STRATEGIES FOR INTEGRATED URBAN DRAINAGE MANAGEMENT IN MONSOON RAINFALL AREAS WITH SPECIAL REFERENCE TO THE INDIAN SUBCONTINENT

Kapil Gupta

Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai 400076, India, email: kgupta@civil.iitb.ac.in

ABSTRACT

Continuing urbanization has led to increasing concentrations of population in urban areas in the Indian subcontinent. Urban centres continue to be a source of employment and thus tend to attract migrations from the rural areas, mainly due to the collapse of a sustainable rural economy, increase in commercialization of economy and inter-dependence and globalization of economy. These increasing migrations and developments in urban areas tend to create pressures on the existing water infrastructure components, namely water supply, drainage systems, wastewater treatment plants and the receiving waters. Almost 25 % of the world's population is concentrated in the Indian sub-continent and it is expected that more than 700 million people would be living in urban areas in the Indian subcontinent alone by 2025. These cities are now caught in the vicious circle of increased impervious surfaces–less recharge–more runoff, thus overloading the existing drainage systems. Thus these cities witness water crisis in the summer and floods during the monsoon season.

This paper identifies the scenarios that would emerge if development continues at its present rate where each component of water supply, drainage and treatment are addressed individually. It then presents the way forward and advantages of implementing integrated urban drainage management with sustainable water management options (for example rainwater harvesting and storage devices). This paper aims to provide a road map for the cities in the Indian subcontinent through appropriate integrated urban drainage management and also describes the recent initiatives taken up by the Government of India in this direction.

Key words: integrated urban drainage management, monsoon, Indian subcontinent

1. INTRODUCTION

Continuing urbanization has led to increasing concentrations of population in urban areas in the Indian subcontinent. Urban centres continue to be a source of employment and thus tend to attract migrations from the rural areas. The main causes of these can broadly be identified as collapse of sustainable rural economy, increase in commercialization of economy and inter-dependence and globalization of economy. These increasing migrations and developments in urban areas tend to create pressures on the existing water infrastructure components, namely water supply, sewer system, wastewater treatment plants and the receiving waters. Almost 25 % of the world's population is concentrated in the Indian sub-continent and it is expected that more than 700 million people would be living in urban areas in the Indian subcontinent alone by 2025.

Many urban conglomerations in the developing world have sprung up due to the cities expanding and occupying the neighbouring villages, subsequently to be merged into the urban conglomeration. From a water supply perspective the original city exhibited piped water supply, the small villages which they absorbed still depended on traditional water sources like tanks and wells. Also, the cities exhibited well designed drainage systems, but the villages which formed the agglomerations, by virtue of the administrative mechanisms, had their wastewaters disposed to the nearest natural stormwater drainage channel. Moreover, rapid urbanization has witnessed informal habitations develop adjacent the drainage channels and in some cases, even on the top of the drainage channels. These cities are now caught in the vicious circle of increased impervious surfaces – less recharge – more runoff, thus overloading the existing drainage systems. Consequently, these cities experience water crisis in the summer and floods during the monsoon season. The unique feature of the monsoon rainfall is that a major part of the sub-continent receives over 75% of the rainfall during June to September with very little rainfall during the remaining 8 months.

This paper first identifies the scenario that would emerge if development continues at its present rate where each component of water supply, drainage and treatment are addressed individually. An example of the crisis situation that resulted in Mumbai during extreme rainfall of 994 mm in 24 hours in July 2005 is also described. It then presents the way forward and advantages of implementing integrated urban water management with sustainable water management options (for example rainwater harvesting and storage devices) taking into consideration the quantity of water supply, wastewater generated and expected stormwater. This paper in intended to provide a scenario analysis for the cities in the Indian subcontinent to enable them to plan appropriate integrated urban water management strategies for the future.

2. SCENARIOS

Three scenarios can be visualized for planning the future urban water systems (Butler, 2004), namely

1. Business as usual (BAU),
2. Crisis, and
3. Sustainable development/proactive management.

Scenario 1- BUSINESS AS USUAL (BAU)

This scenario has seen severe neglect of the urban drainage systems. There have been many failures of the existing systems due to ageing and sewer collapses are now common in many of the Victorian sewers constructed in UK (Read and Vickridge, 1997) and other parts of the world, for example, Mumbai (Gupta, 2006). Dilapidated sewers and drains with reduced capacity are one of the main causes for increased urban flooding. Therefore, there is an urgent need for replacement of the ageing drainage infrastructure keeping in mind the overall aims of integrated urban water management and the overall future city development master plan.

With respect to drainage systems in the major cities, the drains in the town centre had been designed to be separate, but due to growth and developments in the city centre, a large number of cross-connections from the house sewers to the stormwater drains have been observed. The net result has been that they function as combined sewers in the dry season with severe surcharging and local flooding during periods of heavy rainfall. In the suburbs, the development of the drainage system has been very slow, thereby resulting in the open stormwater drains receiving increasing quantity of sewage and sullage. Due to their reduced capacity, contaminated stormwater from these drains frequently overflows into the informal settlements located on the periphery of the drains. This not only results in unaesthetic conditions, but has grave consequences for urban health and sanitation, which are particularly severe during times of high intensity rainfall (> 100 mm/hr) when overflows result in loss of lives due to flooding and epidemics due to polluted waters. The outbreak of epidemics is common during the monsoon in urban areas in India and the various diseases are shown in Table 1.

Table 1 Major monsoon diseases in the Indian subcontinent

S no	Disease	Description	Mechanism of infection	Incubation period	Symptoms	Preventive Measures
1	Leptospirosis	An infection that spreads through *leptospira* bacteria particularly through flood water contaminated with the urine of rats and dogs	Enters body through skin abrasions or the nose	5-10 days	Fever, muscle pain, vomiting, loose motions	Avoid walking through waterlogged areas
2	Gastroenteritis	Infection or inflammation of the digestive tract	Through drinking contaminated water	12-24 hours	Vomitting, loose motions, Viral fever	Drink boiled water
3	Viral fever	Viral infection that raises body temperature and causes fever	Through prolonged exposure to rain and wet clothes and shoes	-	Fever, chills, aching body, cough and cold	Change into dry clothes ASAP, Avoid air conditioned rooms
4	Malaria	Infection caused by a parasite and transmitted by the female *anopheles* mosquito from one person to another; *Falciperum* malaria is most life-threatening	Through bites from mosquitoes breeding in stagnant waters	7-21 days	Fever with chills, joint pain, vomiting, anaemia, convulsions	Prevent stagnation of waters, e.g. empty flowerpots, discarded tyres, pots and pans and use mosquito nets
5	Dengue	Infectious disease transmitted by the *Aedes* (tiger) mosqutio from person to person – can sometimes be fatal	Through bites from mosquitoes breeding in stagnant waters	3-10 days	High fever (105 degrees) , severe headache, falling blood platelet count and joint and muscle pain	- as above-
6	Jaundice	Disorder of liver caused by hepatitis A or E virus	Through consuming contaminated water and food	15 – 20 days	Yellow tinge on skin and eyes, nausea, vomiting and fever	Drink boiled water, vaccinations for children below 16 available
7	Typhoid	Caused by the bacteria Salmonella typhi that causes inflammation of the intestines	Through consuming contaminated water and food	10 days	Unrelenting fever, rashes and overall weakness	Drink boiled water, wash hands and maintain general personal hygiene
8	Cholera	Water-borne bacterial disease	Through consuming contaminated water	5 h – 5 days	Diarrhoea, dry skin, dehydration, nausea, abdominal cramps	Drink only boiled water

Another major cause for concern with respect to urban drainage systems is the effect that climate change may have on flooding in urban areas. The Intergovernmental Panel on Climate Change (IPCC) has observed that “the marked increase in atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) since 1750 is the result of human activities” and that “the implications of global warming over the coming decades for our industrial economy, water supplies, agriculture, biological diversity and even geopolitics are massive” (IPCC, 2007). The main findings of the climate change studies, of relevance to urban drainage, are an increase in the total precipitation (and hence runoff) and increased storm intensities (Butler and Davies, 2004) and the potential implications have been summarized as follows:

1. Increased flows that may exceed the capacity of existing sewer systems leading to more frequent surcharging and flooding,
2. Greater deterioration of sewers due to more frequent surcharging,
3. More frequent combined sewer overflows (CSOs),
4. Greater build-up and mobilization of surface pollutants in summer,
5. Poorer water quality in rivers due to extra surface water and CSO spills and reduced base flows in summer,
6. Increased flows of dilute wastewater at sewage treatment plants due to higher rainfall and infiltration, potentially leading to poorer treatment by biological processes.

Scenario 2- CRISIS

Crisis with respect to urban drainage systems may result from a combination of one or more of the following factors:

1. Flooding of the city due to extreme rainfall events caused by excess meteorological activity: for example Mumbai (July 2005), Djakarta (February 2007) and Kolkata (July 2007). In each case, the drainage systems were either inadequate to accommodate the excess flows or were non-existent.
2. Flooding of the city located on river banks due to release of excess waters from the dams located upstream: In the case of New Orleans, USA (August 2005), the levees of the Lakes failed, whereas in the case of Surat, India (August 2006), the waters from the dam upstream of the city were released abruptly thereby causing over 90% of the city to be submerged. Environmental problems in terms of widespread epidemics in cities due to contamination and backflow of drainage waters also caused significant fatalities.

Box 1: 26 July 2005 floods: 994 mm in 24 hours in Mumbai

The extreme rainfall event of 994 mm on 26th July 2005 has been a lesson for Mumbai and it has indicated the perils of rapid development in highly concentrated urban areas. Mumbai city having an area of 437 sq km with a population of 12 million came to a complete halt due to the unprecedented rainfall of 994 mm during the 24 hours starting 0830 on 26 July 2005. At least 419 people (and 16,000 cattle) were killed due to the ensuing flash floods and landslides in Mumbai municipal area, and another 216 due to flood related illnesses. Over 100,000 residential and commercial establishments and 30,000 vehicles were damaged.

This event has resulted in Mumbai setting up a much better flood response mechanism based on real-time monitoring of rainfall at 27 locations in the city to handle recurrences of similar events during the monsoon. These rain gauges have been programmed to display rainfall intensity in real time (every 15 minutes) at the emergency operations centre of the Municipal Corporation of Greater Mumbai (MCGM). Resources are mobilised based on the exceedence of threshold rainfall values (>40 mm/h). Also, the Central Water Power Research Station, Pune is currently (2007-08) in the process of preparing a detailed scale model for carrying out the hydraulic model studies for the Mithi River in Mumbai. This model is intended to provide a basis for long-term planning of Mumbai taking into account the impacts of climate change and sea-level rise. It would also help in identifying the tidal impact on the flooding and estimate the extent of inundation of low lying areas through the progression of low and high tides. Concurrently, another study has been commissioned by the MCGM to redesign the drainage system to accommodate design rainfall intensities of 100 mm/h over the time of concentration which have been exceeded 5 times during 1999-2007. The results of this study are intended to recommend various structural, non-structural and pumping options for Mumbai city for the long-term and an amount of 200 m. Euros has been allocated for implementing these measures. The Mumbai experience should be helpful for planning response strategies for other large cities to cope with similar events in the future (Gupta, 2006b).

Scenario 3: SUSTAINABLE DEVELOPMENT/PROACTIVE MANAGEMENT

Proactive management measures for reducing flooding in urban areas have been referred to as Best Management Practices (BMPs) in the USA, Sustainable urban Drainage Systems (SuDS) in the UK and Europe and Water Sensitive Urban Design (WSUD) in Australia. Various BMPs have been documented in literature, for example, Mays (2001). BMPs for urban drainage include both structural and non-structural measures and are summarised in Table 2.

Table 2. BMPs for flood and pollution control in urban drainage systems

S No				
1	Source Control	Land use planning		
2		Maintenance of natural drainage	Swales	
3		Local disposal	Infiltration	Infiltration beds/ trenches/basins
4			Percolation	Percolation sub drain/ dry well
5			Porous pavements	Parking areas
6		Storage	Rainwater harvesting	Rooftop Storage
7		Storage with controlled storm water entry/exit	Stilling ponds	Vortex valves
8			High side weir	
9			Vortex separators	
10		On-site detention	Ditches	
11			Detention (dry) pond	
12			Retention (wet) pond	
13			Wetlands	
14	Downstream storage	In-line/off-line detention	Channel/pipe storage	
15		Detention at the treatment plant	Equalization basin	
16	Planned urban flow routing		Syphonic drainage	
17	Increased application of real-time control			

Structural measures incorporate engineered devices to control, treat or prevent stormwater runoff and/or pollution, green roofs, alternative site design, storage on rooftop and aquatic buffers. Structural controls can be implemented through infiltration/filtering systems, stormwater ponds, open channels and constructed treatment wetlands. Also, innovative structures for distributed storage, source control and satellite treatment are now commercially available. Downstream controls need to be supplemented or replaced with upstream controls for the BMPs to succeed. Storage of the first flush of pollutants has been identified as one of the methods to achieve significant reduction of the pollutant loads reaching the receiving waters. Examples of non-structural measures are zoning and ordinances, public education programmes, pollution prevention and good management. The availability of these techniques and their successful implementation in various parts of the world has been communicated to over 1000 field engineers in the Indian sub-continent by organising state-of-the-art courses on urban drainage management in various parts of India. The engineers have shown a keen desire in implementing these techniques. However, it has been observed that the institutional arrangements need to be strengthened with clear guidelines for implementation maintenance and accountability.

The philosophy of the traditional solutions with respect to limiting flood damage from overflowing drainage systems has been of a reactive nature, i.e. to get rid of the stormwater as quickly as possible – an out-of-sight-out-of-mind-approach using conventional sewerage pipe systems, open channel drains, wastewater treatment plants and the associated infrastructure. However, it has been found that the conventional wastewater systems are expensive and unaffordable for the majority of the cities and even the wealthy nations are finding the costs of rehabilitating and upgrading conventional systems prohibitive. The integrated urban drainage approach places special emphasis on prevention of flooding and pollution through source control measures such as land use planning, provision of natural drainage, porous pavements, controlled stormwater entry, litter control and provision of storage facilities for stormwater.

3. CURRENT STATUS IN INDIA

The Government of India has launched a major initiative - the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) which integrates urban drainage within the overall urban development plans in 63 of the largest cities in India. This initiative is part of the Government of India's commitment to meet the Millennium Development Goals and is targeted to be achieved by 2011. The JNNURM covers integrated infrastructural development with provision of planned roads, environmental upgradation and adequate urban infrastructure, particularly provision of drinking water in each house, rain water harvesting, planned sewage and modern drainage systems and water recycling. The Ministry of Urban Development (MUD) has been designated as the Executing Agency (EA) for the infrastructure and governance component of the JNNURM and the total budget outlay is 9000 million Euros over a 7 year period.

4. SUMMARY AND CONCLUSIONS

Many cities of the world, particularly those located in the monsoon belt are now becoming increasingly vulnerable to urban flooding due to inadequate provision of urban drainage infrastructure for the expanding populations. The flood risk is likely to increase in the future due to the combined effects of climate change, global warming, local heat island effects and rising sea levels. A well formulated integrated urban drainage management strategy should take into consideration the location of the buildings, roads, road drainage and also the quantity of water supplied, wastewater generated and expected stormwater based on analysis of extreme rainfall events. Urban drainage management efforts should involve all stakeholders with special focus on public participation in an inclusive and integrated manner. The Government of India has launched a major initiative - the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) which integrates urban drainage within the overall urban development plans in 63 of the largest cities in India.

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