by the inhabitants or be discharged into the municipal ewer main where it exists or to the nearby canal or pond esignated for it (Bose, 2009, 2008 & 2006)[10,21,22]. All new large architectural projects in Kolkata comply with this directive since 2004-2005. The rainwater from roofs of the buildings is collected separately into a storage tank with provision for use and recharging it into the aquifer. Rainwater harvesting helps reducing drainage problem, and provides water for use (Gupta & Biswas, 2004)[23].

Effort to increase open area with vegetative cover

In any large architectural project, a large portion of the open area (mandatory open space being 60% of the plot area) is directed to be treated with green cover (grass lawn and trees) as children's playground and recreational area, which helps in minimizing quantity of run-off to some extent and provide for some rainwater recharging into the ground. More often, some old trees are being kept by architects in their positions and integrated into the new design of the built forms as components of the environment (KMC, 2004)[7].

Conservation and retention of water bodies and recovery of wetland

The Government enforces the West Bengal Inland Fisheries Act, 1993 (Amended) to restrict filling up of any water body. The Municipality is keeping vigilance and taking legal action against any offender and reclaiming the water body at the offender's cost. The State Environment Department has declared the 'The East Kolkata Wetlands (Conservation & Management) Ordinance 2005' (Government of West Bengal, 2005)[24] to define the wetland area. In the assembly meeting of the councilors of KMC held on 22.10.2011, a resolution has been taken that an inventory of wetland and water bodies would be prepared ward-wise in the city, and the tendency of construction of buildings reclaiming land from water bodies at the added areas has been condemned and strict vigilance to control it was proposed (Sambaddata, 2011)[25].

De-silting and cleaning of sewer lines, outfalls and canals

14 vehicles with jetting cum suction pump machine to suck and dredge silts deposited in the sewer lines have been bought from abroad up to 2005 and engaged in operation. In some areas with narrow roads, human beings remove silts manually. The State Government acknowledges the need to dredge and conserve canals. Some canal restoration projects were started by the State Irrigation Department and the KMC (Bose, 2008)[21].

Kolkata Metropolitan Development Authority's recent works

The Government has taken up projects with financial assistance from the Central Government under the "National Urban Renewal Mission" implemented by the KMDA with an objective of improvement of the drainage and sewerage system of the city and northern fringes across five municipalities (KMDA, 2009)[26]. Moreover, the KMDA has been doing several works for improvement of drainage in and around Kolkata.

Works under Kolkata Environmental Improvement Project (KEIP)

This is a multi-agency endeavour to arrest environmental degradation in fringe areas where drainage and sewerage networks are inadequate. Its work has included – (i) efficient interception and collection of sewage by providing secondary sewers, (ii) build trunk sewers in addition to existing trunk lines, (iii) develop separate storm water drainage systems including pumping stations where necessary, (iv) laying new underground conduits in narrow roads and connect properties to the new networks, (v) construct/rehabilitate pumping stations, and (vi) upgrade treatment plants and construct new ones where necessary (KEIP, 2009)[27].

Gross physical planning and fund investment by Government and Municipality

A total of Rs.2520 crore (around US$550 million) has been spent over a period from 2005 to 2009 by the Government and Municipality through the Jawaharlal Nehru National Urban Renewal Mission (funded partly by US Aid, partly by Central Government), Kolkata Environmental Improvement Project (funded partly by Asian Development Bank), and Project *Nikashi* (Drainage) (KMC, 2009)[7]. The major works taken up under these projects are– dredging and re-excavation of canals, revamp of drainage and sewer system and network, drainage development, setting up of new pumping stations, repair and restoration of old pumping stations, automation in pumping stations, procurement of sewage-cleaning machines, etc.

Proposal for integrated drainage water management by author

A recent study reveals that out of the 141 wards under the KMC area, 42 wards have no park in them at all; 24 parks have canopy cover more than 25% of park area, 39 pa have 15-24% canopy cover, 61 parks have 6-14% canopy co and 166 parks have 0-5% canopy cover (Sivaramakrishnan Sengupta, 2010)[28]. Only 5% of municipal area of Kolkata park and garden area. Out of that 50% area is the *Maid* (vast open space with little green) area at Chowringhe Esplanade (central) area in Kolkata. So, parks and garde actually occupy 2.5% of the municipal area of the city. Mu of that area is further covered with concrete for various reasc (Dutta, 2011)[29]. There are some areas in the city which ha major or large water bodies in them but with inadequa numbers of trees. These and other suitable park areas in t city are to be designated for creation of urban forest w thick plantation at maximum area of each of them a enlargement of area of water bodies, wherever possible, create a local biosphere. The total capacity of carbon dioxi absorption and generation of oxygen of such urban fore would be high because of high density of plantation. Such water body is proposed for use as a local reservoir for stori monsoon rainwater from surface run-off load and from t roofs of buildings at the local region through dedicat underground drainage conduits for minimising load on city main drainage system and for rainwater harvesting by whic the problem of inundation during monsoon and the urge need for recharging the ground water level in the city a equally solved along with control of local climate (**Fig. 8**). This urban forest-ecosystem with suitable fruit-trees will al help growth and survival of a section of the animal kingdo and would bring back various birds that do not visit the ci because of urbanization in it. Necessary technological contro mechanism, as required, is to be designed and employed the inlet points where accumulated rainwater falls into t water bodies.

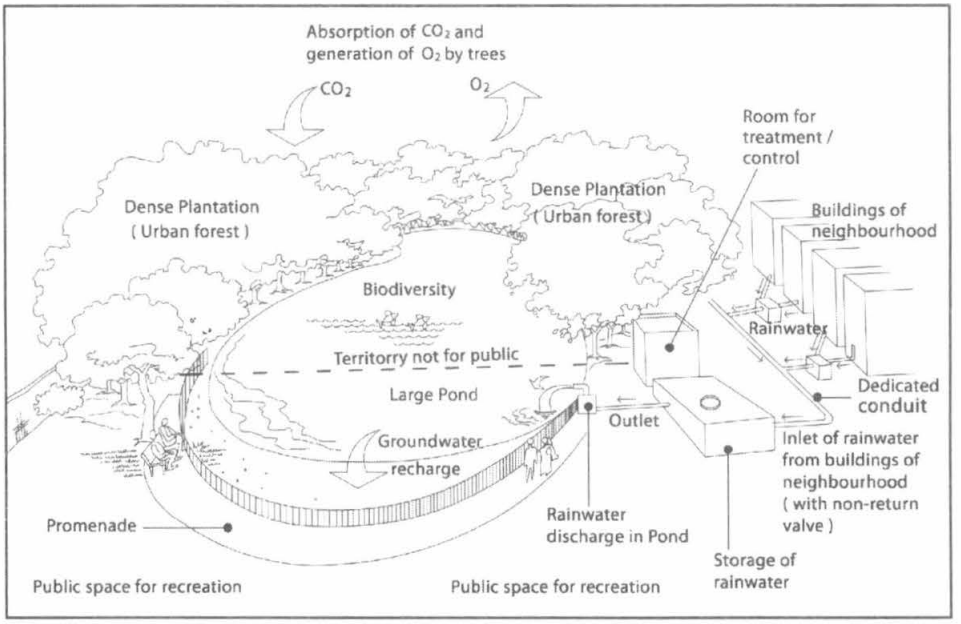

Fig. 8 : A schematic diagram showing planning for drainage and environmental solution

(Source: Bose, 2011)[45]

Conclusion

Even after many measures taken in Kolkata, still, flooding during monsoon at many areas of the city is observed till 2011. Notable achievement is that the area under inundation during monsoon has been minimized substantially. So, it has become urgent to take up an integrated approach of management of drainage under broader physical, technological, ecological and environmental parameters for minimizing perennial urban flooding, and attaining environmental sustainability of the city. On one hand, the city's capacity to drain out excessive quantity of rainwater during monsoon is not adequate; on the other hand, because of depletion of aquifer, a huge quantity of water needs to be recharged in aquifer. Pollution in air is heavy from traffic (about 55%) and building industry (about 30%) (WBPCB, 2005-2008)[30]; carbon dioxide in air is in high proportion; and green areas are limited and do not contain enough trees. The report by the Central Ground Water Board of the Union Water Resources Ministry published in 2009 underlined the need to "reduce the stress on underground water" and "undertake recharging schemes" in Kolkata (Ganguly & Basu, 2009)[16]. For addressing the inundation problem, it is required that the input-load is minimised at source first, then better technological applications are to be employed with constant monitoring (of performance) for better management of the drainage-stress during heavy rainfall in monsoon.

Mitigation of this problem not only needs proper environmental planning, but also sincere participation and effort of all sections of the community and administration. Good coordination amongst various urban planning and development departments of the state government and the autonomous municipal corporation is extremely required. Research findings on drainage and related environmental issues by any individual researcher as well as NGO bodies are to be seriously considered and accepted by the state government in the making of planning policies. Proper emphasis is to be given on research, capacity building and participatory programmes of stakeholders and public for broadened awareness, proper cooperation and practical pro-sustainable activity in this regard to achieve the community's common goal.

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