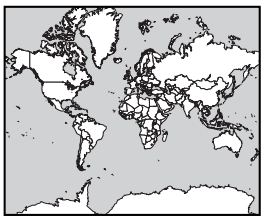

# Drainage and stormwater management strategies for low-income urban communities

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*SUMMARY: Based upon a review of the literature, this paper focuses on the provision of drainage systems and stormwater management strategies in low-income urban settlements. Although engineered infrastructure is a necessary component for drainage of urban runoff, non-structural approaches are important complementary measures, focusing on actions to prevent and mitigate problems related to flooding, as well as those related to pollution and deterioration in environmental health conditions. As these rely predominantly on behavioural changes to be effective, a participatory approach is recommended within a strategic framework of urban stormwater planning.*

## I. URBAN DEVELOPMENT, STORMWATER RUNOFF AND IMPACTS OF FLOODING

URBAN CONDITIONS EXACERBATE drainage problems; runoff is increased by impermeable urban surfaces and, due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for stormwater drainage. The poor are disproportionately affected; they often reside in informal settlements located on marginal land – low-lying land, riverbanks, floodplains and steep hillsides – that the formal housing market does not want or need.(1) Although these sites are vulnerable to the impacts of flooding, the benefits of living nearer sources of employment and urban services generally outweigh the disadvantages associated with flooding, which is generally perceived as a natural and seasonal event.(2) To assist in the analysis of problems related to stormwater runoff and urban drainage, and the impacts on urban communities, three broad categories of flooding are identified here. These are summarized in Table 1 in relation to their physical and environmental health impacts, which are discussed below.

### a. Physical impacts

As shown in Photo 1, flooding can cause widespread disruption to transportation, power and communication systems, as well as structural damage to buildings and infrastructure. The disruption, damage to properties, loss of possessions, as well as financial worries and other stresses from living in damp houses mean that flood events can place a considerable strain on households. These factors are recognized to be significant even in countries

| Table 1: | Typology of flood types, characteristics and impacts |
|---|---|
| Flood type | Characteristics of flooding and impacts |
| Type A | Localized flooding caused by inadequate drainage of stormwater runoff, which can happen virtually every time it rains where the provision of drainage infrastructure is very poor. The main impacts of these events are related to a deterioration in environmental health conditions – notably those related to water-related diseases. |
| Type B | Flood events of this type occur less frequently than type A floods, but affect larger areas. The impacts may include temporary disruption to transportation systems and inconveniences to city life. These events contribute to the propagation of water-related diseases and can cause structural damage, but not as severe as those related to type C events. |
| Type C | Large-scale inundation causing widespread disruption and damage affecting communities and businesses throughout cities. These events are infrequent and often reach the headlines due to the dramatic scale of the impacts and structural damage. |

such as the United Kingdom, where flooding is typically small-scale, short-lived and shallow,[3] but these factors take on an extra dimension in cities in tropical regions. Due to the high intensities of rainfall during rainy seasons, the lack of drainage infrastructure and the failure to maintain existing systems, the impacts of flooding are widespread and, as described below, it is the poor who are most susceptible and consequently suffer the most.[4] The nature of flooding events relates to the physical context and may affect communities in different ways. Although floods are often associated with large-scale events with disastrous consequences, there is also more frequent flooding related to factors at a local level, which can cause many problems in the urban environment, although they are often a less immediate and obvious cause for concern.[5]

## b. Environmental health impacts

Although it is difficult to prove conclusively because of the complexities of disease transmission routes, there is considerable empirical evidence to indicate that flooding and poor drainage have a significant impact on the prevalence of illness, and that large-scale flooding may disrupt water supply and sanitation systems and result in disease epidemics.[6] In poorly drained areas with inadequate sanitation, urban runoff mixes with excreta – spreading pathogens around communities and increasing risks to health from various waterborne diseases (Figure 1). Infiltration of polluted water into low-pressure water supply systems can contaminate drinking water and is frequently a source of gastrointestinal disorders. Wet soils in poorly drained areas, which become faecally contaminated due to poor sanitation, also provide ideal conditions for the eggs of parasitic worms, such as round-worm and hookworm, which can cause debilitating intestinal infections.[7]

Open drainage channels are potential sources of infection and disease,[8] especially to children who play in them, and polluted water from drains is often used for agriculture, where water resources are scare. Flooded septic tanks and leach pits, and blocked drains (see Photo 2) provide breeding sites for *Culex* mosquitoes, which transmit filariasis, a condition that can lead to elephantiasis and its painful swelling of the legs. Also

1. Main, H and S W William (editors) (1994), *Marginal Urban Environments as Havens for Low-income Housing: Third World Regional Comparisons in Environment and Housing in Third World Cities*, John Wiley and Sons, Chichester.

2. Parkinson, J (2002), "Urban drainage in developing countries – challenges and opportunities", *Waterlines* Vol 20, No 4.

3. Tapsell, S (1999), "The health effects of floods – the Easter 1998 floods in England", Article Series Vol 3, No 99, Flood Hazard Research Centre, Middlesex University, UK.

4. UN–HABITAT (2003), *Water and Sanitation in the World's Cities – Local Action for Global Goals*, published in association with United Nations Human Settlement Programme (UN–HABITAT), Earthscan, London, UK.

5. Andjelkovic, I (2001), "Guidelines on non-structural measures in urban flood management", Technical Documents in Hydrology Series No 50, IHP–V UNESCO International Hydrological Programme, Paris.

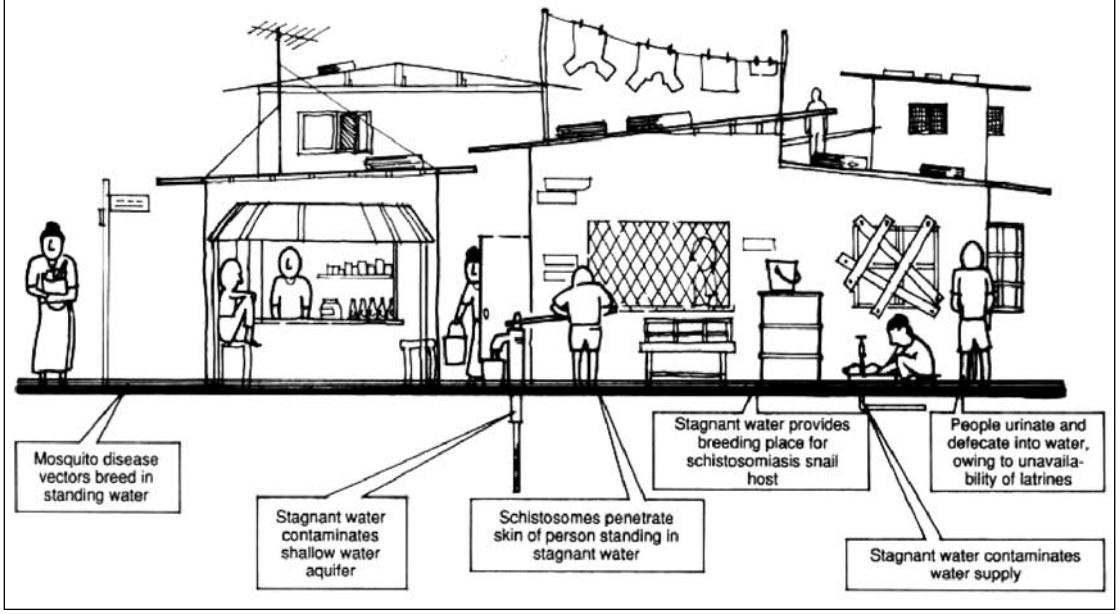
6. See reference 4.

7. Kolsky, P (1999), "Performance-based evaluation of surface water drainage for low-income communities: a case study in Indore, Madhya Pradesh", PhD thesis, London School of Hygiene & Tropical Medicine, University of London.

8. Cairncross, S and E A R Ouano (1991), *Surface Water Drainage for Low-income Communities*, WHO/UNEP, World Health Organization, Geneva, Switzerland.

Photo 1: Flooding in Dhaka causes widespread disruption to city life. Photo: Mr. Terry van Kalken, DHI – Water & Environment

**Figure 1: Stagnant water and disease transmission – the health consequences of poor drainage**




SOURCE: Cairncross, S and E A R Ouano (1991), *Surface Water Drainage for Low-income Communities*, WHO/UNEP, World Health Organization, Geneva, Switzerland.

Photo 2: Slum settlement living adjacent to a polluted drainage channel in Lucknow, India. Blocked, polluted drains like this one in Lucknow are important breeding sites for Culex quinquefasciatus mosquitoes. Low-income communities living in slums next to drainage channels are especially susceptible to environment health problems as well as those related to flooding. Photo: Shaleen Singhal, TERI (The Energy and Resources Institute), New Delhi, India

related to drainage conditions are *Aedes* mosquitoes, which transmit yellow fever, dengue and dengue haemorrhagic fever. These mosquitoes often breed in containers which fill with water during rain, such as domestic water storage containers, discarded cans, tyres, plastic bags and coconut shells. *Anopheles* mosquitoes, which transmit malaria, are also a risk in urban areas, and they lay their eggs in still, unpolluted water, for instance in wetlands and on pond surface waters, which are commonly found where drainage is poor.[9]

## II. IMPACT OF FLOODING ON THE URBAN POOR

IT HAS ALREADY been noted above that the environmental health impacts of flooding are compounded in poor communities. The consequences of flood events can be devastating for these communities. The poor have fewer resources available for rebuilding and they generally receive little external support to recover from flooding.[10] Their livelihoods are more vulnerable to the risks associated with flooding and are more susceptible to disruption.

The location of poor neighbourhoods and the inferior construction materials used to build homes for the poor contribute to their greater vulnerability.[11] A lack of transportation may also prevent poor households from moving themselves and their possessions out of harm's way. More affluent communities often contribute to the flood problem by investing in drainage infrastructure which exacerbates flood problems elsewhere.[12]

A study of poor communities in informal settlements in East Java in Indonesia indicated that the poor often worry about the risks to their liveli-

9. Kolsky, P (1999), "Engineers and urban malaria: part of the solution, or part of the problem?" *Environment and Urbanization* Vol 11, No 1, April, pages 159–163.

10. Napier, M, L A de Bustillos, H Santosa and M Rubin (2002), "Understanding the interface between the environment and sustainable livelihoods in the integration of informal settlements in Asia, Latin America and Africa: a review of current thinking and practice", CSIR Building and Construction Technology, Pretoria, South Africa,March 2003. http://www.csir.co.za/akani

11. Francis, J (2000), Implications of gender in floods, Gender and Water Alliance, November. http://www.genderandwateralliance.org/reports/discussion_paper_on_gender_and_floods_by_JF.doc

12. See reference 5.

13. Santosa, H (2003), "Environmental hazards management in informal settlements to achieve sustainable livelihoods of the poor: the case of East Java, Indonesia, CSIR Building and Construction

Technology, Pretoria, South Africa, March 2003 http://www.csir.co.za/akani

14. Stephens, C, R Patnaik and S Lewin (1994), "This is my beautiful home: risk perceptions towards flooding and environment in low-income urban communities: case study in Indore, India", Urban Health Programme Publication, London School of Hygiene & Tropical Medicine, London.

15. Lines, J (2002), "How not to grow mosquitoes in African towns", *Waterlines Journal* Special Edition on Urban Stormwater Drainage, April, Intermediate Technology Development Group.

16. Affeltranger, B (2001), "Public participation in the design of local strategies for flood mitigation and control", Technical Documents in Hydrology No 48, International Hydrological Programme, UNESCO, Paris.

17. See reference 11.

hoods and health from flooding.[13] However, research in Indore in India highlighted the fact that poor communities expect flooding, and perceive it to be a part of life. Residents noted that flooding was ranked low in comparison to other risks and problems, such as improvements in job opportunities, provision of housing, mosquitoes and smelly back lanes.[14]

Damage to homes caused by flooding places extra demands on the limited resources of the poor. There are also indirect effects, such as the loss of working days required to repair structural damage, or the increased prevalence of illness, causing families to redirect assets towards treatment. Also, even where filariasis is not a problem, *Culex* mosquitoes cause widespread irritation and the urban poor can spend relatively large portions of their income seeking temporary relief by buying mosquito coils.[15]

The poor are not a homogenous group, and preparedness for environment-related hazards such as flooding, and the degree of vulnerability, will differ amongst community members. Groups that are at particular risk include children, the elderly and physically disabled people who experience particular difficulties in dealing with disasters and who may be particularly vulnerable to adverse health effects from floods. Otherwise known as "social amplification" of disasters,[16] this variation among those affected depends upon factors related to their socioeconomic and cultural status, which will also affect their adopted response strategies.

The problems of poor drainage and flooding of domestic properties tend to have a disproportionate effect upon women. Women have to deal not only with the economic devastation and disruption of livelihood systems but also are often left to cope with the social and emotional upheaval that comes from dealing with the death, disease and food shortages that invariably occur in the aftermath of floods. In addition to this, cultural practices in some countries require women always to be escorted in public by male relatives, which can increase women's vulnerability during flood events and may even result in women drowning if they are unable to leave their homes without being accompanied.[17]

## III. STRATEGIC APPROACHES TO URBAN DRAINAGE AND STORMWATER MANAGEMENT

IN ORDER FOR urban authorities to address the diverse problems related to flooding described above and the complexities of urban environmental management, it is important that they adopt a strategic approach towards the development and implementation of stormwater management plans. A combination of structural and non-structural stormwater management strategies are considered to be complementary aspects of a comprehensive and integrated stormwater management strategy.

### a. Structural stormwater management strategies

Structural stormwater management strategies focus on physical interventions and investments in engineered infrastructure for improved drainage. It is generally difficult to provide conclusive evidence that drainage improves health, but results of a study in Salvador, Brazil demonstrated that community sanitation infrastructure can have a significant impact on diarrhoeal disease, even without any significant measures to promote hygiene behaviour changes within the household.[18]

Conventional approaches to infrastructure provision tend to be inappropriate for informal settlements, as they do not take into account the irregularities and unplanned nature of squatter settlements, which are characterized by narrow access routes, occupation of areas of risk, and the lack of a precise definition of public and private spaces.[19] The more obvious physical characteristics of informal settlements are inherently different from those associated with formal settlements, and may have significant implications for the design and implementation of urban drainage systems.

In relation to the risk factor associated with living in flood prone areas, the concept of return frequency is an important parameter in the design of stormwater drainage systems. Conventional drainage system designs are inappropriate because they fail to take the potential for flooding into account.[20] According to Kolsky and Butler,[21] as well as the frequency of flooding, the duration, depth and extent of flooding should be considered in relation to the implications for the communities that are affected.

## b. Non-structural stormwater management strategies

Non-structural stormwater management strategies for mitigation of flood impacts focus upon preventative action and rely predominantly on behavioural changes in order to be effective. These are particularly relevant in low-income communities in tropical climates, where flooding is inevitable and resources for infrastructure are scarce. Faisal et al.[22] concluded that a well-coordinated and balanced combination of both structural and non-structural measures is required as part of the long-term flood mitigation strategies for Dhaka in Bangladesh. Examples of different types of non-structural stormwater management strategies are summarized in Table 2 and described in more detail below.

**Table 2: Non-structural strategies for flood control and mitigation of environmental health problems**

| | |
|---|---|
| **Flooding problems** | |
| Flood avoidance | Preventative responses which aim to ensure that flood problems are avoided. |
| Flood mitigation | Immediate responses to flood warnings before a flood, and the course of action to take during a flood to reduce risks. |
| Flood recovery | Action to be taken after a flood event to enable communities to recover from the impacts of a flood event. |
| **Environmental health problems** | |
| Solid waste management | Control of solids waste to avoid blockages and reduction in hydraulic capacity of the drainage system. |
| Pollution mitigation | Reduction in the discharge of pollutants into the stormwater drainage system. |
| Vector control | Improved practices to reduce vector transmission of diseases related to urban drainage and flooding. |

18. Moraes, L R S, J Azevedo Cancio, S Cairncross and S Huttly (2003), "Impact of drainage and sewerage on diarrhoea in poor urban areas in Salvador, Brazil", *Transactions of the Royal Society of Tropical Medicine and Hygiene*, London, (in press).

19. Imparato, I and J Ruster (2003), "Slum upgrading and participation", World Bank, Washington DC, USA.

20. Kolsky, P J (1998), *Storm Drainage: An Engineering Guide to the Low-cost Evaluation of System Performance*, Intermediate Technology Publications, London.

21. Kolsky, P J and D Butler (2000), "Solids size distribution and transport capacity in an Indian drain", *Urban Water* Vol 2, No 4, pages 357-362.

22. Faisal, I M, M R Kabir and A Nishat (1999), "Non-structural flood mitigation measures for Dhaka city", *Urban Water* Vol 1, No 2, page 112.

## IV. NON-STRUCTURAL STRATEGIES FOR FLOOD PREVENTION AND MANAGEMENT

THIS SECTION SUMMARIZES non-structural measures for urban flood control, which complement structural approaches for urban drainage and form part of an integrated and comprehensive strategy for stormwater management. Broadly, these are categorized as follows.

### a. Flood prevention strategies

Flood avoidance strategies are precautionary interventions that involve structural adaptations to constructions to reduce the impacts of inundation, or the relocation of houses that are on drainage pathways and floodplains. Experience indicates that large-scale eviction and forced relocation can exacerbate social problems, which can be more problematic for urban authorities than the original drainage problem.[23] As demand for land in cities is high, it is not possible to assign land purely for flood management purposes – it therefore needs to have an alternative use to ensure that informal settlements do not appear. Innovative approaches to land control may be employed which have positive benefits during flood conditions. For example, in Porto Alegre in Brazil, areas designated for flood control are also used as football pitches to discourage further illegal invasions and squatter settlements.[24]

Where resettlement is the only viable option, it will be necessary to ensure that resettlement plans are designed and implemented with the groups that are being resettled (especially with regard to the choice of the relocation site). In order to ensure that people remain in the new settlements, it is necessary to provide appropriate infrastructure services and opportunities to support people's livelihoods.[25] In a different context, but relevant to flood prevention, Patel et al. describe a resettlement programme involving the relocation of 60,000 low-income people who moved without coercion, in order to make way for improvements to Mumbai's railway system. The process was underpinned by strong levels of community organization and by involvement in the design, planning and implementation of the resettlement programme, and in the management of settlements to which they relocated.[26]

### b. Flood mitigation strategies

Flood mitigation strategies involve responses, both before and during a flood event, which include advance warnings, the operation of flood control works, and emergency unblocking of blocked inlets and drains. An important aspect is the identification of potential events, and communication is critical to ensure that mobilization and evacuation response strategies are effective. Because of illiteracy or the absence of telephones, radios and televisions, poor families may not learn about impending disasters or evacuation plans. It may also be necessary to consider the choice of evacuation routes, especially in crowded urban slums that have limited and narrow access routes.

Of particular importance is the fact that poor communities often have already developed informal, but sophisticated, coping strategies, which may originally have developed in rural communities.[27] Local perceptions of flood warnings and existing coping strategies should be understood and taken into account in the design of interventions which aim to reduce the effects of flooding.[28]

23. Tucci, C E M (2001), "Urban drainage management", in Tucci, C E M (editor), "Urban drainage in the humid tropics", UNESCO International Hydrological Programme (IHP-V) Technical Documents in Hydrology No 40, Vol 1, UNESCO, Paris, pages 157–176.

24. Tucci, C E M (2002), "Flood control and urban drainage management in Brazil", *Waterlines Journal* Special Edition on Urban Stormwater Drainage, vol. 20, no 4..

25. See reference 13.

26. Patel, S, C d'Cruz and S Burra (2002), "Beyond evictions in a global city: people-managed resettlement in Mumbai", *Environment and Urbanization* Vol 14, No 1, pages 159-173.

27. Schware, R (1982), "Official and folk flood warning systems: an assessment", *Journal of Environmental Management* Vol 6, No 3, pages 209–216.

28. See reference 14.

### c. Flood recovery strategies

Post-flood recovery strategies aim to enable communities to respond effectively to the consequences of floods, and to permit local and central authorities to organize and coordinate relief activities, including making the best use of local resources and properly managing national and international relief assistance. Medium to long-term interventions may be needed to support populations affected by flooding.[29]

Post-flood recovery involves numerous activities in relation to the return to normal life, including evaluation of damages, rehabilitation of damaged properties and the provision of flood assistance to flood victims. There is often little assistance given by urban authorities in low-income areas for flood recovery and, especially for the urban poor, the recovery from a severe flood event can consume considerable time, energy and resources.

29. WHO (2002), "Flooding: health effects and preventive measures", WHO Fact Sheet 05/02, Copenhagen and Rome, 13 September.

## V. NON-STRUCTURAL STRATEGIES FOR MITIGATION OF ENVIRONMENTAL HEALTH PROBLEMS

### a. Pollution mitigation and solid waste management

PROBLEMS RELATED TO poor drainage are exacerbated by poor solid waste management, as uncollected solid waste often enters surface drains and sewers, causing blockages and reduced flow capacity. Flooding is more likely to occur if solid waste accumulates in drains, and blocked drains create insect breeding sites, thus encouraging disease transmission.[30]

Structural elements such as the incorporation of solid waste traps are an important design aspect of drainage systems,[31] but non-structural solid waste management strategies may reduce the need for extensive cleaning of stormwater drainage systems prior to the onset of the flood season. Primarily, these strategies should promote awareness of the impacts of solid waste in relation to the flooding and health hazards associated with blocked drains.

Similarly, pollution from stormwater runoff may be reduced by the introduction of non-structural strategies aimed at limiting the ingress of pollutants into the drainage system, especially from construction site and industrial sites. Attempts to control pollutants from stormwater drainage systems include a range of practices such as efforts to inform residents of the polluting effects of improper disposal of pollutants into surface drains and the provision of collection services for toxic chemicals.[32] Although these practices are widely promoted in higher-income countries, they are also relevant in low- and middle-income countries, especially where the livelihoods of communities living downstream are affected by pollution.

30. See reference 20.

31. Armitage, N P and A Rooseboom (2000), "The removal of urban litter from stormwater conduits and streams. Paper 1 – the quantities involved and catchment litter management options", *Water* SA Vol 26, No 2, April.

32. Taylor, A (2002), "Non-structural stormwater quality best management practices – monitoring and evaluation guidelines", Cooperative Research Centre for Catchment Hydrology Working Document 02/6, Monash University, Australia.

### b. Control of disease vectors

Non-structural strategies relevant to stormwater management, which focus on improved environmental health, are particularly important in relation to the control of mosquito breeding sites. Drainage of runoff by controlling surface water and waterlogging and by eliminating unnecessary open water surfaces is an essential and effective tool for reducing and eliminat-

ing mosquito breeding sites. Poorly maintained drainage canals can provide potential breeding sites for various mosquito species if they are permanently flooded and aquatic weeds are not cleared.(33)

It is important that efforts be well targeted. For instance, a filariasis vector control research project carried out in Pondicherry in India surveyed a range of different breeding sites, such as drains, soakage pits and flooded land, and measured the number of mosquito larvae and pupae. The survey found wide variations in the distribution of breeding sites and, surprisingly, U-shaped drains produced far more mosquitoes than unlined drains. However, in this case, the lining of drains was considered to be of less importance than addressing wrongly designed and poorly constructed drains.(34)

Much of the disease associated with poor drainage can be avoided without investments in large-scale drainage infrastructure. For example, greater benefits for dengue control are potentially achievable if people eliminate breeding sites for the *Aedes* mosquitoes, such as water containers, old tyres and urns.(35) Although these approaches are not directly associated with the provision of drainage infrastructure *per se*, they form part of an integrated strategy for environmental health improvement programs. Lloyd(36) stresses that this approach provides a flexible framework through which a wide variety of actions can be undertaken in an integrated and coherent fashion, and that it may also pave the way for greater intersectoral collaboration through advocacy and reduction of duplication of efforts. Coordinated efforts may result in multiple gains related to improved drainage and environmental health.

## VI. INSTITUTIONAL ARRANGEMENTS AND PARTICIPATION IN URBAN STORMWATER MANAGEMENT

A KEY ELEMENT for the successful implementation of non-structural stormwater management programmes is an inclusive approach, which promotes participation of stakeholders in the development and implementation of urban drainage plans.(37) In this section, the importance of participation in non-structural stormwater management programmes is stressed, and these programmes are discussed in relation to the partnerships and institutional arrangements for management and implementation.

Public participation is an opportunity for urban authorities to assess the social feasibility of stormwater management systems and flood response strategies. Experiences from high-income countries, such as the United States, demonstrate that urban runoff control programmes need public backing and involvement to succeed; a strong motivation to act is essential to the success of stormwater management projects.(38)

Urban drainage systems cannot be designed in isolation from the communities that they serve. For example, in India, "slum networking" exploits the linkage between the slums and the natural drainage paths that influence the urban infrastructure and environment of the city. This approach aims to solve problems of flooding for the city as a whole, while simultaneously providing services for the slum dwellers in low-lying areas adjacent to natural drainage paths. Implementation may be problematic, however, due to ineffective solid waste management and a possible lack of willingness on the part of slum dwellers to invest in household

33. Madramootoo, Chandra A, William R Johnston and Lyman S Willardson (1997), "Health issues related to drainage water management", Chapter 7 in *Management of Agricultural Drainage Water Quality,* Water Reports 13, International Commission on Irrigation and Drainage, Food and Agriculture Organization of the United Nations, Rome.

34. Menon, P K B and P K Rajagopalan (1980), "Relative importance of different types of breeding habitats in contributing to the population of *Culex pipiens fatigans* in Pondicherry", *Indian Journal of Medical Research* Vol 71, page 725.

35. See reference 15.

36. Lloyd, L S (2003), "Best practices for dengue prevention and control in the Americas", Strategic Report 7, Environmental Health Project, US Agency for International Development, Washington DC, USA.

37. See reference 16.

38. NVSWCD (1994), "Developing successful runoff control programs for urbanized areas", Northern Virginia Soil and Water Conservation District, US Environmental Protection Agency, http://ntl.bts.gov/DOCS/RUNOFF.html

infrastructure to connect to the city drainage network.[39]

Those responsible for urban stormwater management should enlist the support of local officials prior to any initiative to implementation,[40] and should engage with the public, building on local knowledge and resources, working with local social organizations and management systems, and using participatory methods for planning, implementation, monitoring and evaluation.[41] It is important to respond to actual problems and deficiencies, recognizing that drainage problems are as likely to stem from management deficiencies, inadequate operation and maintenance, and poor coordination between stakeholders as from an absolute lack of facilities. In this context, institutions should be viewed not just in terms of structures and systems but also in terms of the way they routinely think and respond to problems and issues.[42]

## a. Planning

For the development of a drainage plan, a considerable amount of physical data is required, but these data may be scarce, especially in informal unplanned settlements. In such cases, the community can help by describing where major flood problems occur and providing information about previous floods.[43] Community members will also be important sources of information in confirming where the drainage problems are worst, and in helping develop a drainage plan that is accepted by the community and one in which community members will play their role in maintaining the system and keeping it clear from blockages.

Singhal and Kapur[44] describe the formulation of a community-based environmental management plan (EMP) for a "critically stressed" urban drainage catchment in Lucknow in India, with a particular focus on improving the quality of life of urban poor people in relation to their environmental conditions and access to services. The tools involved in the development of the plan were based upon an evaluation of the existing conditions using participatory rapid appraisal (PRA) techniques such as transect walks, and these methods can be important in achieving communal support for the EMP.

## b. Implementation

There are numerous examples of slum upgrading projects which incorporate stormwater drainage as a component. According to Imparato and Ruster, squatter settlement upgrading cannot be achieved without the participation of the beneficiary communities, especially where peoples' lives will be disrupted by removal, relocation and partial demolition of their homes. These are complex operations requiring technical skill, ingenuity and patience, but this sort of consensus and collaboration is essential for successful implementation and can only be achieved through participation.[45]

Among the many potential roles for community members in the implementation of urban drainage projects is direct employment in construction activities, in order to reduce the total cost. This may also stimulate local enterprise initiatives, training and the development of skills. Alternatively, where private contractors are employed to undertake the physical works, community members may be involved with the monitoring of the quality of the construction.[46]

39. Gita Dewan Verma (nd), "Indore's slum project – a worm's eye view from the ground", the Best Practices and Local Leadership Programme (BLP) Internet site, http://www.blpnet.org/blp/learning/casestudies

40. Rosensweig, F and E Perez (2002), "Improving sanitation in small towns in Latin America and the Caribbean", *Waterlines* Vol 21, No 1, July.

41. Pretty J and R Sandbrook (1991), "Operationalizing sustainable development at community level: primary environmental care", paper presented to DAC working party on Development Assistance and the Environment, OECD, Paris, October 1991.

42. Carley, M, P Jenkins and H Smith (editors) (2001), *Urban Development and Civil Society: The Role of Communities in Sustainable Cities*, Earthscan, London.

43. Howard, G, C Bogh, G Goldstein, J Morgan, R Shaw and J Teuton (2002), *Healthy Villages: a Guide for Communities and Community Health Workers*, WHO, Geneva.

44. Singhal, S and A Kapur (2002), "Environmental management plans for the communities of Lucknow", *Waterlines Journal* Special Edition on Urban Stormwater Drainage, vol. 20, no 4.

45. See reference 19.

46. Cotton, A P, M Sohail and W K Tayler (1998), "Community initiatives in urban infrastructure", Water, Engineering and Development Centre, Loughborough University, UK.

47. UNCHS (1986), "Community participation and low-cost drainage – a training module", United Nations Centre for Human Settlements, Nairobi, Kenya.

48. See reference 43.

49. Lammerink, M P and E Bolt (2002), "Supporting community management – a manual for training in community management in the water and sanitation sector", Occasional Paper Series OP 34 E IRC, International Water and Sanitation Centre, Delft/Haarlem, the Netherlands.

### c. Operation and maintenance

The successful construction of a drainage system in a neighbourhood does not guarantee a successful drainage project. Users need to be aware of operation and maintenance requirements at the neighbourhood level.[47] Often, one of the best solutions for maintenance is for community members to be responsible for the management of the drainage system, as the regular inspection and cleaning of drains is an important task that can be performed without specialized skills.[48] An enhanced management role for user communities is a way of increasing cost-effectiveness, improving reliability and ensuring sustainability, by placing a larger share of the responsibility in the hands of the users themselves.[49] However, the organization of community members who are ultimately responsible for actually carrying out the cleaning of the drains can be problematic.

This can be achieved most effectively by establishing a special drainage committee in the neighbourhood, or by adding drainage to the list of responsibilities of an already active community committee established for the management of other forms for environmental services (such as water supply and solid waste collection and disposal).

In many situations, it may be more appropriate to contract the services of a member of the local community to be responsible for drain cleaning. This person may be contracted by a management committee, which collects a small fee from community members to pay for the cleaning services. This may overcome problems of reliance on the active participation of all households in drain-cleaning activities, when some may perceive these activities to be degrading or unnecessary – especially where they do not suffer from any of the problems related to poor draining.

## VII. POTENTIAL CONSTRAINTS TO IMPLEMENTATION

A REVIEW OF the literature indicates that there are a considerable number of alternative approaches to stormwater management that are appropriate for low-income communities in informal settlements. Although engineered components of drainage infrastructure remain an integral part of strategies to improve drainage, a broader view of stormwater management is required which incorporates non-structural, as well as structural, elements. However, these non-structural approaches are not panaceas and there are a number of constraints, briefly outlined below, that will affect successful implementation.

Institutional responsibility for urban drainage is often narrow. Public utilities or water companies may have the responsibility for sewerage, whereas road drainage is often the responsibility of the highways authority, and receiving waters may be the responsibility of the local authority or environmental agency. Responsibility for solid waste management is virtually always the responsibility of another department in the municipality. Also, hydrological systems are not constrained by administrative boundaries, and effective drainage area planning requires careful coordination between the relevant institutions responsible for urban drainage in different areas. Therefore, the overall planning framework needs to be considered in relation to land use in urban and peri-urban areas and, in particular, those communities who inhabit this land.

The design and implementation of disaster mitigation at the local level,

such as that associated with flooding, is a complex task for urban authorities, particularly as they have to cope with a wide diversity of stakeholders, which may be especially heterogeneous in the urban communities.[50] These stakeholders have different perceptions and relationships to natural hazards, a reflection of different socioeconomic and sociopsychological backgrounds. The involvement of a diverse cross-section of stakeholders' groups can cause many problems and disputes. Participatory approaches can take considerable time and, therefore, may not satisfy the demands for immediate investments in infrastructure, which is envisaged as necessary to bring about improvements.

50. See reference 16.

Non-structural approaches to stormwater management can work well, provided the municipal authorities are receptive to the involvement of community groups in project implementation. Collaboration between government agencies and non-governmental organizations, in conjunction with communities, is essential but often challenging. Many of these constraints may be overcome if there is a political and institutional commitment to overcoming problems and, specifically, a consideration of and concern with the needs of the urban poor.