INTERNATIONAL HYDROLOGICAL PROGRAMME

GUIDELINES
ON
NON-STRUCTURAL MEASURES IN URBAN FLOOD MANAGEMENT

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Preface

These Guidelines have been prepared within the framework of the Fifth Phase of UNESCO's International Hydrologic Programme as a contribution to Theme 7*: Integrated Urban Water Management*, Project 7.1 *Non-structural flood control measures to balance risk-cost-benefit in flood control management in urban areas*. Flooding in cities originates from extreme high flows and stages in major neighbouring rivers as a result of extreme area-wide meteorological disturbances, as well as from local severe thunderstorms occurring over the urbanised areas. This document takes into account the physical damages and the consequences of pollution caused by urban flooding.

The primary target audience for these Guidelines is government professionals at all levels engaged in the planning and implementation of flood mitigation programmes. Consulting engineers, urban planners, educators and legislators may also find this document interesting and useful for widening the scope of their work.

The purpose of the Guidelines is to offer a set of complementary approaches to already well-known engineering, structural measures, rather than to propose ready-made solutions. Flood mitigation is a site-specific discipline, institutionalised through local governments and founded on integrated, multidisciplinary consideration of various concepts, measures, and technique. It aims towards flooding control solutions that satisfy the requirements of environmental and economic sustainability. It requires public participation based on an ongoing development of public awareness as well as on the evaluation of the past experience.

Rehabilitation of forgotten wisdom, application of modern communication means, education, and training are the cornerstones of the process of changing public perception of flooding, the primary prerequisite for introducing non-structural flood management measures into common practice.

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1.1. Origin of floods

Floods are natural disasters that have been affecting human lives since time immemorial. Throughout history, nature has shown little respect for man's unwise occupancy of nature's right-of-way and has insured that the message has been clearly understood by sporadically flooding people's properties and taking their lives.

Flood are associated with some extreme natural events that happen on a geographical area known as a drainage basin, which is also referred to as a river basin, a catchment area or a watershed. Drainage basins can be rural (natural) and urban, the former commonly being much larger than the latter. Hence, flooding can be rural and urban. One of the goals of these Guidelines is to clarify the difference between floods in those two environments.

An extreme natural event only becomes a disaster when it has an impact on human settlements and activities. Therefore, there is both a strong social and natural science component to floods.

The basic cause of rural or river basin flooding is heavy rainfall or rainfall combined with snowmelt, followed by slow development of flood flows, which exceed the capacity of natural waterways. Other causes of rural floods are:

- surcharge in water levels due to natural or man-made obstructions in the flood path (bridges, gated spillways, weirs)
- sudden dam failure
- landslide
- mud flow
- inadequate urbanisation (excessive encroachment in the floodway)
- ice jam
- rapid snowmelt
- deforestation of the catchment basin

Rural floods are river-basin events, whereas urban floods can have both area-wide and local origin, and are accompanied with serious water pollution problems. Urban flood occurrence is not bound by local administrative boundaries because stormwater drainage and protection facilities are part of an environmental system that is larger than an incorporated city territory.

A large portion of the world's population lives along river banks because the streams, aside from providing water for human use, industrial production, and sanitation, have built over geological time alluvium deposits that created the best agricultural lands. Urban settlements organised the protection against flooding by building dikes and river training works, whereas most of the land behind the line of protection has remained unchanged.

Streams carried eroded material from the upper parts of the watershed into the lower segments of the river course. Alteration of the sediment transport pattern in the rivers caused sediment deposition and gradual elevating of the natural riverbed. The land adjacent to the river became higher in elevation than the land farther away due to the continuous deposition of the eroded material. In such a way, natural water stages became elevated as well and flooding of the riverbanks was made possible.

1.2. Different aspects of flooding

Flooding has several aspects, such as climatic, social, economic, institutional, and technical, that are differently addressed for rural and urban conditions.

The climatic of flooding deals with the climatic conditions that may lead to the occurrence of floods. In urban conditions, short and intensive showers proved to be just as critical as long lasting rains, but in rural conditions long lasting rains over an area-wide territory, accompanied with snow melting in the river basin, are recognised as possibly more influential.

The social of flooding deals with the way the floods occur in different settings. In urban conditions, one can negotiate the intensity and frequency of the disruption of public life and traffic, whereas in regional conditions the common term is disaster, although there were many situations where local urban flooding had disastrous consequences (casualties and property losses) as well. However, floods do not necessarily always need to be associated with disastrous consequences.

The economic of flooding deals with the issues of financing the capital improvement, operation, and maintenance of flood protection schemes. Local stormwater drainage and flood protection is usually financed by local revenues, such as local taxation, service fee, or user charge fee, collected on the basis of land use, whereas the regional protection is mostly carried out through general taxation.

The institutional of flooding deals with the role of governments in the process of decision making. In local conditions all major decisions are made by local governmental institutions and water-related companies, whereas in regional issues federal government and ministries take over the full responsibility. Increasing participation of non-governmental organisations is becoming noticeable as well.

The technical of flooding deals with the concepts and works usually applied in flood protection. In urban conditions, the "dual drainage" concept is most commonly applied, introducing the distinction between the stormwater drainage service and urban flood protection, whereas in area-wide conditions flood control measures are always regarded as a part of the regional or state-wide flood control schemes.

1.3. Flooding in urban environment

Cities concentrate production and population and provide some obvious advantages over rural settlements. Those are, among many, lower specific cost for the provision of potable water supplies, sewers and drains, garbage collection, telecommunication, transportation and most forms of health, educational and emergency services, as well as the possibilities of collecting taxes and charging the public for providing different communal services. On the other hand, the concentration of domestic, commercial and industrial wastes causes major environmental and health problems for the city inhabitants that are spread by water movement. Principal phases of the urban water cycle are given in fig. 1.1.

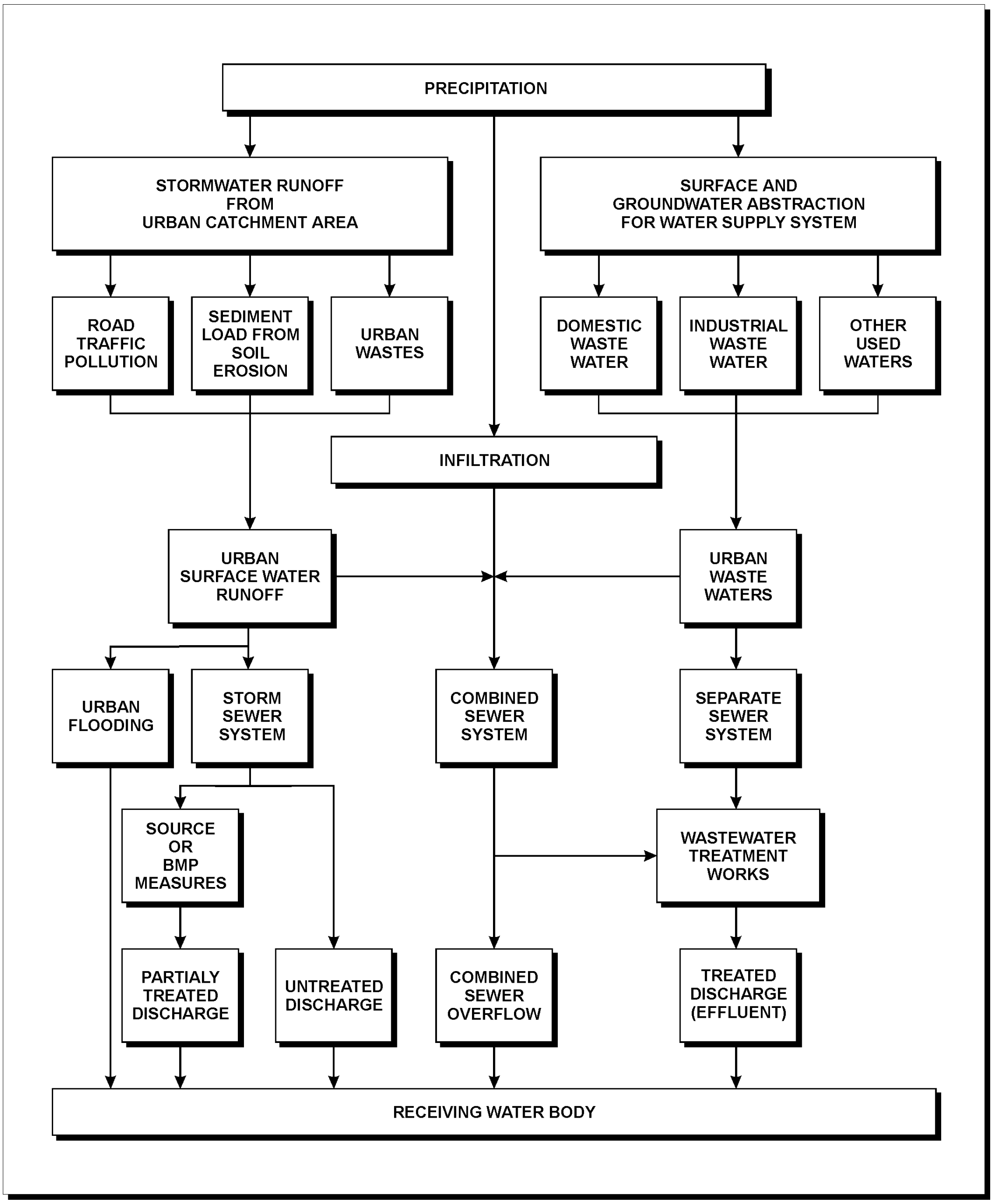


Fig. 1.1. Movement of water in urban environment

In the past, due to the absence of planning, expansion of cities took place on the best quality farmland in the vicinity of the waterways. The result of that process is the present situation in cities of both the developing and developed countries, where poorer, but larger, segments of population live on land which is ill-suited to housing, because those are the only land sites they could have afforded. People that occupy the high lands in cities rightfully take the advantage of their favourable elevated position, but very often the level of their financial participation in flood control is below the level of their contribution, expressed in monetary units, in worsening the problem of urban flooding.

Cities have been permanently developing their water-related infrastructure and discharging their urban waters into the nearest water body. During time, natural, undisturbed, discharging conditions were becoming deteriorated due to the raising of the river water stages.

The problems of discharging urban waters became particularly expressed at the sites where waste water and storm water were being conveyed in common trunks, due to submergence of the outfalls and possible back-flow during high water stages. It is not uncommon that normal flood control measures between the flood protection dikes are performed simultaneously with the emergency, near-to-accident, measures behind the dikes, where mixed waste and storm waters overflow into basements or flow out onto the streets through street grated inlets (fig 1.2). Urban waters proved to need an integral treatment.

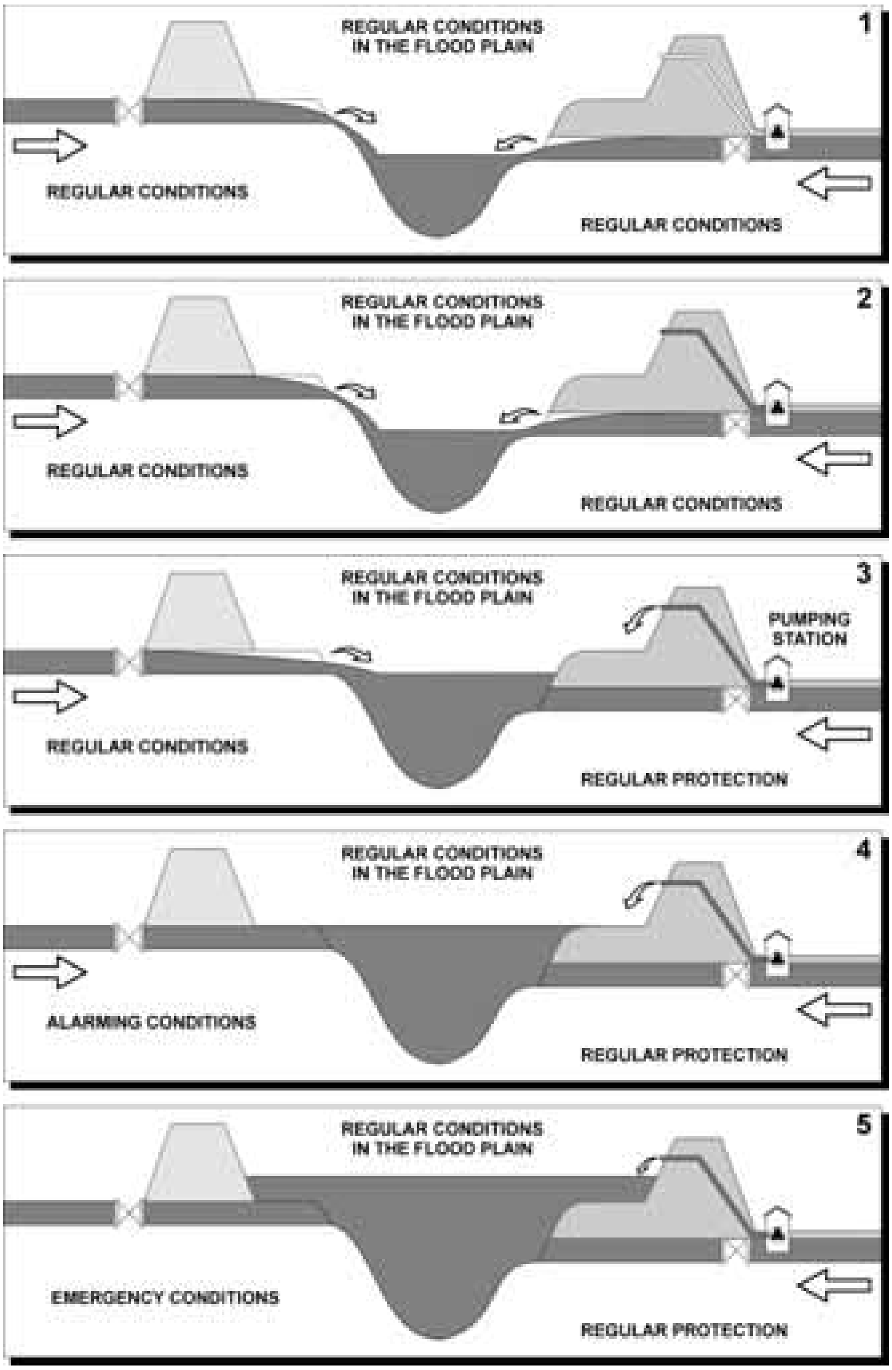


Fig. 1.2. Possible different flooding conditions in urban environment

The primary cause of urban flooding is a severe thunderstorm or a rainstorm proceeded by a long-lasting moderate rainfall that saturates the soil. Floods in urban conditions are flashy in nature and occur both on urbanised surfaces (streets, parking lots, yards, parks) and in small urban creeks that deliver water to large water bodies. Other causes of urban floods are:

- inadequate land use and channelisation of natural waterways
- failure of the city protection dikes
- inflow from the river during high stages into urban drainage system
- surcharge due to blockage of drains and street inlets
- soil erosion generating material that clogs drainage system and inlets
- inadequate street cleaning practice that clogs street inlets

Floods disrupt the social systems of the countries and the cities, and cause enormous economic losses. Impacts produced by increased runoff in urban setting are the following:

- loss of human life
- flooding of housing, commercial and industrial properties
- flooding of streets, intersections and transportation systems, causing traffic delays
- recurring basement backups from surcharged sanitary sewers
- inflow of stormwater into sanitary sewers
- municipal waste water treatment plant by-passing
- combined sewer overflows
- spilling the surcharged sewers content into streets
- damage to public and personal property
- health hazards
- disruption of services such as water supply, sewerage and power supply
- delays in public transportation
- cleanup demands
- adverse effects upon the aesthetics
- disturbance of wildlife habitats
- economic losses
- pollution of local waterways and receiving water bodies

1.4. Hydrologic impacts of urbanisation

Urbanisation has many definitions. One of the simplified ones describes urbanisation as a process of artificial land use alteration during time. Temporal dimension of urbanisation is usually quantified by a design period, defined as a period of time in which reliable forecast of urban changes can be made. It usually ranges between 15 and 25 years.

Conversion by people of pervious natural surfaces to less- or non-pervious artificial surfaces is responsible for increases in both the stormwater runoff rates and the total runoff volumes, due to decreasing the natural water storage capacity of the soil. Natural storage in a watershed is being made available by the effects of infiltration, vegetation wetting, interception and depression storage. An often neglected fact is that change of natural water storage as a consequence of urbanisation, also causes significant changes to the temporal characteristics of runoff from an urbanised area, such as shortening the runoff travel time and giving to the event a flashing appearance.

Urbanisation is also responsible for an alarming increase of pollutants in natural water bodies. Stormwater runoff may contain organic wastes, nutrients, bacteria, suspended solids, heavy metals, oils, animal waste, tire and vehicle exhaust residues, de-icing chemicals, street litter, and sediments from construction sites. Improvements in sampling and monitoring techniques indicated that there is a rapid increase in concentration of pollutants which occurs throughout the storm event. Effects of urbanisation on urban waters are simplified in a graphical form in fig. 1.3.

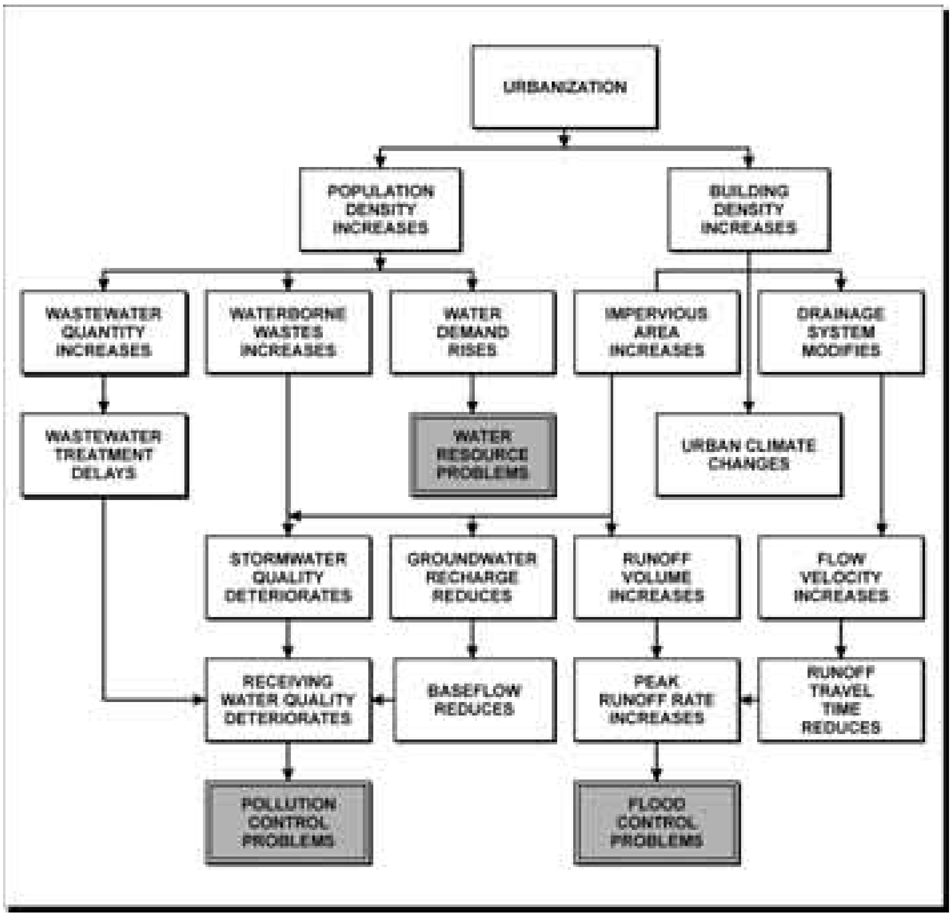


Fig. 1.3: Hydrological impacts of urbanisation

In some ancient civilisations, stormwater was stored and preserved. However, during the industrial revolution the stormwater has been considered a nuisance in urban life and water was evacuated from the city areas as fast as possible. Urbanisation changed natural runoff pattern and accelerated transport of water, pollutants and sediment from the urban areas. At the same time, effects of the rural areas on natural waters changed significantly by deforestation and by the introduction of fertilisers in agriculture.

The traditional “efficient conveyance” approach was shifted gradually towards the “water storing” approach, focusing on detention, retention and recharge. However, since stormwater was becoming a significant source of pollution, new concepts of source control, flow attenuation and treatment in natural and artificial biological systems were introduced. There is no doubt that in near future urban stormwater will become again a precious resource for man's survival.

Stormwater may be discharged in a number of ways. Pipes, channels, and drainage ditches are the most obvious ones. But stormwater discharges can also appear in a form of small rivulets in dirt roads, swales, infiltration soakways, porous pavement, and different depressions on the ground surface. Even "sheet flow", like that across a flat area, is considered a stormwater discharge if it ends in a storm sewer or any receiving water body.

Urban stormwater control systems have two components: (i) the system "minor", a stormwater drainage system conceptualized on the basis of a pre-determined level of accepted risk, composed of sewers, open channels, curbs, gutters, inlets and swales, and (ii) the system "major", which operates whenever the capacity of the other system is exceeded and is composed of natural and man-made flow paths that lead excess overland flow towards the receiving water bodies. Many communities have not recognised that system major existed until a severe runoff event occurred. To their dismay they discovered that system “major” included their homes, basements, industrial areas, parks, and commercial buildings constructed in low lands.

The problems caused by excessive precipitation in urban setting are ordinarily grouped in five categories:

- stormwater drainage and flooding control
- soil erosion
- sedimentation of eroded material
- pollution of land and water bodies
- interference with groundwater supply

1.5. Perspectives of flood management

Floods cannot be prevented but planning the emergency measures through flood management can often reduce their disastrous consequences.

Inception of flood management normally begins after a major flood event. People always have some other priorities until a major disaster happens. Throughout history, progress in water-related disciplines often came as a reaction to severe emergency situations : water supply systems were extended after major droughts, sewerage systems upgraded after outbreaks of major epidemics, pollution control schemes introduced after major spills of pollutants that destroyed life in water courses, and stormwater drainage systems built after major floods.

Flood management is a broad spectrum of water resources activities aimed at reducing potential harmful impacts of floods on people, environment and economy of the region. The main limitation of the current flood management methodologies comes from favouring mostly economic impacts and paying minor attention to the environmental and social impacts of floods.

Current urban flood management practice includes an non-quantified safety factor. Because statistically homogeneous measured data from the past is generally lacking, one cannot predict frequencies of occurrence of various runoff features such as peak flows, volumes, overflows etc. However, there are places where reliable precipitation and runoff data are readily obtainable. The fact that a particular outflow can result from many combinations of hydrologic conditions is often neglected. Two identical rainfalls do not necessarily create identical runoffs, because of possible different antecedent conditions in the drainage basin. Therefore, flood management policies should be basically founded on mathematical modelling and sound engineering practice rather than on statistic and probabilistic analyses.

Total flood protection is unrealistic and unwise. The ultimate goal of flood loss prevention is the improvement of the quality of life by reducing the impact of flooding and flood liability on individuals, as well as by reducing private and public losses resulting from the flooding. The objectives of the urban flood management are to provide answer to the question of how to deal effectively with the possibility of flooding in urban environment and how to cope with the associated uncertainties.

2. Unified urban flood management

2.1. Flood management planning

At the heart of master planning lies the identification of problems, opportunities and constraints, the setting of goals and objectives, the establishment of policies and priorities that govern overall effort, and, finally, the development of criteria and standards for evaluating systems' performance under future development scenarios.

A primary *goal* of the urban flood management is to have a unified conceptual program for stormwater drainage and flood control, in order to mitigate future flood damages while systematically reducing annual flood damages. Goals serve to orient planners and those who wish to develop property within the community.

Objectives of flood management are specific final results that have to be achieved in a predetermined time frame. Those are:

- reducing exposure of people and property to flood hazards
- reducing existing level of flood damages
- minimising soil erosion and sedimentation problems
- protecting environmental quality and well-being by reducing in-the-catchment pollution
- improving the usefulness of floodplains
- minimising receiving water pollution
- reducing future after-development flow rates to pre-development levels
- enhancing recreational opportunities and improving overall urban amenities
- replenishing ground water
- supplementing domestic water supply
- capturing water for irrigation
- protecting public health
- providing open space and parklands
- using stormwater as a resource

Objectives are accomplished by incorporating them into a *policy*. To be effective, the policy must recognise the need to treat developed and undeveloped land separately.

Criteria are specific operational, performance oriented, requirements relative to construction, operation and maintenance of stormwater drainage and flood control facilities. They should be reviewed periodically and revised in the light of new knowledge and changing urban circumstances. Unless otherwise required, reviews of criteria should be made at time intervals ranging from five to ten years.

Goals, objectives and criteria represent the cornerstones of an urban master planning process. This process should result in a document that is commonly known as *Urban Flood and Pollution Control (UFPC) Master Plan*. This document is becoming an inevitable planning document that directs flood and pollution controlled urbanisation in an undeveloped or underdeveloped area or mitigates adverse consequences of flooding and pollution in the areas that have already experienced flood and pollution problems. In other words, there are two aspects of stormwater master planning: preventive and remedial.

Following the UFPC Master Plan approval, when funding is assured, detailed plans and designs are prepared as an advanced step toward implementation.

Traditional Master Plan determined concepts of how to reduce future flood damages. They defined what was needed to be done, at what cost, and were followed by structural flood control measures. However, in practical applications it was recognised that, in order to facilitate the implementation and to ensure the realisation of the objectives, a variety of additional pre-flood and post-flood mitigation activities would be needed, usually recognised as non-structural measures. Today, both structural and non-structural measures, adequately related in time and space, represent the cornerstones of an *unified contemporary urban flood management concept* (fig 2.1).

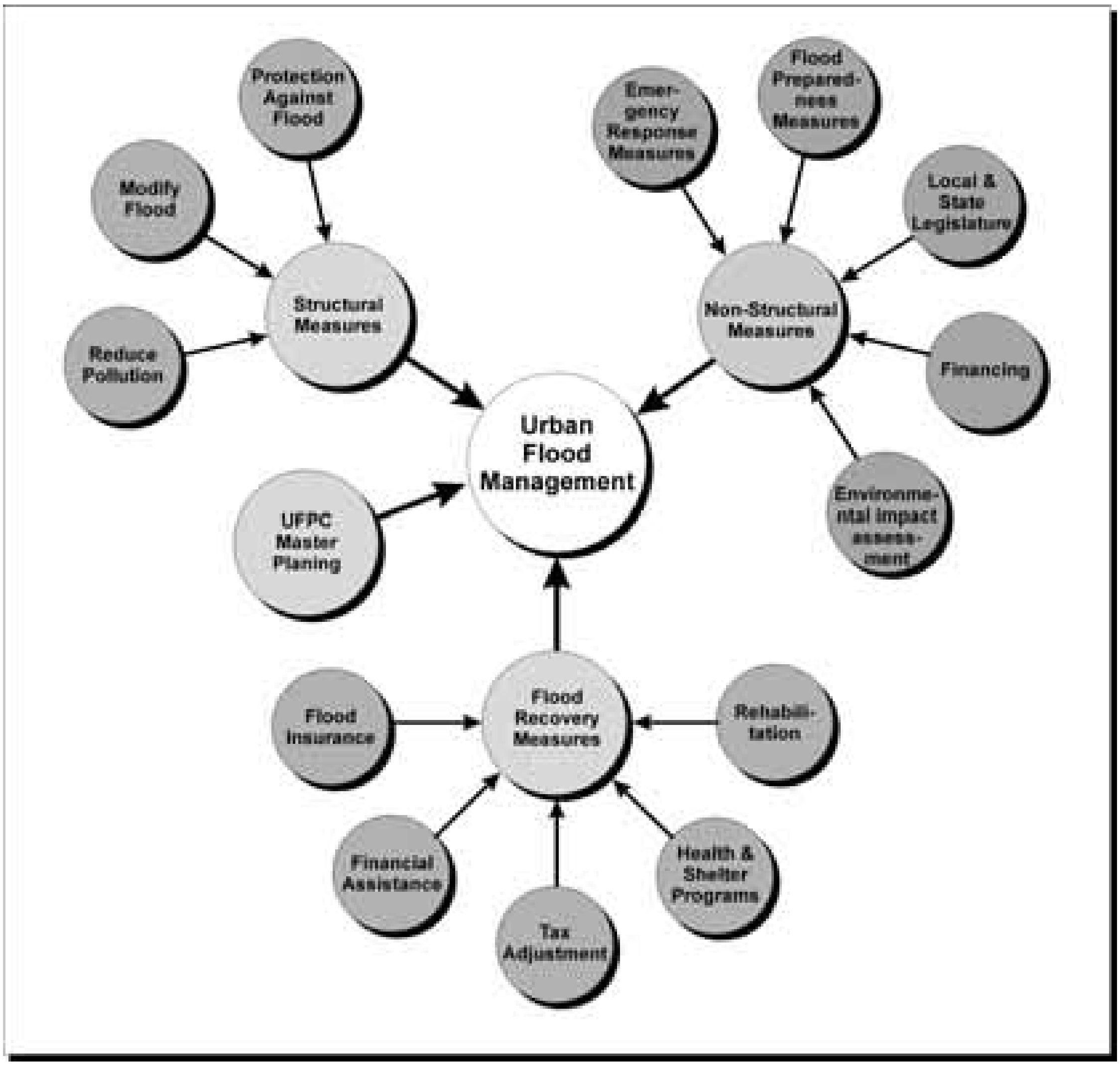


Fig 2.1. Unified urban flood management

Contemporary Master Plans, commonly known as Flood Studies, can be used as the means of raising public awareness of flood hazard situations and as an initial planning document.

The scope of master planning and concepts commonly used are briefly described in the remaining part of this chapter, while all other chapters of the Guidelines are dedicated to non-structural measures. It is the author's opinion that the target audience for these Guidelines may be very diversified and that some basic information on technical aspects of the flood management would be helpful in understanding the role of non-structural measures.

2.2. Scope of master planning

The flood management master planning process is a system approach that includes:

(i) setting up preliminary goals and objectives for a foreseeable future, consistent with laws in force and other constraints
(ii) documentation of the problem; investigation of the causes of the problems; determination of needs and the planning criteria
(iii) problem inventory; appraisal of feasible solutions; setting up flooding standards based on social, economic, and environmental factors
(iv) collection of all baseline data and identification of baseline conditions, including political, geographic, hydraulic and environmental issues
(v) systematic interviews and site visits
(vi) description of the existing stormwater practice and its inadequacies
(vii) definition of hydrologic conditions and constraints that proposed changes or development would have on baseline conditions
(viii) definition of interdependencies with neighbouring administrative areas an related municipal infrastructure services
(ix) analytical work that includes hydrologic, hydraulic and water quality analysis
(x) definition of priorities and alternative solutions (interim solutions, long-range solutions)
(xi) description and cost estimate of proposed facilities and measures
(xii) benefit/cost analysis and comparative evaluation of alternative solutions, including valuation of benefits, damage assessment, cost of traffic disruption, environmental and social factors; other assessment techniques that are more appropriate to urban conditions
(xiii) recognition of alternative plans; recognition of emergency plans
(xiv) practical financing program; identification of the sources of funds
(xv) drafting legal documents needed to implement the adopted measures

Preventive master plan for an individual basin includes evaluation of the basin hydrology under existing conditions in order to identify existing drainage problems. Basin hydrology is then analyzed assuming full development of the basin area in order to identify improvement necessary to serve future development. Two approaches are common: to perform cost-benefit analysis where flood damages can be identified, the minimum of which determines the solution to implement, or to comply with the locally adopted stormwater drainage criteria based on a pre-determined, commonly accepted, level of risk. Three principal, performance oriented, criteria are usually applied such as:

- storage volume criterion
- effluent concentration criterion
- long-term pollutant removal criterion

Remedial master plan is site specific and less standardised in scope, since the problems of flooding and pollution can be solved only by creating a Chinese menu-type mosaic of different methods, procedures and techniques that best suit local conditions and required accuracy.

2.3. Basic concepts used in master planning

Comprehensive master planning is the starting point for providing an efficient management plan. On the other hand, there are schools of thought that promote stormwater drainage planning based on engineering judgement tempered by experience. The truth is that only the combination of the contemporary analytical approaches and empirical techniques may lead to an integrated, environmentally sustainable and economically feasible management plan.

In order to eliminate any eventual impression that these Guidelines underestimate the importance of thorough planning, (because of not dealing with master planning in details), basic concepts used in urban flood management planning are given hereafter. It is the intention of these Guidelines to promote, but not to limit to, five aspects of urban flood management:

- scientific aspect, because of research and deductive reasoning being used
- artistic aspect, because of creativity needed
- technical aspect, because of approximations needed due to shortage of reliable measured data
- legal aspect, because of legislature needed to enforce the proposed measures
- political aspect, because of priority issues and necessary trade-off between the calculated risk and the proposed protection level

2.3.1. Holistic and integrated approaches

The holistic approach recognises drainage system complexity and inter-connectivity of its elements and is also known as the ecosystem approach. For a holistic approach, three groups of objectives must be addressed on a river basin scale, such as social, economic and environmental. The solution needs to be found in a triangle of geoscientists, environmentalists and urban planners that have to be brought together at early stage of flood mitigation planning. For example, utilisation of stormwater may greatly affect the reduction of potable water consumption. If all toilets are flushed with stormwater instead traditionally with potable water, a 30% reduction is achieved.

Integrated approach is another term for the same concept and is traditionally used in urban conditions. It understands a comprehensive consideration of interactions between stormwater drainage and flood control on one hand, and a number of disciplines such as water supply, wastewater collection and treatment, water pollution control, water reuse, soil erosion, solid waste management and urban development, on the other. Integrated approach to urban flood management also understands harmonisation of relevant local and state laws dealing with urban development, environmental protection, use of water and management of communal infrastructure systems.

2.3.2. Sustainable development

Sustainable development represents a new approach that stipulates that human needs of the present should be met without undermining the resource and ecological base which future generations require to meet their own needs. Meeting economic, social and political goals falls within the sustainable development as well. Where social issues exist, political issues emerge inevitably. A successful city in sustainable development terms is the one where many different goals of its inhabitants and enterprises are met without passing on cost to other people in space or time.

In stormwater drainage control and flood management, source water discharge and pollution control is a key concept supporting sustainability, since it is focused on prevention, rather then on the cure of water quantity and quality problems. Anticipated benefits of the *source control* concept are:

- reduced capital expenditures downstream of source control due to reduced need for upgrading the conveyance system
- reduced flows to water treatment plants
- reduced river flooding risks
- natural replenishment of groundwater
- improved river water quality
- maintaining the existing and creating of new wildlife habitats

Issues of who benefits and who pays often hamper source control efforts. The key objective of a source control development process is balancing the rights of property owners and other affected by source measures with the rights of individuals whose health and welfare depend on the quality of source measures that could be degraded by the exercise of unrestricted property rights.

Recognised barriers to this new concept are danger of groundwater contamination, unknown costs, lack of information on long-term performance, as well as the lack of experience in maintenance, health and safety.

It is certain that traditional stormwater systems designed according to the “efficient conveyance” principle will be used in central parts of cities for a long time. There will be situations where some source control measure is implemented, but the major improvement of the existing systems will mostly be achieved by the end-of-pipe measures. However, full recognition and implementation of the source control concept is expected to occur in newly developed areas, where timely and thorough planning is possible.

2.3.3. Dual-drainage concept

Detrimental effects of urban flooding during extreme rainfall events, when conduit design capacity is exceeded, can be mitigated by configuring urban surfaces so that they direct excessive surface runoff to areas where the damage will be minimised - parks or less dense populated parts of the city.

This new principle of stormwater management requires communication of water engineers with local planners and their active participation in the planning process.

A significant role in the dual-drainage concept is awarded to streets and other urban traffic arteries, in a sense that they are expected, in addition to carrying vehicular traffic, to carry excess stormwater. Hydraulic capacity of a pavement cross section is defined as a quantity of stormwater that does not exceed an allowable criterion for depth of water at the curb. Inlet capacity is not the maximum stormwater flow an inlet may be able to intercept, but is the stormwater quantity intercepted for a given set of local conditions. Proper design, construction and maintenance of street inlets are one of the most important tasks in applying dual-drainage concept in a city, so that they do not become “bottle-necks” of the system.

A new concept known as *single pipe system* involves the systematic use of an overland drainage system and source control measures to limit inflow rates and volumes to the piped system. Though a single pipe for carrying both waste and surface water is proposed, the need for combined sewer overflows, as used in the combined systems, is eliminated by restricting the intake flow rates. When the rates of flow exceed the capacity of the sewers, the excessive water quantity is retained adjacent to the intakes in a local transient storage or in other source control facilities. In such a way, a single pipe discharging a controllable peak rate of flow to a treatment ensures that all water that enters the piped drainage system is treated before discharge. At best, stormwater can be fully retained on the surface, infiltrated into the soil or reused, so that the single pipe is used exclusively for waste water.

2.3.4. Modelling flooding in urban conditions

Major rural floods are usually associated with very infrequent events occurring every 50 to 100 years. Many measured hydrologic data do not cover periods of 50 years or more, so that estimation of peak discharges of lesser frequency necessitates extrapolation, the accuracy of which is considered to be questionable. On the other hand, measured flow data in urban stormwater drainage systems are scarce (Maksimovic, 1986). Therefore, floods in rural and urban conditions have to be analysed differently.

Two methods are used for calculating maximum discharges of the stormwater runoff in rural conditions. The first is based on plotting the probability distribution curve of maximum discharges based on a series of observations of runoff and extrapolating the curve to the region of low probabilities. The second method is based on estimating the extreme unfavourable meteorological effects on a drainage basin and on calculating of corresponding surface runoffs.

Since urban settlements are undergoing permanent development, eventual data on flow rates from the past would not form homogeneous statistical series that can be analysed in terms of probability. Therefore, in urban hydrology, the questionable statistical approach is replaced by deterministic mathematical modelling, supported by hydrologic field measuring for calibration purpose.

Rainfall-runoff modelling is man's attempt to simplify and mathematically rationalise complexity of natural events that govern the urban catchment response to precipitation. Those models imitate natural phenomena and their quality depends on their reliability, as well as on the quality of input data obtained through site investigation works.

2.3.5. Water storage

The contemporary practice of stormwater management includes the practice of containing or detaining stormwater runoff within the areas undergoing urbanisation in order to mitigate the effects of flooding, pollutant distribution, soil erosion, and sedimentation. Excess runoff is usually detained on-site and released at controlled rates over an extended time period in order to provide adequate peak flow reduction. For example, to keep discharge rates within the capacities of existing downstream stormwater drainage system or at the levels that existed before urbanisation.

Recharge and d*etention basins* are built in an attempt to recreate the natural infiltration, storage and attenuation that have been lost through development. On the other hand, *retention* *basins* are temporary storage basins without any positive outlet. Detention basins combine retention and controlled release of water. Detention can be off-site and on-site (out of or on the land where runoff is generated), as well as on-stream and off-stream (within or outside the main conduit). Schemes of how flow equalisation basins can be systematised according to their basic function are presented in fig. 2.2

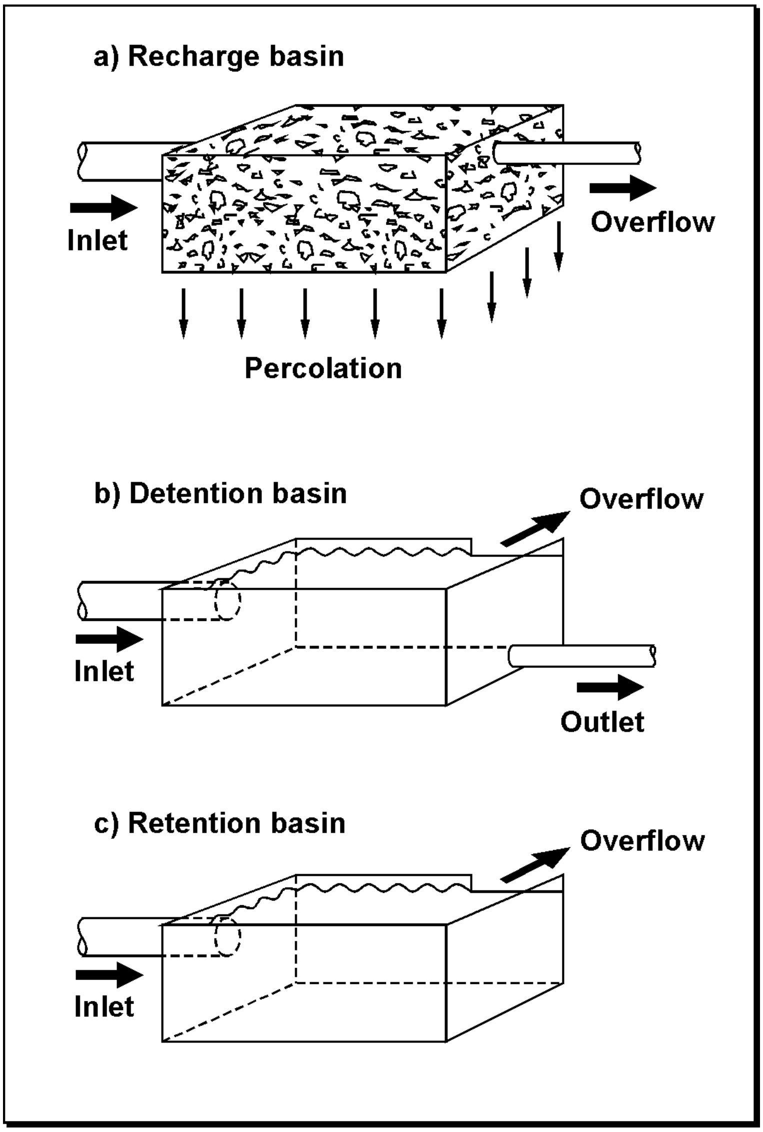


Fig. 2.2. Major types of flow equalisation basins (W. DeGroot, 1982)

2.3.6. Assessment tools for decision making

(i) Benefit-cost analysis

Benefit-cost analysis provides a rational and systematic method for evaluating all the potential costs and benefits of an flood control action, as it expresses all effects in monetary units. Where investment of public money is at stake, the decisions taken should reflect the values and concerns of the public who pay the costs, which represents the axiomatic base of benefit-cost analysis. However, this method does not always offer a complete input for socio-political decision making, particularly when a lot of stakeholders are involved and where there are significant intangible impacts, such as improvement of environment, increased amenity values, enhanced quality of life, etc.

The decision-making process involves the creation of alternative choices that appear to satisfy development criteria that are financially feasible and institutionally acceptable. Development criteria may be characterised as economic and financial, while their implementation must be based on social and environmental impact assessment. The most obvious benefits derived from flood management are those arising from the reduction in flood damage, which expressed in economic terms, represent cost savings of disruption of services, replacement, repair, evacuation, relief and rehabilitation.

The results of economic analysis do not provide sufficient information on the financial viability of different flood damage reduction alternatives. Once an alternative is selected based on economic criteria, financial criteria are applied to determine the needs for financing the project construction and handling the flow of costs and revenues after the project goes into operation.

The success of flood management decisions always depends on an effective balance of local cost and distributed benefits. Social assessments are essential in suggesting appropriate trade-off of these costs and benefits. Correct analysis that will support decision-making should not rely solely on tangible benefits and measurable costs, which makes the cost-benefit analysis a technique of limited significance. However, it is not possible to measure all social and environmental benefits in monetary units, such as preservation of environmental quality or social well-being of all the people. There are other ways to enrich the process of decision making in master planning such as the techniques that follow here below.

(ii) Multi-attribute technique

Social criteria can be viewed as an important starting point in the development of a multi-objective decision-making process that reflects the concept of sustainability and weights all of the concerns of an undertaking.

The multi-attribute technique (MAT) enables measuring impacts in either qualitative or quantitative terms. Through the application of scoring and weighting methods, diverse information is converted to a common measurement scale and aggregated to provide an overall measure of performance. Alternative options are compared on the basis of their relative performance, or decisions can be based on whether a threshold has been reached. This technique includes four steps:

- identification of key concerns and impacts
- provision of system for scoring or rating each concern or impact
- development and application of a weighting system
- aggregation of weighted scores into an overall measure of performance

A risk analysis sample form based on multi-attribute technique is shown in table. 2.1.

Table 2.1: Risk analysis using MAT

WHAT CAN GO WRONG?	ACTIVITY STEP AFFECTED?	(A) HOW LIKELY IS IT?	(B) HOW SERIOUS IS IT?	A x B = DEGREE OF RISK	ACTIONS	
					PREVENTIVE	CONTINGENT
1)						
2)						
3)						
4)						
5)						
6)						
7)						
8)						
9)						
10)						
11)						
12)						

CRITERIA:
1: LOW
3: MEDIUM
5: HIGH

(iii) Attitude surveys

Attitude surveys are conducted among the flood-prone communities in order to identify acceptable flood damage reduction measures. The survey includes interviews with local officials as well as with randomly selected residents. An active, personal, participation in the interviews is preferable, in order to gain insight into issues of how the community perceives flooding problems and solutions.

It is not unusual to proceed with some management schemes on mainly social grounds. It is the world-wide experience that flood protection schemes are uneconomical in formal cost/benefit terms. More often-cost effectiveness approach is preferred.

(iv) Contingent valuation method

In evaluating environment protection, alternative discrepancies between private and social costs and benefits are inevitable. The main problem is that the environmental damages (such as water pollution or urban soil erosion), resulting from some economic undertaking, cannot be valued on the basis of the present market prices. The contingent valuation method is an economic valuation method for environmental impacts that is based on the individual willingness to pay for improving environmental quality as compared to the willingness to accept an environmental deterioration. By asking the respondents to state their willingness to pay for the improved water quality, an indication can be obtained about the monetary value of some environment protection undertaking.

(v) Cost effectiveness analysis

Cost effectiveness analysis results in the least cost solution that meets some predetermined environmental requirements (such as certain concentration of pollutants at specific locations or certain water depth at specific point in a floodway). By analysing the monetary value of various alternative undertakings, ranking can be made according to their cost.

Cost are composed of private and social ones. In case of the minimisation of private costs, a solution may be selected that shows minimum cost, but that will more likely raise substantially the level of pollution or the extent of damage in the future. It has been proved on many occasions that environmental impacts cannot be measured in a single environmental indicator.

(vi) Value engineering

Value engineering is a proven, effective tool for both the continuous improvement and design enhancement. It optimises the allocation of limited funds without reducing the quality of the project. A value engineering team with diverse background is assembled at the onset of a project. The outcome of value engineering studies is often cost reduction, but primary focus is "value improvement". This may result in improvements in defining proper scope, functional design, internal and external co-ordination and schedule for development. Other value improvements may include, but are not limited to, reduced environmental impact, reduced public inconvenience and reduced overall operation costs.

At the conceptual stage of design, the project scope and cost are under consideration. At this stage there is the maximum opportunity to consider the various alternatives or solutions.

At the schematic design stage, the project scope and cost have been established and major decisions have been made. At this stage, the established project scope, cost and schedule define the limits of the value engineering study.

At the completion stage of app. 35% most of the important project decisions have been established and the opportunity to effect the project design is already limited.

2.3.7. Combined sewer overflow (CSO)

Combined sewer systems consist of a single conduit that collects and transports domestic and industrial wastewater along with the stormwater originating either from rainstorms or snow melting. Two characteristic conditions determine the operation of the combined systems: dry weather flow and wet weather flow. During wet weather conditions, combined surface runoff and sewage largely exceed the capacity of the conduit, thus causing overflows into receiving waters. In addition to overflows that occur at special hydraulic structures, excessive runoff occurs at the urbanised surface as well, causing flooding and possible pollution of the land while flowing towards the receiving water body.

Urban land exposure to the destructive action of water, associated with pollution caused by high content of the impurities both in the surface water and in the mixed, channeled, underground water, represent two typical hydrologic events in many cities when heavy rainfall occurs. Because of their large volumes, combined sewer overflows (CSO) represent also a major source of pollution of the receiving water bodies. The problem of urban flooding is complex because it may address the external causes, such as high stages in the river due to area-wide weather changes, as well as the internal causes, such as local rainstorms. In both those urban flooding scenarios, pollution is an inevitable companion.

Usually environmental impacts cannot be measured in a single environmental indicator. Some solution will result in little water pollution, but will be very material and energy intensive, because of large quantities of water involved. Others may result in pollution of heavy metals, instead of organic pollution. For these problems, the methodology of multi-criteria analysis may help decision makers rank the various alternative schemes on the basis of weights attached to the various criteria.

2.3.8. Risk and hazard assessment and mapping

People know the price for living in urban areas and are willing to accept a certain risk by not providing full stormwater drainage and flood protection in order to be able to save and spend their money not only on utility bills, but on other things as well. It is a duty of the flood management professionals to propose the levels of acceptable risk based on specific site conditions, to make people aware what risk is present in their lives, and to assist them in making formal acceptance, based on which adequate flood protection measures will be proposed. Drainage professionals make and clarify proposals but politicians and voters make decisions.

Flood hazard means the threat to life or the threat of damage to property as a consequence of flooding. Planners attempt, for regulatory purpose, to assess flood hazard for a standard, baseline conditions. Each community needs to agree upon its level of acceptable risk of flooding, which is described by the chance (probability of occurrence) that a flood will occur in any given year. However, determination of the chance, usually designated as recurrence interval or return period, does do not specify the time interval between floods, which makes it possible, although unlikely, for a flood of a given magnitude to occur in successive years.

For reasons of simplicity many authorities adopt an uniform flood risk, such as 1-in-20 year flood or 1-in-20 year design rainfall. In other cases, flood authorities may adopt the highest recorded flood as the appropriate standard. Because of economic reasons many developing countries and their cities may prefer to opt for a lower flood standards in the short term, and increase the standard in the future as additional financial resources become available.

The first step in assessing flood hazard is estimating the probable future runoff rates and associated characteristics (depths of water, velocities, etc.) on the basis of rainfall characteristics, topography, hydrologic soil characteristics, land use pattern and morphology of the natural and artificial water courses. The most important prerequisite for any successful flood assessment is the systematic, comprehensive and error-free acquisition of pre- and post-urbanisation data.

The result of that exercise is the *flood extent (boundary) maps* such as the iso-depth map, which denotes inundation for selected baseline probability of occurrence. Such a map is not necessarily the flood hazard maps, since simple presence of water does not automatically mean that hazard is present. For example, very shallow water pounding is not dangerous for safety but may trigger the movement of an eventual major landslide, with catastrophic consequences. It cannot be assumed that lands outside the standard flood limits will be free of flood damage.

Hazard maps have to be presented in a form that is fully understandable, with all affected populated areas, facilities and structures indicated and marked. Hazard zoning maps present hazard levels together with the probable intensity of magnitude in each hazard zone. An example of a flood hazard boundary map is given in fig. 2.3.

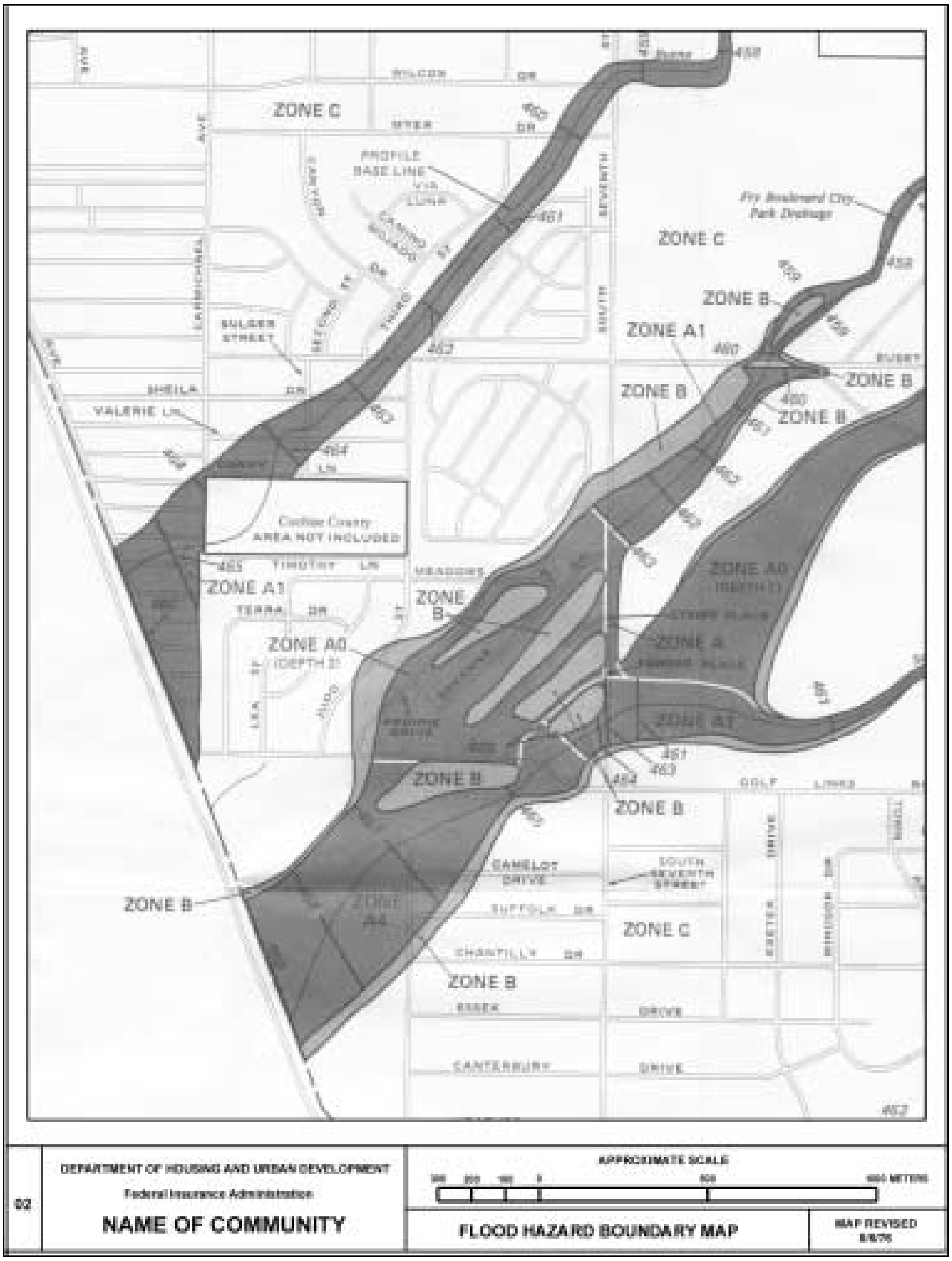


Fig. 2.3. Example of a flood hazard boundary map

Risk is a quantification of hazard. Risk mapping is the activity where elements at risk are plotted on hazard maps. *Risk maps* may include certain guidance, advice and indication of escape routes, safe access ways etc. Risk assessment that provides the planner with an estimate of the expected material losses includes:

- identification of areas at risk upon its exposure to hazard
- classification of structures according to function
- estimation of risk for each structure type
- estimate sum of all risks for each function and then for each area

There are also economically non-quantifiable aspects, such as potential loss of life and indirect secondary losses. For their evaluation and assessment standard indicators for housing areas, infrastructure and various economic activities are eventually made available by state authorities that regulate insurance policies.

A flood risk map has several direct economic effects, since it causes revision of all planning maps for the area. On the negative side, it may lower property value in the flood-prone areas and may stop development. On the positive side, the map initiates the construction of flood loss prevention structures, alerts prospective land and property owners, as well as provides new developing ideas to the local planning authorities.

2.4. Unified urban flood management

The conventional approach to flood management was based on river-basin oriented programs and plans that were needed during floods to minimise their impact on the individuals and the community. Those traditional programs dealt mostly with measures of a structural nature, which included also some flood recovery activities, but did not fully address the specifics of an urban environment that might have remained confined within the boundaries of a structural flood protection scheme. Conventional approach focused mostly on measures that modified flooding or provided protection against flooding, such as dams, storage reservoirs, dikes, floodwalls, flood diversion, channels and land treatment practice.

The contemporary concept addresses the problem of flooding by considering the best mix of flood management options available, selected among both the structural works and non-structural measures. It is based on an integrated and environmentally sustainable approach, addressing fully all aspects of flood occurrence in an urban setting, where other kinds of urban waters and the land itself are exposed to the action of excessive stormwater. Experience has shown that flood related pollution issues, such as hazard to health, due to water borne diseases, and large cleanup costs, deserve the same attention as traditionally favoured flood related physical destruction themes.

Conventional structural measures also need to be replaced by an alternative, contemporary set of structural measures. Introduction of contemporary urban structural measures require the revision of their scope by adding an important objective of reducing water pollution through non-point source pollution control, combined sewer overflow control, recovery of wetlands and erosion control. In addition, traditional flood modifying and against-flood protecting measures need to be amended with two new measures characteristic only for urban settings: small near-to-source detention structures and low cost protection techniques.

Low-cost structural measures for reducing flooding and pollution include, but are not limited to:

- distributing flood water in thin layers over land, where a portion of it infiltrates into the sub-soil
- deliberate flooding of certain areas in order to protect another more valuable area
- limitation in use of manure, fertilisers and pesticides
- restoration of local urbanised waterways (uncovering urban creeks)
- construction of protective grass and bush covered land strips along streams and rivers
- local measures initiated in co-operation with residents (disconnecting roofs from street drainage conduits, providing gravel beds below lawns, replacing concrete with permeable asphalt, regular removal of sediment deposited in the low lands, etc.)
- stormwater quality improvements (changing roof materials, painting galvanised objects, introducing dry street cleaning techniques instead of washing material and grit into storm drain inlets, decreasing traffic pollution)
- displaying flood stage forecasts on the posts at public places

- raising community centres at elevations not liable to floods
- compartmentalisation of the flood plain and encouraging the land use commensurate with the protection system
- land treatment (contour plowing, grading)
- tree management
- flood proofing
- construction site stabilisation measures that reduces erosion and sedimentation (temporary seeding, mulching, geo-textile, silt fences, hay bales, sediment traps, storm drain inlet protection, etc.)

Structural measures tend to create a false sense of security in the population protected by the works. They are usually known as engineering technical measures and should be addressed in their own Guidelines. For information purpose only, the concept of flood management structural measures is graphically presented in fig 2.4.

The remaining part of these Guidelines is dedicated, in accordance with the original mission set for this document, to non-structural measures, which represent a complementary component of an unified urban flood management plan.

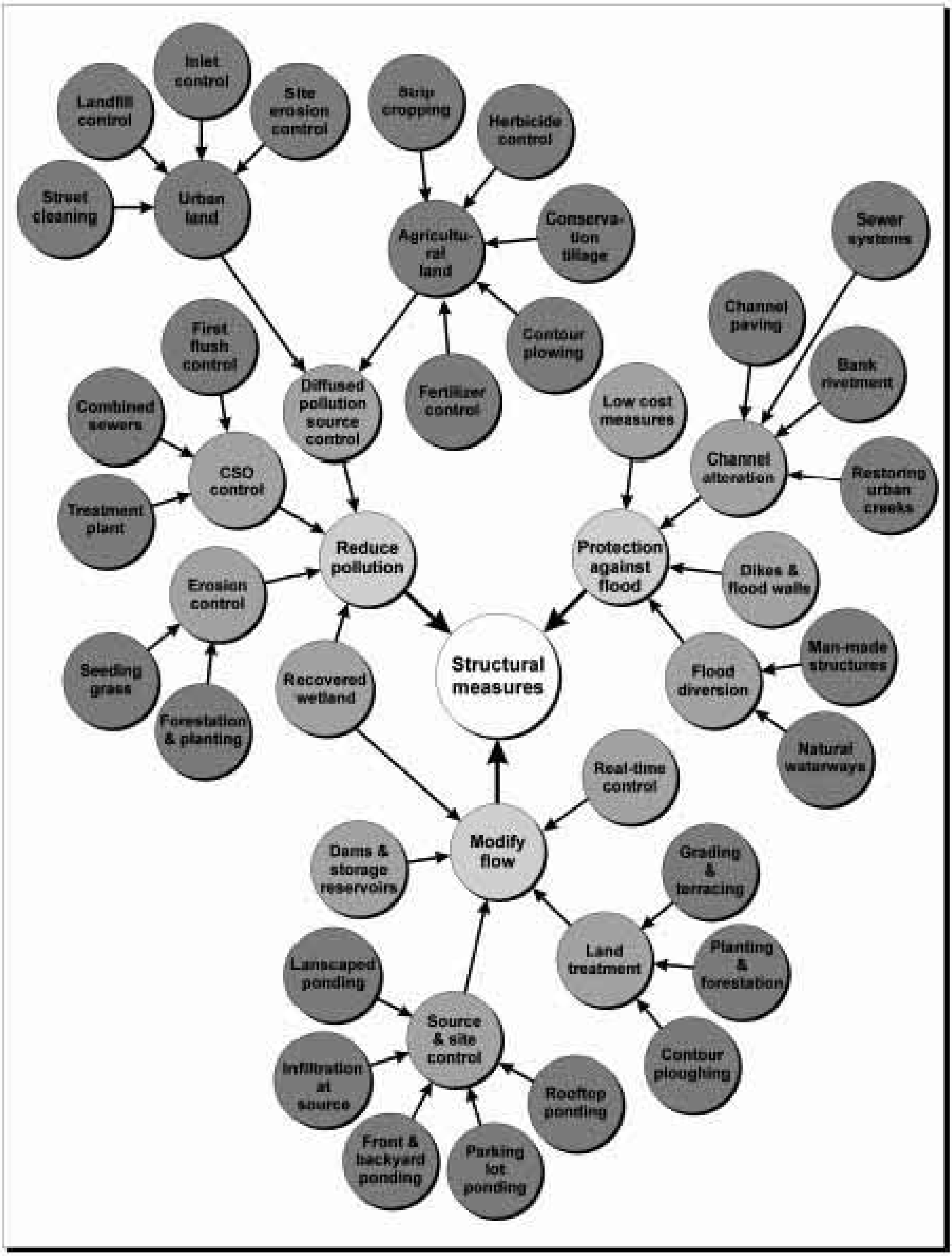


Fig. 2.4. Structural measures for flood management

3. Flood mitigation

3.1. Mitigation concept

Mitigation is a long-term and ongoing process, prior to the occurrence of a disaster that is directed at reducing future flood damages of the community and the nation. Technically speaking, there is no flood risk that cannot be mitigated through engineering measures, but cost is the determining factor. This process teaches people how to live rationally with floods. Mitigation measures, active and passive, rely on the experience and capacity of people where disaster occurs. Active measures encompass those activities, which require direct contact with people.

Mitigation measures are traditionally referred to as non-structural measures. Unified concept of urban flood management introduces *flood recovery measures* as a separate entity in order to emphasize the specifics of spreading the cost of compensation over time and among a large number of people exposed to similar risks.

Non-structural measures, shown in fig. 2.1, such as preparedness, response, legislature, financing, environmental impact assessment, reconstruction and rehabilitation planning, and their component techniques, contribute directly towards reducing losses of life and damage to property.

The order in which the mitigation measures is applied is of primary importance. An ideal sequence would be to first develop public awareness that leads to creating political will, followed by drafting and passing the laws and regulations, and secondly, to propose risk-reducing measures, and finally, to offer education and carry out training. Ultimately, market-oriented conditions for flood insurance industry should be created in order to spread potentially high flood damage cost over a long period of time and among large number of people.

Other mitigating actions include reducing physical vulnerability, reducing vulnerability of the economy, and strengthening the social structure of the community. These actions can be undertaken at individual, community, and state levels. Non-governmental organisations, voluntary, and socio-cultural organisations may also play an important role in this respect.

Although not having a formal definition, flood mitigation can be accepted as a variety of measures that alter the exposure of life and property to flooding. It reflects the holistic nature of those flood management measures that do not have structural nature. Its non-structural nature led some countries to denote mitigation as *institutional* measures, while other countries preferred to use the name of *best management practice (BMP*). The latter is in use in urban conditions for many years and is separately addressed in section 3.4. In Europe, the term SUD (sustainable urban drainage) is obtaining increased popularity.

Mitigating means planning, programming, setting policies, co-ordinating, facilitating, raising awareness, assisting and strengthening. It also understands educating, training, regulating, reporting, forecasting, warning and informing. However, it does not exclude insuring, assessing, financing, relieving and rehabilitating. If structural measures are the bones of a flood management program, then mitigation is its flesh.

3.2 Non-structural measures

3.2.1. Flood preparedness measures

Community flood preparedness is an analysis of possible disaster scenarios for determining how authority and responsibility for action should be delegated, what local human and material resources exist, and how these can be deployed.

Flood preparedness plan is a series of sub-plans, including emergency response planning and training, raising public awareness, flood forecasting and warning, setting development policy, land use regulation, flood proofing, setting alternative plans, and local social structure strengthening (fig 3.1).

Individual preparedness planning is based on raising public awareness. Realistic treatment of flooding related problems is a prerequisite for building confidence, as compared to pictures that may be portrayed by media and government officials. Confusion during evacuation, disruption of daily routine, strain on families removed from their homes, distress, altered social relationships, loss of feeling of security, personal vulnerability and many others are real psychological issues that need to be addressed in this planning stage and treated as inevitable events and a quite normal behaviour.

3.2.2. Emergency response measures

Emergency response can be considered as a series of sub-plans that address communication and public information management, search and rescue co-ordination, shelter management, stockpiling and distributing of food and supplies, contacting and requesting additional support, debris management, financial management, volunteers co-ordination and donations management.

The foundations of a flood emergency action are a mobilisation plan, comprehensive disaster plan and well co-ordinated and trained flood fighting corps.

A flood fighting corps may be mobilised to a state of alert with various stages: mobilisation, preparation and stand-by and dismissal. It is useful to have powers to call up the inhabitants when high water threatens, with preference given to volunteers.

Organisation and training of search and rescue teams are done locally, regionally or nationally but in real flood conditions, participation of volunteers, citizens and relatives is significant, thus requiring the co-ordination to develop as the action proceeds.

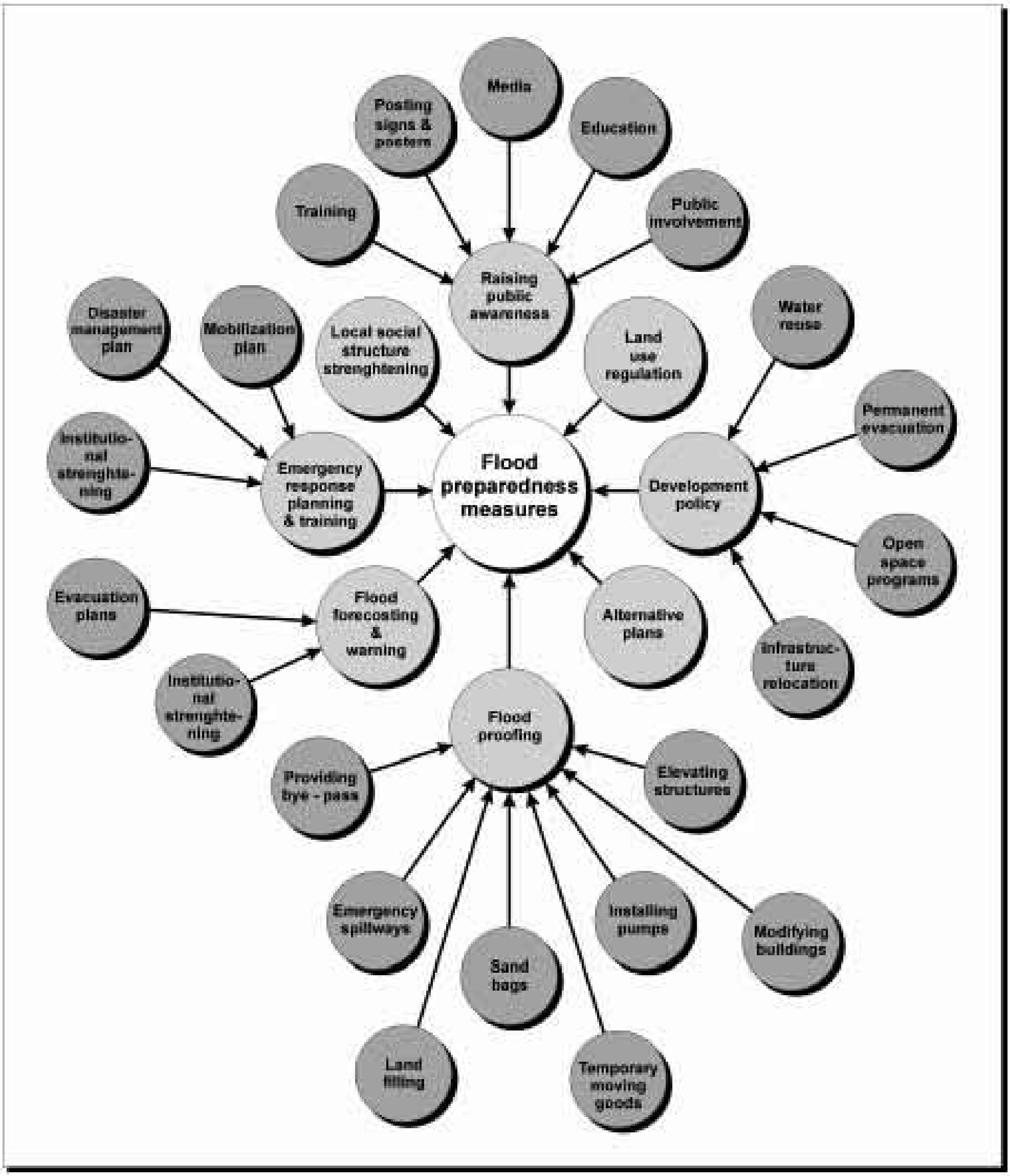


Fig. 3.1. Flood preparedness measures

Fig. 3.2. Emergency response measures

3.2.3. Environmental issues

In every national water pollution control program, regulating discharges of wastewater is the primary concern. Formal procedure of permitting and licensing is introduced in urban practice, thus limiting the pollution from point sources such as municipal sewerage outfalls, industrial wastewater discharges and treatment plant effluents. Combined sewer systems are also considered as point (discrete) polluters due to frequent spills of wastewater during wet weather conditions.

Municipal stormwater discharges can contain many pollutants, such as metals and organic compounds traditionally found in wastewater from discrete facilities. Unlike other wastewater discharges, the sources of stormwater pollutants are diffuse and highly variable. Pollutants come from roads, parking lots, residential, commercial, and industrial activities within each municipality.

Control of municipal stormwater does not fit with the traditional wastewater discharge permit requirements. Therefore, a comprehensive pollution control plan is needed that should be watershed-based and should control all wet-weather-related discharges.

Stormwater drainage and flooding-related environmental issues are separately addressed in chapter 11 of these Guidelines.

3.2.4. Government and legislature

Governments have a wide range of structural and non-structural instruments at their disposal to mitigate the risk of flood. They should provide leadership and assistance in developing a comprehensive multi-level hierarchical flood management plan where responsibility and authority of each participant in flood fighting is clarified.

The central government initiates elaboration of the flood preparedness program. This program is based on flood hazard studies and mapping, flood forecasting and warning, public education, and response planning. The local government is then responsible for implementation and maintenance of the site-specific programs.

All preparedness measures need to be supported by appropriate legislation in a form of the national flood control laws, regulations, and local ordinances. Legislation for flood reduction measures should be incorporated within the technical legislation covering urban development, regional development, environmental management, resource management, communication, housing etc.

Very often there are instances where flooding problems between neighboring countries need to be resolved. Those situations require appropriate transboundary aspects to be addresses and legal documents to be prepared.

Legal and institutional issues are additionally addressed in chapter 8 of these Guidelines.

3.2.5. Financing

The stormwater drainage and flood control financing concept should represent a stable, adequate and publicly acceptable funding mechanism for drainage capital investment, operations, and routine and remedial maintenance.

Stormwater is a difficult resource to manage primarily because urban drainage systems are in a constant state of flux. Even a natural drainage system in its undeveloped condition is not static: streams meander, banks erode, and ponds are filled with sediment.

Present stormwater management financing sources are revenues for annual operating expenses and maintenance (property taxes, local sales, income taxes, street fund created through gas sale taxation, user charges and commercial loans), funding for major capital improvements (general obligation bonds repaid by property taxes, revenue bonds repaid by utility service charges, utility tax revenues, community development grant funds) and fees and charges.

Basically there are many other methods available for local financing: various means of borrowing, current revenues, special revenues, grants of funds from the federal, state and county governments, contribution of land owners, and finally, special user charges.

More on innovative methods of financing stormwater drainage and urban flood control can be found in chapter 10 of these Guidelines.

3.3. Flood recovery measures

3.3.1. Flood insurance

Flood insurance enables the property owners, subject to potential flooding. to spread an uncertain but large loss over a long period of time. It also provides mechanisms of spreading flood loss over a large area and a large number of individuals.

Flood insurance is a complementary tool of hazard reduction. The purpose of flood insurance is to provide compensation for losses caused by flood when damages are not avoidable at acceptable cost. In most countries coverage is fragmented and property owners have to purchase different policies in order to insure against all major disasters.

Flood insurance can only be seriously considered by property owners after necessary structural and non-structural mitigation measures have been satisfactorily undertaken. The insurance sector in developing countries is still weak and not in position to calculate a realistic premium to build up a flood insurance portfolio.

It is expected that the central government should provide financial and political support. Policymakers are expected to change the social behavior by modifying the incentives of the marketplace and to strengthen market conditions in order to attract more participation. Currently, particularly in developing countries, the insurance industry seldom includes flood risks or vulnerability data, based on zoning information, in their premium structure.

Federally subsidized flood insurance programs may be available for property located in flood-prone areas. Property located in designated flood hazard areas should not be able to qualify for federally insured financing or federal grants unless flood insurance is obtained. Such a program is the most effective tool in preventing the unwise urban development. The program is based on field and office work that should produce the flood hazard boundary maps and the insurance premium rate maps.

Analysis of risks should be undertaken before new development is approved in flood-prone areas, and micro-zoning risk maps for hazards should be included in land use maps and land use policies.

The experience gained world-wide proves that there is no practical and sustainable alternative to a nationally led flood insurance scheme.

3.3.2. Rehabilitation measures

Post-flood management problems can be pre-planned. In order to achieve this, objective surveys need to be carried out during the flood for preparing the situation report covering human casualties and material damage. These surveys are needed for making decisions on the actions during the immediate emergency and in the period that follows. Later on, a thorough study needs to be made in order to perform a formal assessment of the damage.

Rehabilitation is providing services and facilities that will restore the former living standard and encourage adjustments to changes caused by the flood (fig 3.3). Restoring morale is one of the most important factors in rehabilitation. Rehabilitation should be carried out separately for the flood victims and the disturbed public services.

Fig. 3.3. Rehabilitation measures

3.4 Best management practice (BMP)

Best management practice (BMP) is a common name for a variety of non-structural and low-cost structural measures in mitigating the flooding and pollution effects in urban settings. In rural conditions, terms such as institutional or non-structural measures are more frequently used. BMP tends to reverse the impacts caused by urbanisation and include a number of proven and promising measures for controlling destruction and pollution caused by urban runoff and combined sewer overflows. The measures should be :

- based on the entire watershed control
- performance (target) oriented
- designed to account for locals characteristics
- supported by local and state government
- technically feasible
- environmentally sustainable
- economically justifiable
- politically acceptable

Best available technology (BAT) is a process that determines the criteria upon which BMPs will be proposed, based on practical experience gained from the implementation and monitoring of the measures already in force, in conjunction with theoretical assessment and common sense. BAT criteria will change as our knowledge about the effects that BMPs have improves, which in other words means "learning by doing". BMPs are based on several principal concepts, such as:

- retaining the natural drainage system
- imitating the natural drainage system
- protecting land during urbanisation and farming
- cleaning urbanised surfaces
- protecting aquatic life

BMP is a set of urban measures and represents one of two major components of a stormwater management and flood control program that is designated as the Wet Weather Control Measures Program. The other component of such a Program is a group of structural (end-of-pipe) measures that include, but are not limited to, a series of measures shown in fig. 3.4. BMP measures are shown in fig. 3.5 and 3.6 and in many aspects are similar to the measures shown in figures 2.1 through 3.2.

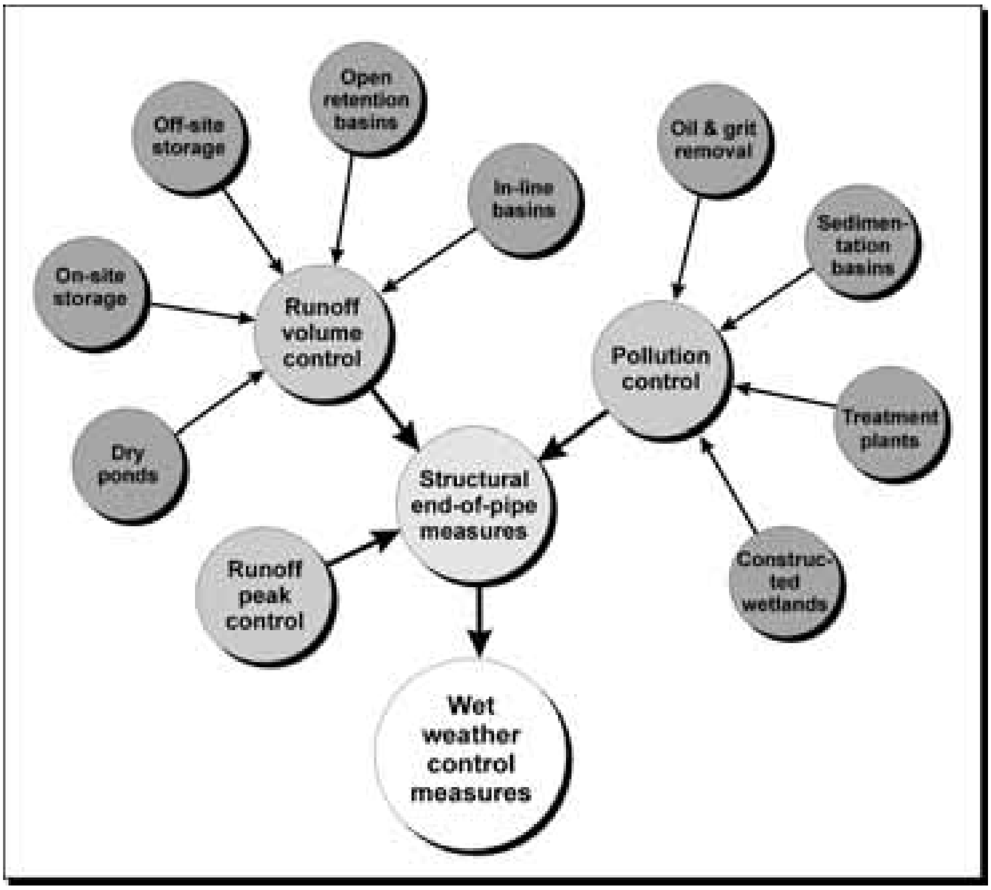


Fig. 3.4. Structural (end-of-pipe) urban measures

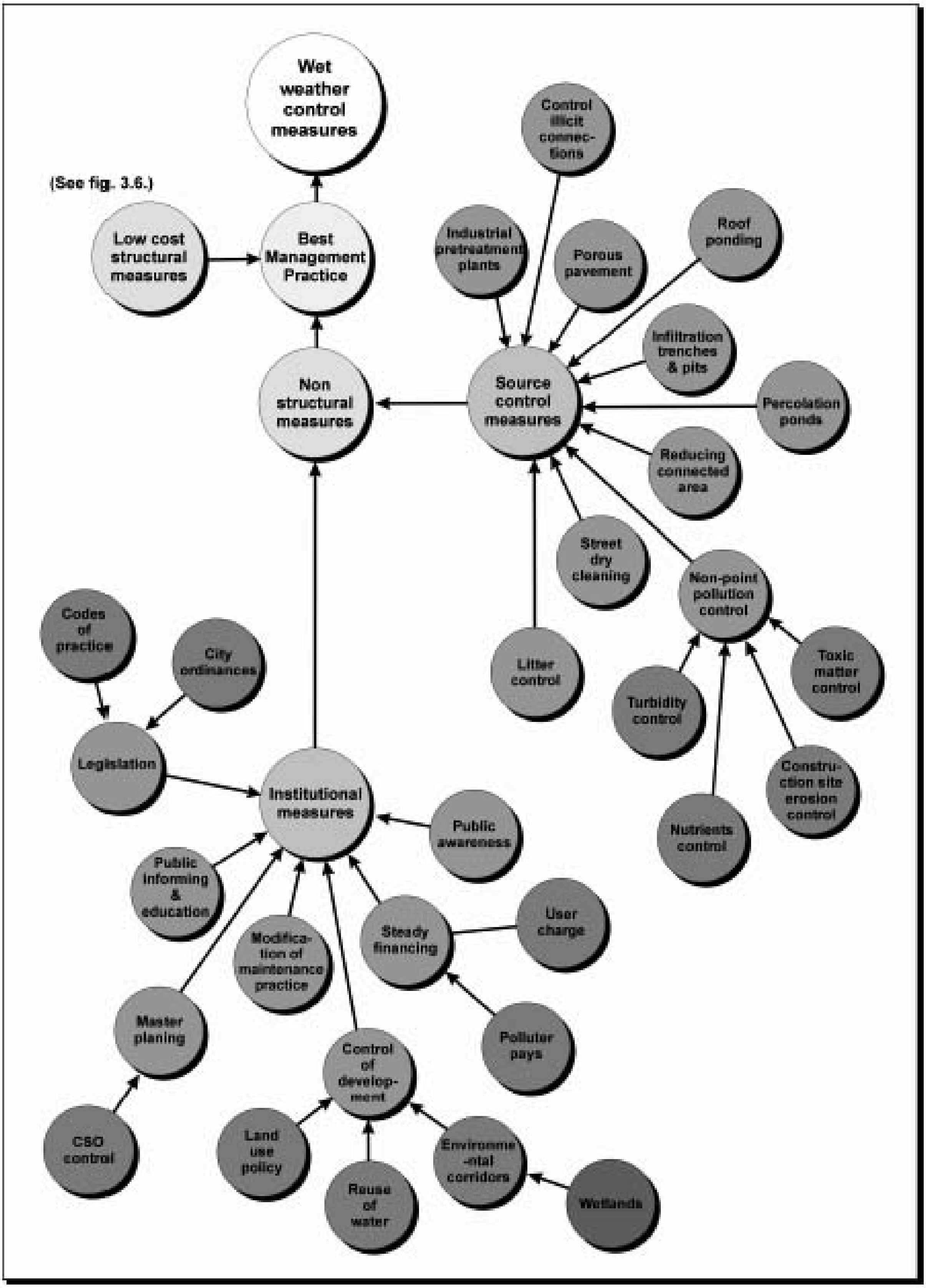


Fig. 3.5. BMP non-structural measures

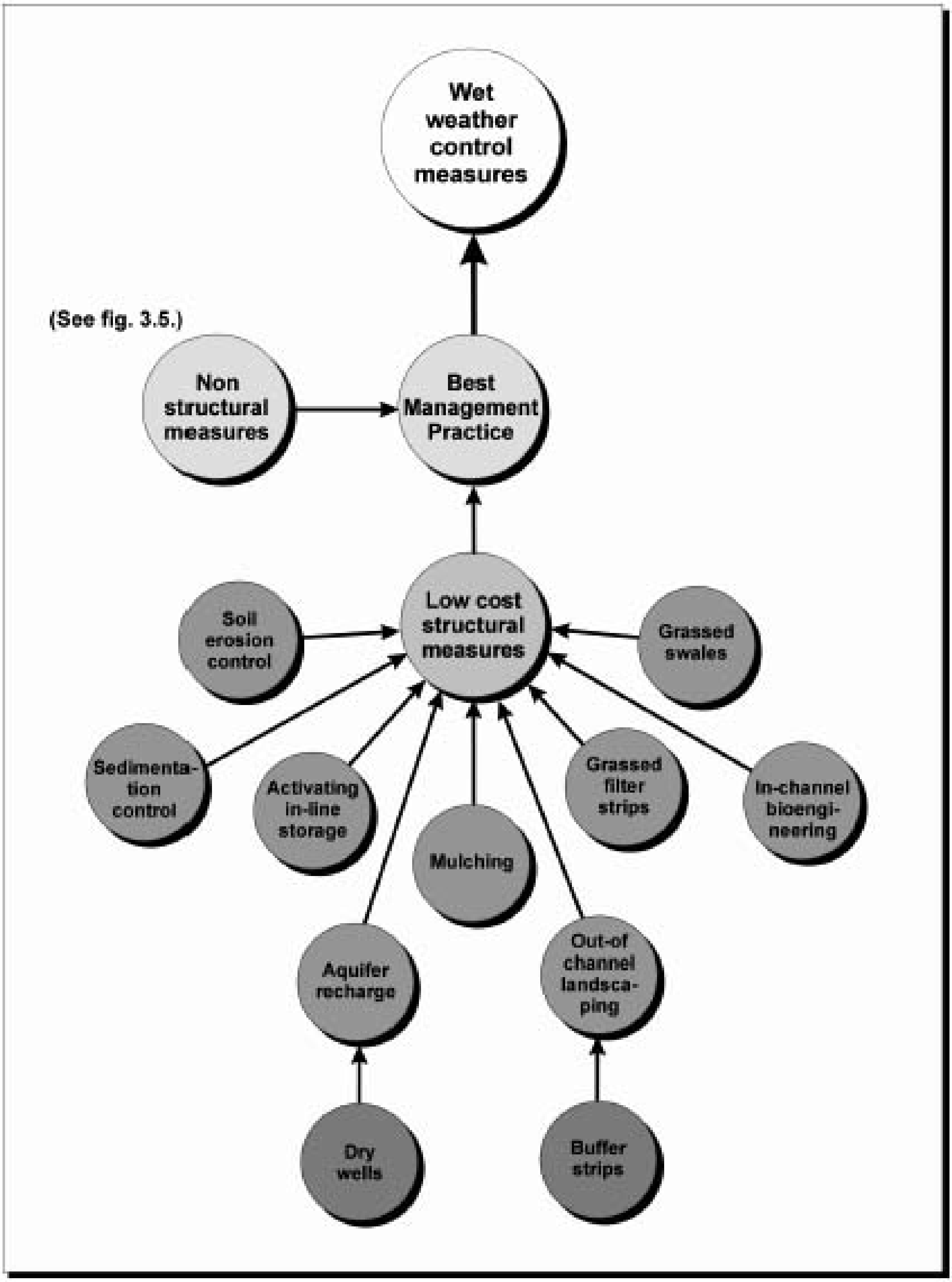


Fig. 3.6. BMP low cost structural measures

4. Development and land use policies

4.1. Regulation of floodplain

Floodplain is an area near the water course that is susceptible to inundation. Technically, it is composed, as shown in fig 4.1, of a central channel known as *floodway* and the *floodway fringes*, placed on both sides of the floodway.

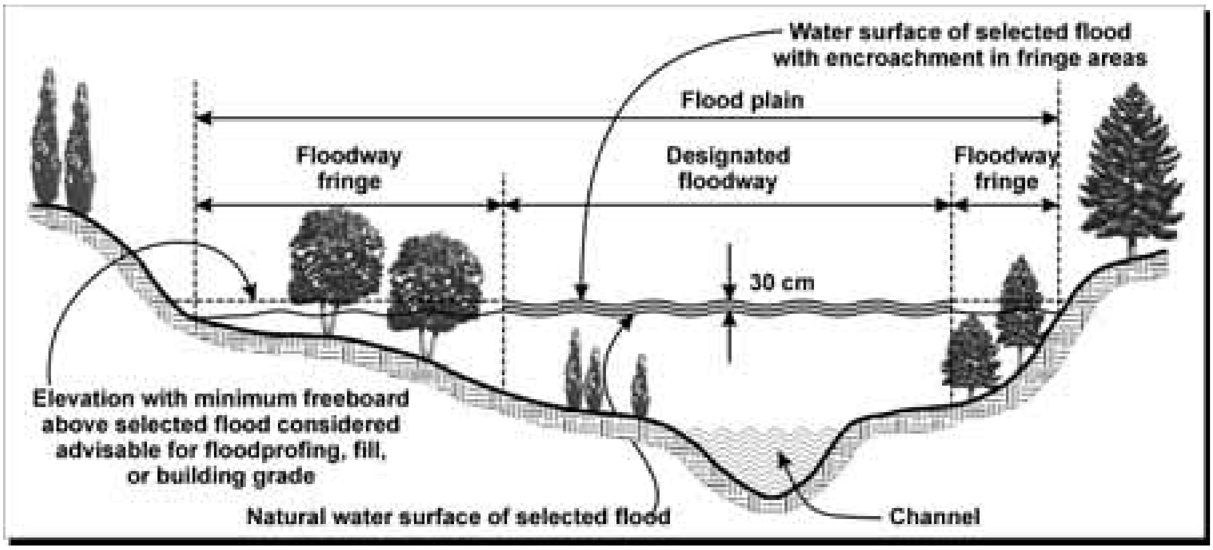


Fig 4.1. Natural floodplain definitions

Natural floodplains have living and biological resource values because they support a wide variety of flora and provide habitat for fish and wildlife. Floodplains are important for the water resources because they provide natural flood and erosion control, help maintain high water quality, and contribute to sustaining ground water supplies. Special portions of natural floodplains are wetlands, the significance of which in flooding and pollution management is growing steadily.

Artificial floodplains, created from natural floodplains through urbanisation, located along the urban creeks which are usually fully contained, are not easy to recognise in an urban setting. Urban runoff does not always flow perpendicularly to the contour lines of the natural terrain because of many objects and infrastructure facilities that constitute an urban environment. Urbanisation of a natural floodplain increases the susceptibility of the neighbouring land to floods. Unfortunately, city boulevards, secondary traffic arteries, side streets and parks, usually in combination with front yards, house basements and other low land spots, take over the duty of evacuating the excessive quantities of stormwater (fig. 4.2). Therefore, once the street layout and vertical alignment are set by urban and traffic planners, the options open to drainage planners are greatly reduced.

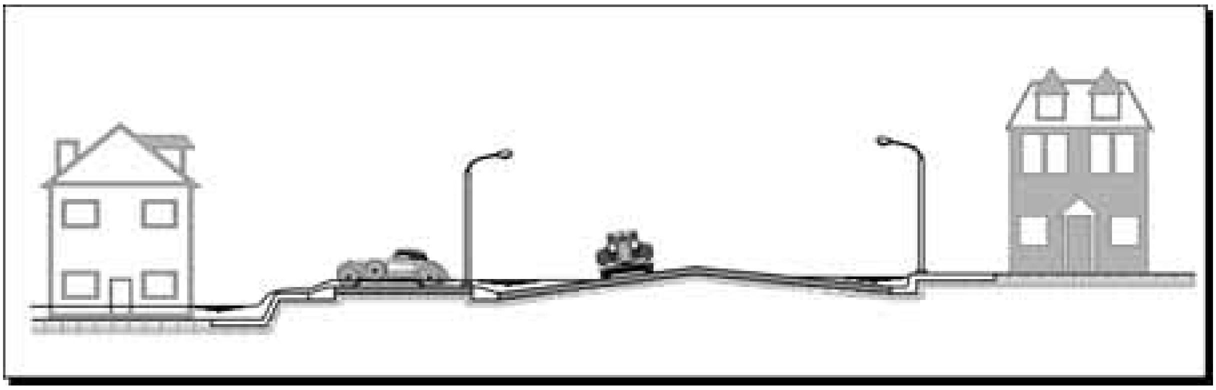


Fig. 4.2. Urban floodplain

Traditional urban stormwater drainage practice includes only consideration of the sub-system "minor", having limited capacity, based on a level of the commonly accepted risk (usually quantified as a return period ranging from 2 to 30 years). On the other hand, contemporary design practice takes into analysis the entire urban floodplain (system "major"), having practically unlimited hydraulic capabilities in situations when the capacity of the sub-system "minor" is exceeded.

4.2. Land use and zoning plans

Land use management employs two principal options: zoning control and development/building control. Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area.

Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanisation of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.

On the basis of an objective assessment of hazard, economic, social, and environmental factors, the responsible authority should impose appropriate conditions to ensure that the future development is compatible with the prevailing flood situation. There are three basic types of floodplain development:

- preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural or recreational purpose
- preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial or industrial purpose as long as the encroachment results in only insignificant increase in the water surface elevation
- restricting the use of the flood plain and leaving it in its original unoccupied state

Those types of floodplain development actions are institutionally accompanied by:

- legal measures that enforce zoning, density and pace of development
- taxation measures that may guide development away from hazard areas
- government action that may alter existing land use or require compulsory purchase of the flood-prone land

In case of allowing the use of flood fringes, land use zoning is the legal tool for implementing and enforcing the land use program. This program includes specifying the types of activities, limiting the population density, changing the pace of development, taxation measures, government action of land acquisition by compulsory purchase, and existing land use alteration.

Land use and zoning policy cannot entirely eliminate the effects of the presence of hazards. Additional measures, such as *building and other codes of practice*, give specifications for design, operation and maintenance for buildings and infrastructure facilities. However, application of building and other codes is a subject that requires a flexible attitude, because using codes may turn out to be very expensive. Building codes generally deal with the following aspects:

- purpose for which the building is constructed
- the criteria for structural strength to withstand water action
- specifications for material
- adequate elevation of basement and first floors

A variety of development and land use techniques (fig. 3.1 and fig. 4.3) for flood management can be proposed such as:

- infrastructure relocation
- permanent evacuation
- open space programs
- zoning ordinances for limiting types of land use
- regional planning
- subdivision regulation
- building codes of practice
- housing codes of practice
- sanitary and other utility codes of practice
- redevelopment policies such as proper design of utilities
- source pollution control
- public acquisition
- flood proofing

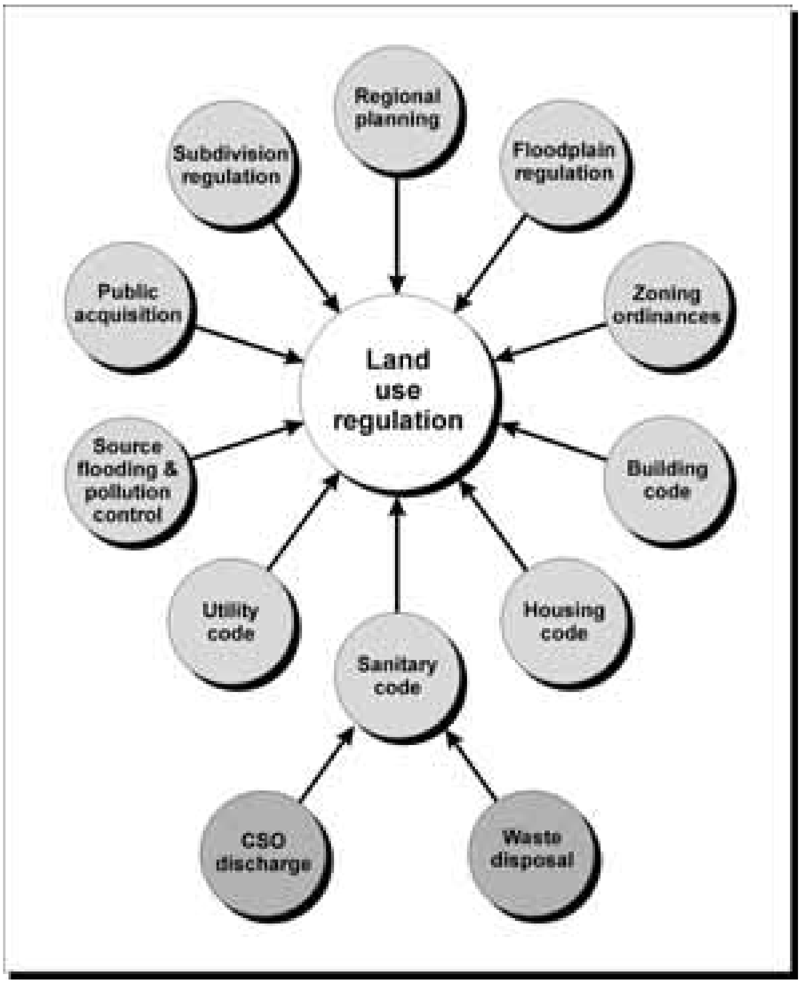


Fig. 4.3. Land used regulation techniques

As a general principle, artificial structures in urban floodplains should be carefully designed and built to fit with their surroundings, and not detract from the harmony of the natural environment (Fig. 4.4).

By using development and land use policies and other non-structural measures, the following flood management solutions can be offered for different situations in the land development process:

(i) For protecting existing development:

- flood control works
- flood warning and evacuation
- flood proofing

(ii) For removal or conversion of existing development:

- public acquisition
- urban redevelopment
- non-conforming uses
- conversion of use or occupancy
- reconstruction of public facilities

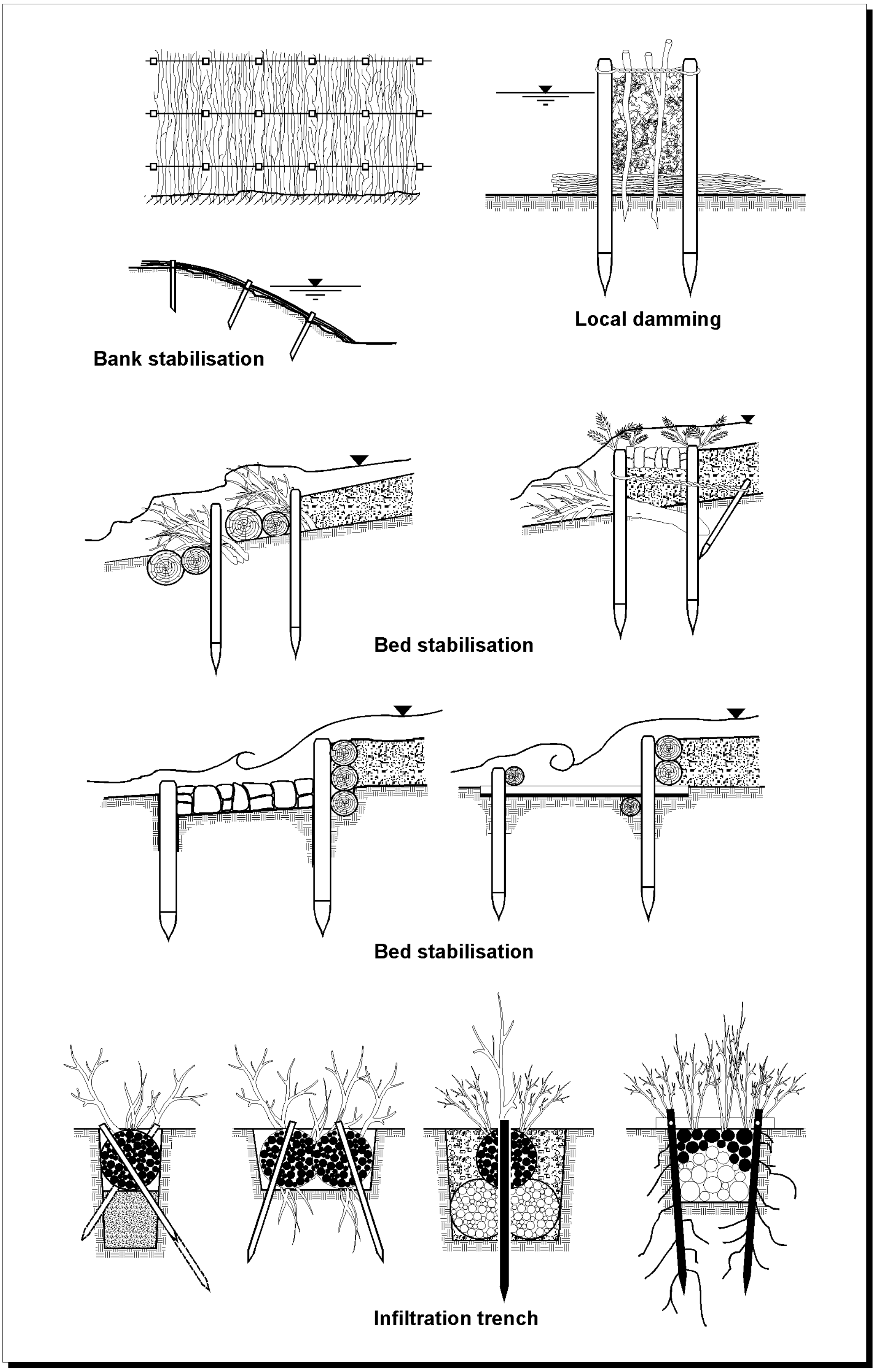


Fig. 4.4. Denaturalisation of urban creeks by using timber and fascines

(iii) For discouraging development:

- public information
- publication of warning signs
- tax-assessment practices
- financing policies
- public facility extensions
- increased flood insurance costs

(iv) For regulating flood plain use:

- zoning ordinances
- floodplain regulation
- waste disposal regulation
- groundwater quality protection regulation
- subdivision ordinances
- building ordinances
- reduction of population densities
- regulation of squatter settlement in flood prone areas
- prohibiting specific functions of land
- relocating elements that block the floodway
- regulating the building material
- providing escape routes to higher places
- state regulated and sponsored insurance policy

Certainly, there are differences between remedial management plans and preventive management plans. Non-structural measures, such as floodplain regulation, subdivision regulation, land acquisition, and other activities to preserve the natural and beneficial functions of the drainage ways, are most appropriate and cost-effective in preventive situations dealing with new developments. However, in many situations, non-structural methods are not cost effective or timely in providing remedial solutions to existing flood hazards.

In general, land-use management seeks to alter the pattern of floodplain land uses in areas of current and future development. To be effective, land use management should not be restricted to the floodplain immediately adjacent to the protected urban areas. Better control over flood plains, land zoning, land use policy, and land development are viewed as the key elements in a stormwater management program.

For more comprehensive treatment of floodplain development and management the reader is referred to the "Manual and Guidelines for Comprehensive Flood Loss Prevention and Management", prepared jointly by ESCAP and UNDP in 1991.

4.3. Land acquisition

A floodplain area is not exposed to the same degree of risk in terms of water depth or flow velocity. Most authorities prefer to partition the floodplain into high and low risk areas. Furthermore, they usually introduce the policy of no urban development on any flood-prone land in high risk areas, thus requiring the developers to find alternative flood-free site, and the politicians to provide financial means for relocating existing buildings and communities. Relocation has many advantages, but also causes major disruption of normal social life and the loss of jobs.

In some situations, the government may purchase by acquisition, the land and property to ensure that future unwarranted expense is not incurred in restoring building and the community after major floods. Acquisition is difficult to justify on economic grounds and should be used as a last resort, after concluding that no proper flood management program can improve the situation. In developing countries, effects of acquisition are difficult to remain durable because of the permanent social pressure on authorities to provide low-cost housing land. In many places in the world those locations turned to uncontrolled urbanisation and illegal squatters.

Relocation is often necessary as a temporary measure following the occurrence of a flood. Permanent relocation can be successful only when it is handled with a high degree of sensitivity.

4.4. Safety code of practice

The problem facing drainage designers and authorities is to determine safety standards that balance hazards against cost of protection. It is commonly accepted worldwide, when safety is in question, that the best rule is "to err on the conservative side". In general, people should be kept away by restricting access through fencing.

Until factors of safety are presented by skilled communicators, flood hazards may seem too remote to the public audience and other priorities appear more prominent. There are some principal recommendation relative to the safety in urban drainage systems, but the following list should not be considered as complete:

- water inlets should be sized and screened by a suitable grate so that a child cannot be admitted
- to prevent pedestrians from being swept along streets, the flow velocities and water depths should be limited
- streets should be trafficable during minor storm events
- wide, grass-lined channels, mildly sloped, are preferable to hard-lined channels with steep or vertical sides
- fencing and warning signs should be appropriate
- arguments that warning signs represent an admission of liability should be neutralized by providing signs that inform the public on the function of the drainage facility
- construction of super-critical flow channels should be avoided
- special escape devices should be provided upstream of closed sections of channel, such as sloping grilles, steps, ladders, and side-bays
- depth of detention basin should be restricted
- groups of pads of rocks placed at irregular intervals increase the turbulence, that gives the runoff a “dangerous” appearance and provides psychological safety factors
- in developing countries poor sanitary conditions can make any pond a sanitary hazard, breeding water borne diseases.

4.5. Landslides prevention

Much damage resulting from flooding is due to landslides, which can be fall, slide or flow in nature. Soil movement occurs when the cohesiveness of soil and the bonding of soil breaks down, permitting movement even on gentle slopes. In extreme cases, landslides combined with mud flow can spread over large areas and create catastrophic consequences.

Water is the main factor in slope instability. Identification of the source, movement, amount of water, and water pressure is as important as the identification of different soil and rock layers. Also, seasonal fluctuation in groundwater flow and pressures may lead to periodic activation of slides. The vegetative cover generally promotes stability. Hazard assessment and mapping are key elements in preparedness raising and landslide hazard mitigation.

4.6. Construction sites regulation

Development of new large urban tracts should be planned in such a manner that disturbance of natural resources is minimal. It is recommended that:

- major streets follow land contours
- land slopes are retained with little disturbance
- mini-forests are preserved between structures
- existing land cover is removed only in areas that are to be completed within the current construction season
- vegetation is restored upon completion of major work items
- gutter inlets adjacent to the construction site are protected against silting i.e. mud flow coming from the site as a result of soil erosion (fig. 4.5).

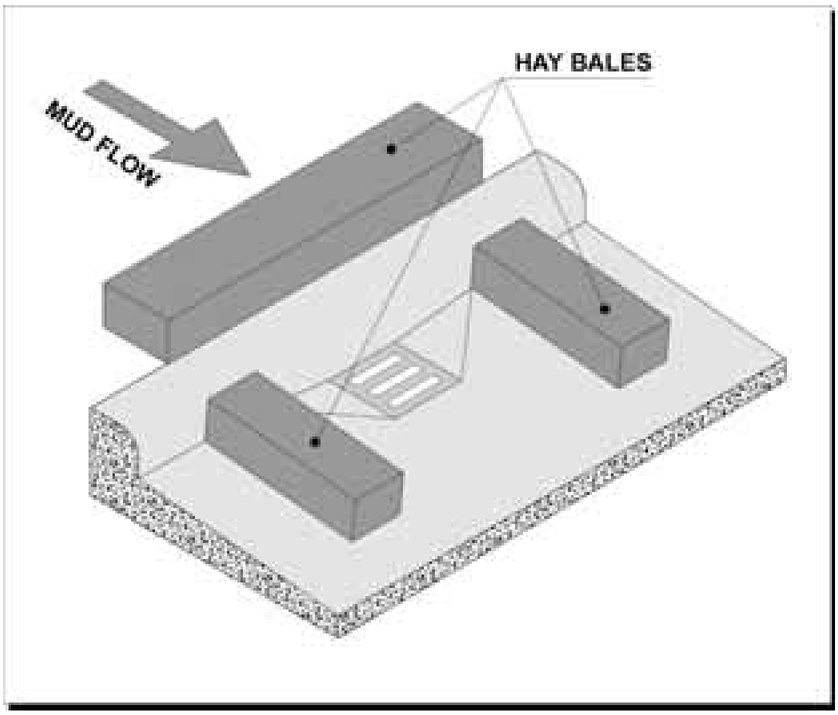


Fig. 4.5. Street inlet protection with hay bales

4.7. Land erosion control

Before issuance of a development or building permit, site development and construction plans shall be submitted for the review showing compliance with applicable provisions of grading, vegetation, drainage, erosion, and sedimentation control. These should show the following:

- stands of existing trees as they are to be preserved upon project completion, specifying their location on the property. Differentiation shall be made between existing trees to be preserved and proposed planted trees. Information shall be supplied concerning the proposed destruction of exceptional trees , where they exist.
- plans for meeting the grading, drainage and erosion and sedimentation control provisions of the city ordinance in force
- an engineering hydraulic analysis of stormwater runoff under existing site conditions and under proposed developed site conditions, and a detailed evaluation of the projected effects on property adjoining the site and on existing drainage facilities and systems.
- the projected sequence of work
- delineation of the boundaries and elevations of the intermediate regional floodplains for streams draining in excess of app. 40 hectares. The actual building site shall be shown in relation to the floodplain drainage easement.
- design items shall meet the applicable minimum requirements of published design standards
- "as built" drawings prepared upon project completion

No site shall be graded except in accordance with approved plans to meet foundation, parking, and drainage requirements.

During development and construction, adequate protective measures shall be provided to minimise damage from surface water to the cut face of excavation or the sloping surfaces of fills. Fills shall not encroach upon natural watercourses, their floodplains, or constructed channels in a manner as to adversely affect other properties.

Positive drainage shall be provided to all areas of the right of way.

Erosion and sedimentation control measures should be co-ordinated with the sequence of grading, development, and construction operations. Control measures such as hydro-seeding, mulching, berms, interceptor ditches, terraces, and sediment traps are recommended to be put into effect prior to the commencement of each increment of the development or construction process. Sediment basins (debris basins, silt traps) should be installed in conjunction with the initial grading operations and maintained through the development process to remove sediment from runoff waters draining from the land undergoing development.

Damage to vegetation and stream banks must be minimised. Existing trees must not be cut or otherwise damaged or destroyed within portions of property to be used for required open space, setbacks or buffer requirements. Exception to this may include road and utility rights of way, stream retention ponds, and related drainage improvements.

No paving with concrete, asphalt or other impervious material within the tree crown zone of trees to be preserved should be allowed. However, all ditches on a grade of 3 % or steeper need to be paved or grassed. The permanent vegetation is recommended to be installed on the construction site as soon as utilities are in place and final grades are achieved. Final grading and removal of vegetation shall not occur more than 30 days prior to scheduled paving.

Retention facilities and drainage structures should, where possible, use natural topography and natural vegetation. Outlets have to be designed in such a way as to prevent bottom scour of the receiving water body.

All on-site facilities shall be properly maintained by the owner such that they do not become nuisances. Nuisance conditions shall include: improper storage resulting in uncontrolled runoff and overflow, stagnant water with excessive algae growth, insect breeding, odours and discarded debris. Aeration facilities to prevent pond stagnation shall be provided.

4.8. Pumping facilities

Drainage water from the protected area behind the levees and floodwalls may be disposed by gravity flow during periods of low river flow, and by pumping during periods when gravity flow is restricted by backwater.

Preventive flooding in the low-lying protected areas requires consideration of the entire drainage system, which services the protected area. The efficient operation of pumping plants requires determination of the necessary water removal rate, the auxiliary storage facilities for minimising the pumping plant, and the location of the plant for an effective outlet. For protected areas in coastal plains that are located along rivers, effects of tides should also be taken into account.

4.9. Source control measures

A natural undeveloped watershed represents a spatially distributed runoff control system in which small volumes of the watershed storage are mobilised to slow down the rate of runoff following urbanisation. Small volume of natural storage are found in pervious soil, natural depressions, wetlands and floodplains, on vegetation and through evapo-transpiration.

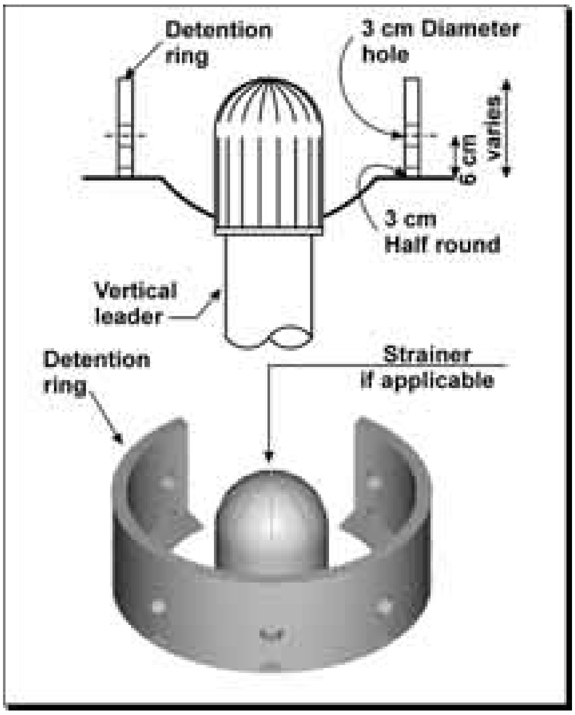
Urbanisation changes those natural hydrological mechanisms by:

- increasing the impermeability of land cover
- changing the land use
- removing the vegetation from the ground surface
- transforming natural watercourses into culverts and channels
- levelling off the irregular natural ground surface

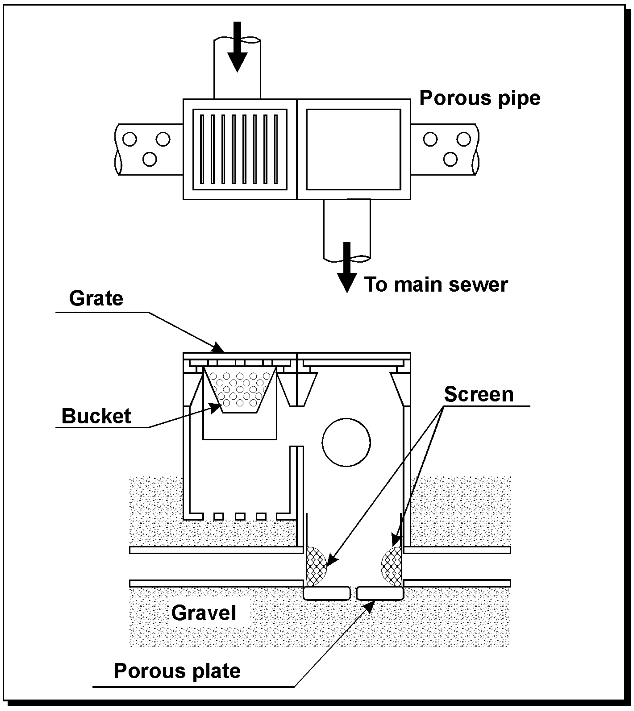
The concept of flooding and pollution source control introduces the measures that mimic the natural ways of attenuating and purifying runoff before it arrives at the problem area. The further upstream a control measure, the closer it is to the nature's way of a spatially distributed control system.

Source control measures do not eliminate the conventional structural techniques. Additional efforts in improving the methods of maintenance of the drainage system, as well as of the monitoring procedure of its behaviour are needed.

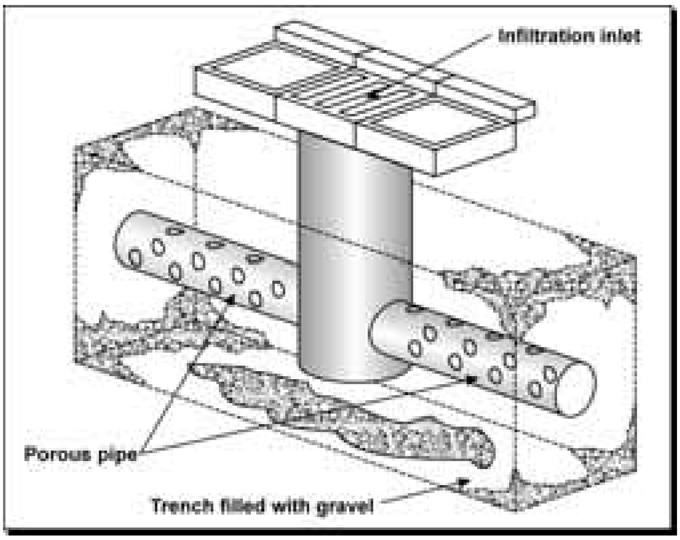
In urban conditions there is a number of low cost structural measures that proved to be very efficient in wet weather conditions. Planning and promoting these low cost structural measures can be classified as a non-structural activity, in which respect some typical urban source control measures are presented in figures 4.6 through 4.8.



(a) - Rooftop detention device

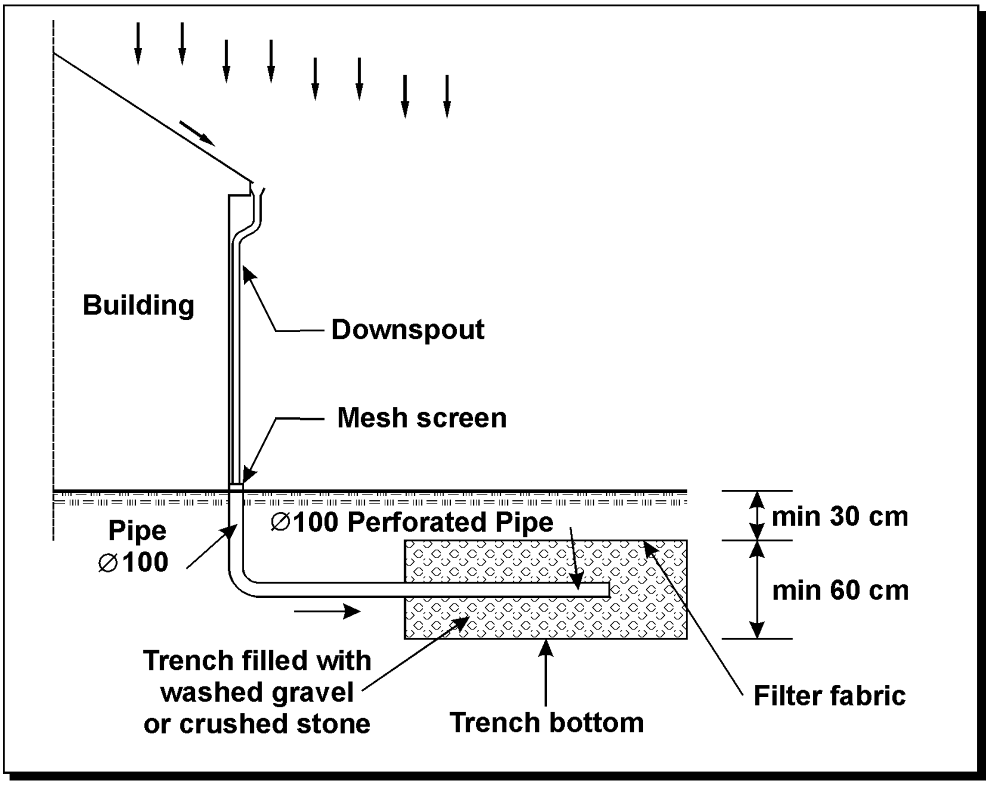


(b) - Infiltration inlet

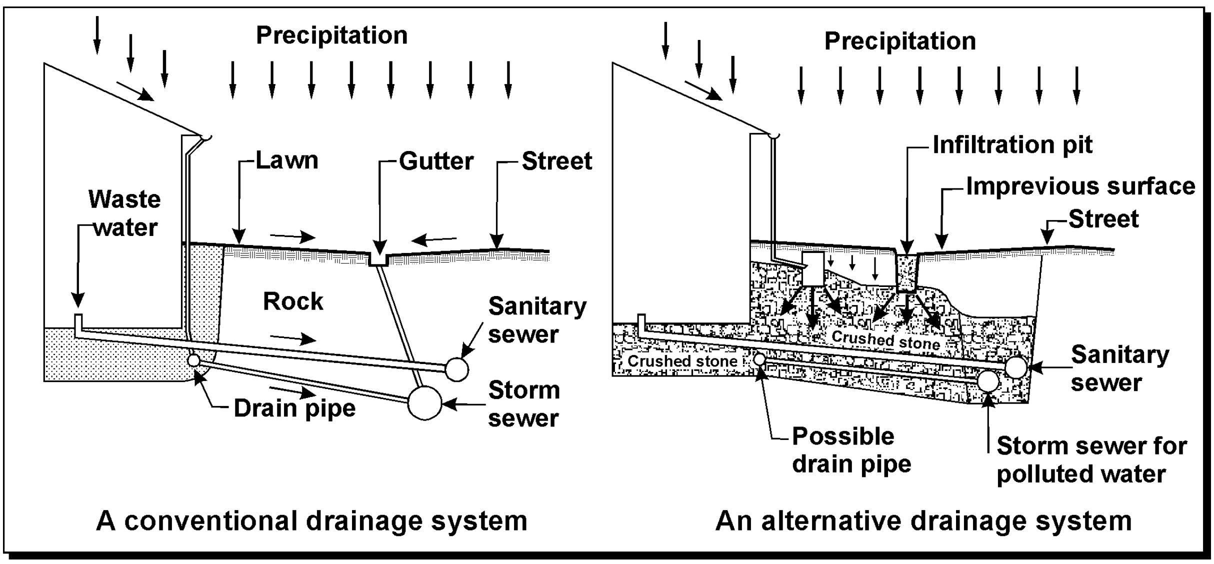


(c) – Infiltration trench

Fig. 4.6. Source control measures (IRTCUD-RCTS, 1998)

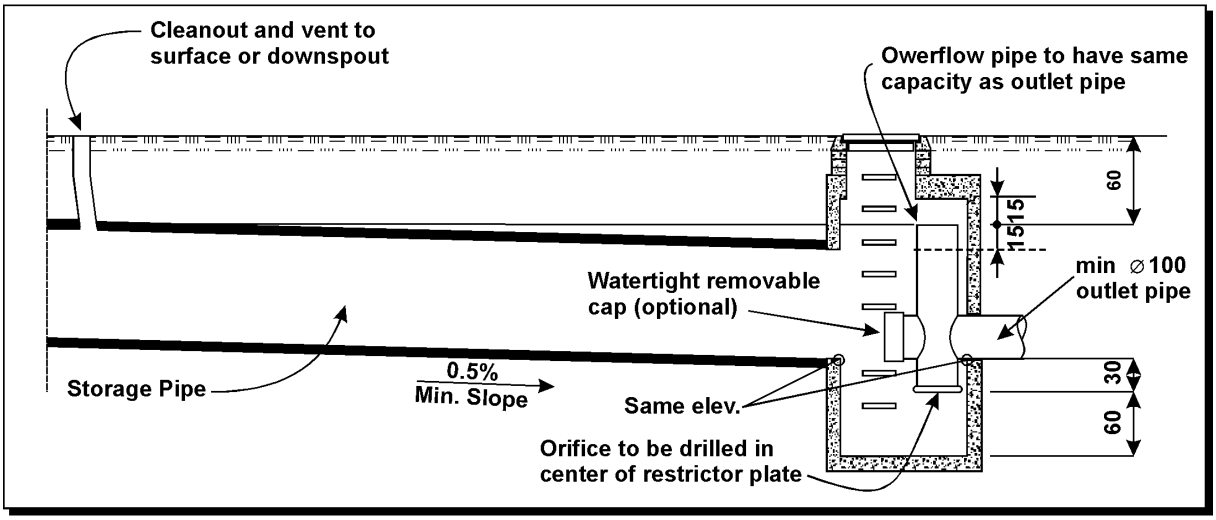


(a) - Infiltration trench

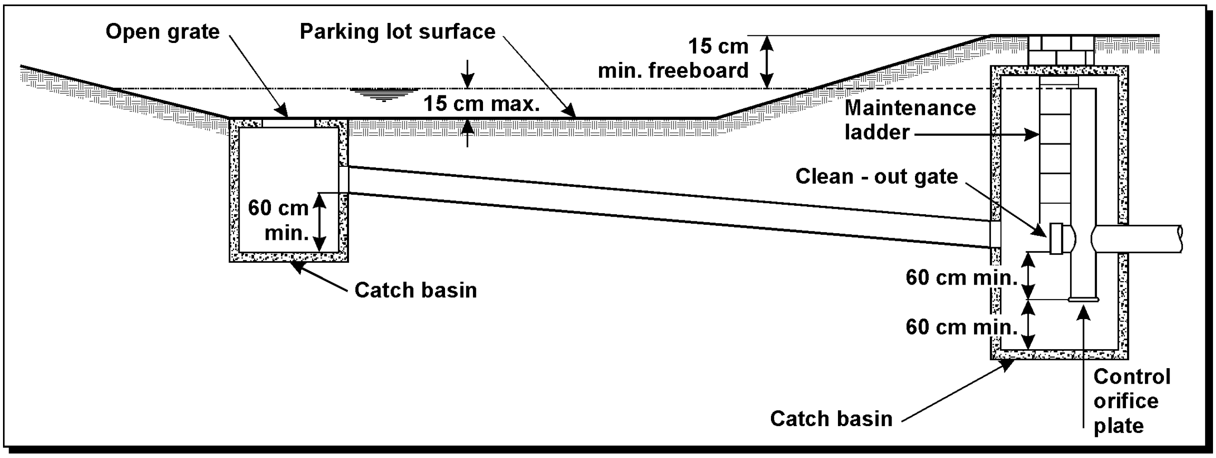


(b) - Infiltration trench

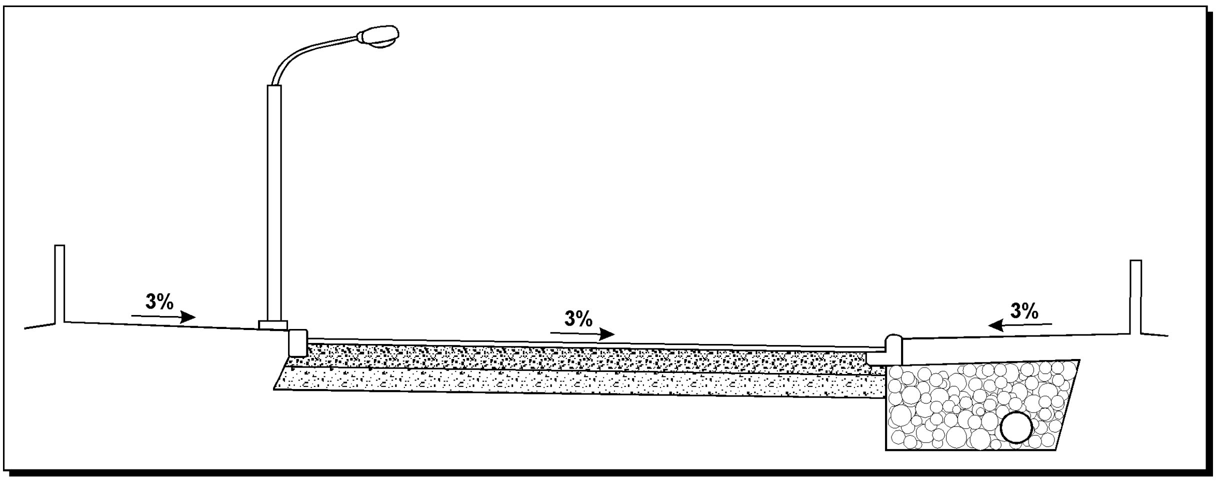
Fig. 4.7. Source control measures (Rowney A.C. et al., 1997)



(a) - Typical pipe storage



(b) - Typical parking lot ponding



(c) - Porous pavement

Fig.4.8. Source control measures

5. Flood forecasting and warning

5.1. Flood forecasting

People can prepare themselves to withstand flood damaging effects, since a flood is a disaster that can be forecast. A highly interdependent and fully co-ordinated system, composed of environmental monitoring, preparation of forecasts and warning, and their dissemination, needs to be established. Meteorologists and hydrologists can contribute to flood reduction at a specified point on a stream, by issuing:

- daily weather forecasts
- advance warning about potentially damaging conditions
- river stage forecasts
- flood forecasts (flow rates, time of occurrence, duration of the peak flows etc.)
- real-time weather data

The greatest success in flood forecasting occurs on large rivers. On the other hand, flash floods warnings associated with heavy thunderstorms in the cities are often very uncertain.

The forecast must be timely and accurate and must be combined with a community awareness program that teaches people what to do after receiving the warning. Forecasts may simply be a warning of danger, but as storm develops, more quantitative statements may be made on the storm progress.

A flood forecasting and warning centre must be established in the community or group of communities that have access to national meteorological and hydrologic data. Forecasting procedures must be developed and a communication system for dissemination of the predictions need to be established. Radar, satellite photographs, wind intensities and expected rainfall amounts all aid in providing ample warning time for flood coming.

An unified program needs to be developed that determines the procedures of forecasting, warning, communicating, mobilising and evacuating. The elements of that unified program are as follows:

- flood monitoring system, composed of the equipment, people and procedures, for rainfall and runoff data acquisition, performing flood analysis and making predictions
- risk mapping, predicting flows in areas that will be flooded and issuing warnings to institutions and communities involved
- public information policy to create awareness of flood problems and inform the public promptly
- emergency plan which identifies actions to be taken before, during and immediately after a flood
- flood management maintenance program, for updating, testing and monitoring flood conditions, warnings and emergency plans

5.2. Flood warning

Flood warning is the advanced notice that a flood may occur in the near future at a certain geographic point. Actions that are intended by warnings are warnings about potential dangers and warnings about imminent dangers that require emergency action.

A warning of a flood event implies an existing threat of danger to life and property and it invites responsive action to reduce threat.

A forecasting and warning system needs to be established, composed of six organisational sub-systems as follows:

- forecasting and warning centre (responsible for collection, evaluation and issuing of warning messages, responsible for monitoring the development of a flood threat and for offering advice and assistance to local emergency organisation; also responsible for training of staff)
- main emergency centre
- other emergency organisations (responsible for particular activities in their local areas such as door-to-door warning, search and rescue, evacuation of residents, moving valuables, clearing debris, registration and welfare of victims, co-ordination with: police, fire-fighters, medical and ambulance services, local utility companies)
- other organisations (Red Cross, churches, schools, universities, charity organisations, non governmental organisations, etc)
- mass media
- general public

The system status must be must be reviewed on a regular basis and, if necessary, constantly updated. An example of information on a flood warning system is given in fig. 5.1 Activities performed in flood forecasting and warning operation are shown in fig. 5.2

FLOOD WARNING SYSTEM

What is the purpose of the Flood Warning Program?	**To warn residents and agencies of impending floodwaters on major rivers in the region so they can take action and prepare themselves before serious flooding occurs. In most locations, the warning system usually provides at least 2 hours lead time before floodwaters reach damaging levels. This warning program does not take the place of individual and local groups making their own flood disaster plans.**
When does flooding and high water typically happen in the region?	**Floods most commonly occur from November through February during periods of heavy rainfall or rapid snowmelt. Historically, rivers in the region have floded in every month but August.**
How does the Flood Warning System operate?	**When floods are imminent local authorities activate Flood Warning Center. Operation of the Center is based on a four-phase warning system, issued independently for each river in the region. The thresholds for each phase are based on river gages which measure the flood flow and stage (flood depth) of the major rivers in various locations. Local flood management agency monitors the gages on a 24 hour basis, so that action can be taken depending on river conditions.**
What other information is available from the Flood Warning Center?	**During a flood, Center works closely with the national weather service to obtain forecast information used to make flood predictions. Close coordination occurs with local authorities responsible for emergenecy management in order to obtain up-to-date information about major flood problems, road closures, evaciuations and othetr emergency services. Coordination also occurs with the Army. Personnel at the Center are available to answer questions and help interpret gage readings during a flood event.**
What can you do to avoid flood disasters?	**Once a warning is issued by the national weather service or by the Center, residents should prepare for flooding. Becoming familiar with the relationship between upstream gage readings and local flood characteristics can help you prepare your individual flood emergency plan. Residents should keep informed of changing river conditions and make early preparation in case of major flooding.**
What does each Phase mean?	**At Phase I, local authorities are put on alert and preparation are made to open the Flood Warning Center. When a Phase II threshold is reached, the Flood Warning Center is opened. Staff at the Center monitor river gages and flood conditions around the clock, and gage information is updated hourly on a recorded massage placed at well publisized phone number. When Phase III threshold is reached, flood investigation crews are sent out to monitor flood control facilities, such as dikes and levees. Phase II-IV warnings are issued to police, fire department and the public through news media and in some neighborhoods through volunteer telephone trees.**

Fig. 5.1. Typical public information for a flood warning system

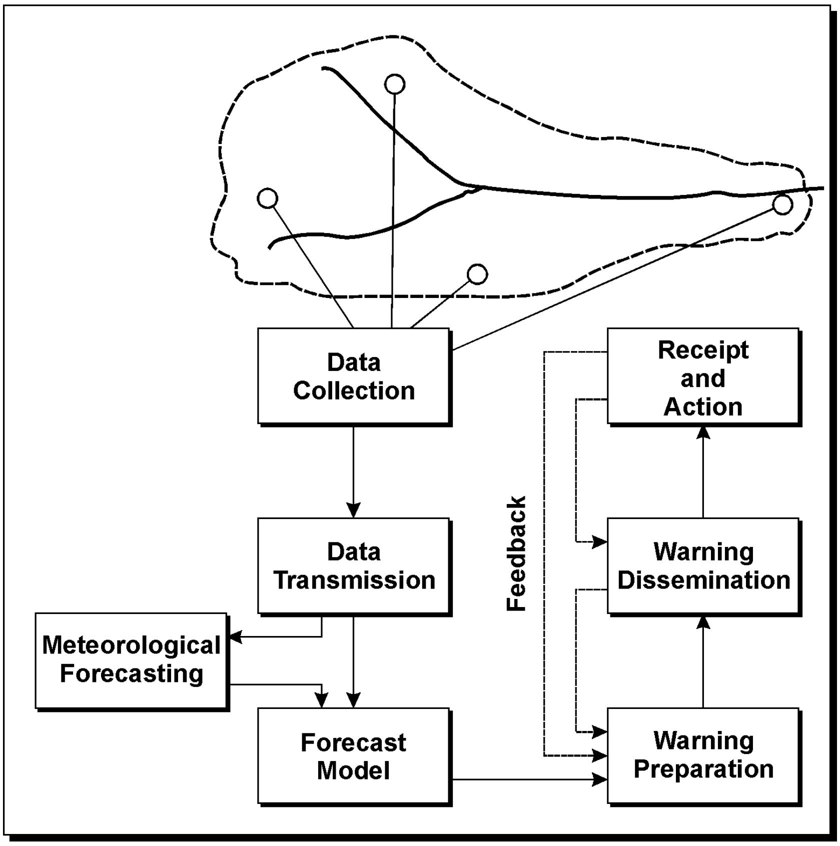


Fig. 5.2. Typical forecasting and warning activities (Rowney A. C. et al, 1997)

5.3. Communications

All parties involved in the process of flood mitigation must understand the necessity of communication and learn how to express themselves in such a way that their input can be inter-linked with the input of others. Communication should be considered with the following in mind:

- what is the objective, i.e. what do we want to achieve ?
- what format do we use, i.e. how do we present our warning ?
- who is the receiver (target audience), i.e. to whom are we addressing ourselves ?

It is clear that the receiver and not the sender of a message should determine its format. In mobilisation more then in any other aspect of flood management, it is essential to check that the message is received, understood and accepted.

Seven principles apply when communicating public information on flooding:

- confidence in the source must be built
- message must be confirming, not contradicting
- simplicity is required in phrasing the message
- repetition and consistency of warning build trust
- content of message must be relevant to the receiver's value system
- media that are respected by the audience should be used
- audience's habits, degree of literacy and knowledge should be taken into account

Wireless communication systems are preferable because telephone systems may fail during floods. Sophisticated and high-technology means of communication may not be always effective to reach the targeted people. Also, warnings can be disseminated in many traditional ways such as loudspeakers, flags, drums, fireworks, church bells, slogans, messengers, etc. Existing social networks such as scout groups, co-operatives and churches can also be used to communicate information.

5.4. Mobilisation

Mobilisation is a concentrated attempt to organise people toward a common goal and to activate their participation. The key factor for mobilisation is motivation, which makes training and appeals for participation worthwhile. Experience of a recent flood gives the strongest possible education and motivation for flood reduction. New communities are therefore more vulnerable because of their lower awareness.

Mobilisation can be political, institutional, cultural, religious, professional, ideological and ethnical. The purpose of mobilisation is to provide relief, food distribution, protection of embankment, maintenance of law and order, community shelters, dissemination of flood warning, distribution of food stock, protection of properties, evacuation, drinking water supply, etc.

A large number of tasks is performed at different levels during the time of mobilisation (fig 5.3). Involvement of the population only in the physical work of implementing a task can hardly be considered as community participation. Active participation includes involvement in conceptualisation of local needs, setting and prioritising goals, lobbying and negotiating, planning objectives and programs, mobilising and raising awareness, activating organisational structures, training, decision-making, engaging in administration, supervision of works, contributing cash, participating in the appraisal of work and finally, redefinition of needs.

Communities that introduce flood management do not always constitute a single community. Inter-community co-ordination may require the development of committees and working groups, based on good communication and adequate representation.

5.5. Evacuation

The key to a successful evacuation program is an affective flood warning system. Evacuation is a short-term measure but if is carried out in the post-flood period, it must be accompanied with relief and rehabilitation measures.

Where warning time permits, evacuation is often the most successful response to a threat. To be effective, evacuation requires careful planning. Before any evacuation begins, care must be taken to ensure that there is time to complete it and that all members of the community are able to leave assisted. Individual evacuation plans must be prepared for institutions such as schools, hospitals and day-care centres. Responsibilities and activities of civil defence organisations need to be clearly defined by legislation.

The choice of evacuation routes is important. Routes should be linked to alternative transportation corridors and free of objects that may be easily damaged. Evacuation plans should include maps showing all clearly designated evacuation routes.

It must be clear whether evacuation is mandatory, and what exceptions can be made.

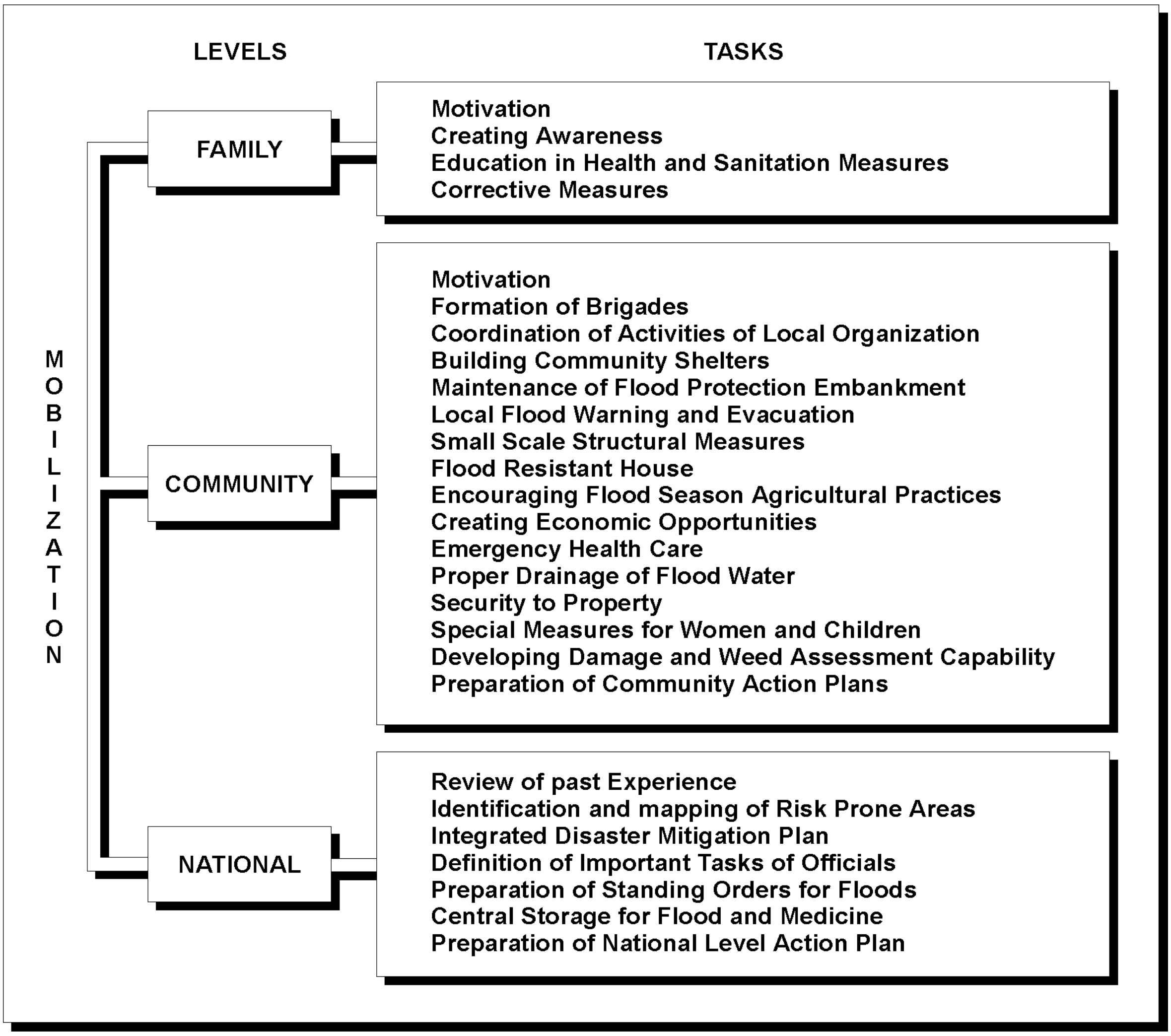


Fig. 5.3. Mobilisation tasks at different levels (UNESCO, 1995)

6. Disaster management

6.1. Vulnerability and risk

Natural disasters are catastrophic events triggered by natural hazards, causing widespread injury and damage. Disasters overpower local resources and require considerable support outside of the local community.

Vulnerability of population is the root cause of disasters. Vulnerability is a potential loss of people and goods as a consequence of a damaging phenomenon, social and economic conditions and perceptions, institutions and policies of the society. Hence, there is no such thing as an entirely natural disaster. (UNESCO, 1995)

Vulnerability rises and falls with time and circumstance, and is treated as a change process. On the other hand, risk is the probability of a damaging event of a certain magnitude, at a particular place, and within a particular period of time. Therefore, calculated risk is static while vulnerability is dynamic.

6.2. Development planning for disaster reduction

Natural disaster impact on development may be direct physical destruction of infrastructure, loss of cash, loss of crops and animal stock, destruction of social infrastructure, and the resulting shortage of materials and equipment, shortage of labor, and depletion of development projects.

In traditional terms, development meant economic growth. In modern terms, development is separated from growth in order to make distinction between the process of growing, defined by growth, and the process of improving and getting better, defined by development.

Development, in modern terms, includes economic aspects of income, trade and production growth statistics, population numbers and distribution, life expectancy, the quality of life as indicated by literacy, supply of water and energy, sanitation, distribution of medical services and access to education. Development also means good government, efficiency, accountability, human rights, equal resource distribution between sectors and between social groups, and environmentally responsible sustainability.

There are countless development projects, programs and reports that ignore evaluation of the above development attributes with respect to disaster potential and disaster recurrence. The reason for this is the institutionalised separation that exists mostly in all governments nowadays. Commonly, special offices, agencies, departments or units, separated from the management of development have been introduced, focusing on disaster effects and only on short-term rehabilitation.

The conventional approach fails to take account of crucial political, institutional, social, cultural, economic and physical factors that are the root causes of vulnerability to natural disasters.

The contemporary approach assumes that disaster management must be shared by all sectors and activities that have any connection with development and change at all levels of policy making. In this approach, vulnerability is reduced by integrating measures for survival, rehabilitation and reconstruction within development planning.

Prerequisites for development planning for disaster reduction are as follows:

- acceptance that disasters can happen
- perceptions of causes, incidence and effects of environmental hazards
- integration of perceptions in a development policy, meaning preparation of development guidelines for disaster reduction
- evaluation of all development proposals against development guidelines

Development planning determines where people and structures are located, what material and methods are used in construction, how topography is altered, what emergency systems are provided, what resource reserves are maintained, what communication and transportation systems are available.

The planning process may be represented as a cycle to emphasise the need for continual development, as opposed to a non-recurring linear process.

Plans are tested through simulation exercises and public drills. However, the real test of protective measures will be an actual flood situation. Following such events there is a requirement for accurate information on the impact of the event in terms of deaths, injuries and damage to property.

The people are organised at various levels of the community, in non-governmental, formal and non-formal organisations. It is only through their co-ordinated efforts that disasters reduction programs will have a chance to be successful.

6.3. Risk assessment

Risk assessment is a diagnostic process of balancing known risks against available resources. The process starts with vulnerability analysis and hazard mapping.

Hazard mapping reveals the areas that are particularly susceptible to floods. Information is needed both in spatial and temporal terms and include location, frequency of occurrence, duration and severity. When this information becomes available it is possible to develop contours which indicate the severity of risk.

Vulnerability assessment determines the vulnerability of elements at risk-persons or property exposure to the hazards which has been mapped. This analysis is site-specific.

Analysis of resources, often termed as assessment of capacities, addresses community coping mechanisms that help people to survive, local leaders and institutions, community facilities, cash, credit, the location and quantity of goods that may be needed in an emergency.

Designing levels of acceptable risk is essentially a political process. Political leaders determine priorities and such decisions are always difficult, concerning what is essential, acceptable, affordable or politically expedient. Defining levels of acceptable risk should be based on both the quantitative analysis, such as cost of flood damage evaluation, and on qualitative multi-attribute analysis. For more detailed explanation of vulnerability and risk issues the reader is referred to the publication " Fighting Floods in Cities". prepared by UNESCO in 1995.

6.4. Flood fighting legislation

Flood fighting means undertaking emergency measures at times of storm and flood surge. Effective flood fighting is based on well-planned and co-ordinated activities that need to be formalized through local and state legislation.

Legislation for disaster preparedness should define the status of a flood fighting corps responsible for planning and conducting flood fighting operations in flood-prone settlements. State and local regulations should cover the following items:

- areas of responsibility
- duties
- patrols and watches along dikes
- communication and transportation facilities
- procedures for operating water works
- mobilisation procedure
- co-operation procedure
- supplies and depots with equipment and material needed for operation
- identification of the existing flood management capabilities of the communities (status of warning system, levees that provide only partial protection, etc.)
- initiating process for a public education program
- alternative plans

6.5. Flood damage assessment

The primary benefit derived from flood management, expressed in economic terms, are those arising from the reduction of flood damage. Cost saving due to reduction of flood damage must be compared with the cost of implementing flood management measures, making flood damage estimate the most important component of a flood appraisal process.

Total flood damages are referred to as tangible (direct and indirect) and intangible ones. In the absence of actual data on the damages, generalised curves based on synthetic data are use to assess the potential direct damage of residential, commercial, industrial and other property. Indirect damages are usually estimated as a proportion of direct damages.

In general, the following procedure needs to be satisfied for assessing potential damages, whereas actual damages are estimated on the basis of a field survey:

- identification of potential damage areas, according to the physical characteristics of the area such as land use, topography, drainage area, outfall system and the capacity of the existing stormwater drainage system. Maps are usually prepared to visualise the results of the identification process.
- selection of damage categories, which are considered appropriate for each damage area under investigation. Those are: public and private clean-up, structural and vehicular damage, damage of contents, traffic related losses and tax revenue losses.
- developing unit cost relationships for various damage categories
- evaluation of the hydraulic conditions such as the volume of pounding areas, street conveyance capacities, storm sewer capacities and inlet capacities
- determination of the extent of flooding expected for several storms of different frequencies of occurrence
- estimating damages for the "do-nothing" alternative for different storm frequencies
- plotting corresponding damages versus probability, in or to measure the area under the curve which represents the average annual damage (base-line damage)
- estimating residual damages in a similar manner, for various alternative plans under study

- calculating annual benefit as the difference between the estimated annual damage before and after the capital improvement.

The estimated annual benefit may be then used in the cost-benefit analysis.

6.6. Flood relief measures

Flood relief measures are usually provided by the government and include financial assistance to help local authorities. The aim of flood relief is to overcome immediate personal hardships and distress, as well as to enable essential repair of houses and infrastructure. These measures do little in reducing the impact of future flood losses.

Non-government organisations can also provide substantial assistance as well, particularly in developing countries.

7. Flood proofing

7.1. General

Decreasing susceptibility to flood damage is achieved by keeping water away from the structure, keeping water out of structures and keeping structures away from water. Flood proofing is the use of permanent, contingent or emergency techniques to either prevent flood waters from reaching buildings and infrastructure facilities, or to minimise the damage from water that does get in.

The danger of flood water is associated with a number of different parameters creating different types of clearly recognisable hazards. These parameters are: depth of water, duration of inundation, velocity of water flow, rate of rise of river level, frequency of occurrence and critical time of rainfall.

Vulnerability analysis in flood-prone areas is carried out separately for different building types and for infrastructure, such as roads and railway systems, bridges, water and electricity supply systems, sewerage systems etc.

Flood proofing is not a replacement for land use control. It reduces substantially post-flood clean-up operations.

7.2. Flood proofing in buildings

Vulnerability analysis of buildings is divided upon the type of building (conventional, modern and traditional), and includes evaluation of the resistance to the force of water (hydrostatic load, uplift, hydrodynamic load) and of the changes of material characteristics when immersed in water (quality of mortar, presence of fine sands and expansive clay at foundations).

Public buildings that are used as shelters must have floor space above the expected flood level. This can be done by constructing the building on natural or artificial high grounds, by placing the building on columns and stilts or by providing access from outside via staircase to the upper floors (fig 7.1). In areas where floodwaters are shallow and slow moving, temporary barriers composed of sand bags may be used to protect individual buildings.

7.3. Flood proofing of infrastructure

Flood damage to infrastructure elements can be caused by direct water forces, by erosion, or by a combination of both.

Road and railways may be damaged easily by water scouring in two ways: the foundation can be washed away and the construction itself can be compromised. A vulnerable part of railway system is the compacted bed on which the tracks are laid.

Insufficient openings in bridges will lead to higher water levels upstream. The river bed upstream and downstream of the bridge should be consolidated by erosion prevention measures. Most techniques that prevent river bed erosion fix the stream bed by stabilising the embankment (by means of masonry or vegetation).

The physical damage of water supply systems is concentrated on the intake points and the locations where the main supply crosses riverbeds. The quality of potable water in conduits is affected by silting and pollution. The problem of water contamination can be easily solved by constructing the pipes above the flood level. The same principle applies to electrical supplies, sewer pipes and telephone lines. Elevation above flood level secures the continuity of operation of those systems.

The application of elevated walkways greatly improves accessibility between houses and important public buildings, such as flood shelters. For proper functioning, these walkways have to be raised above the average flood level.

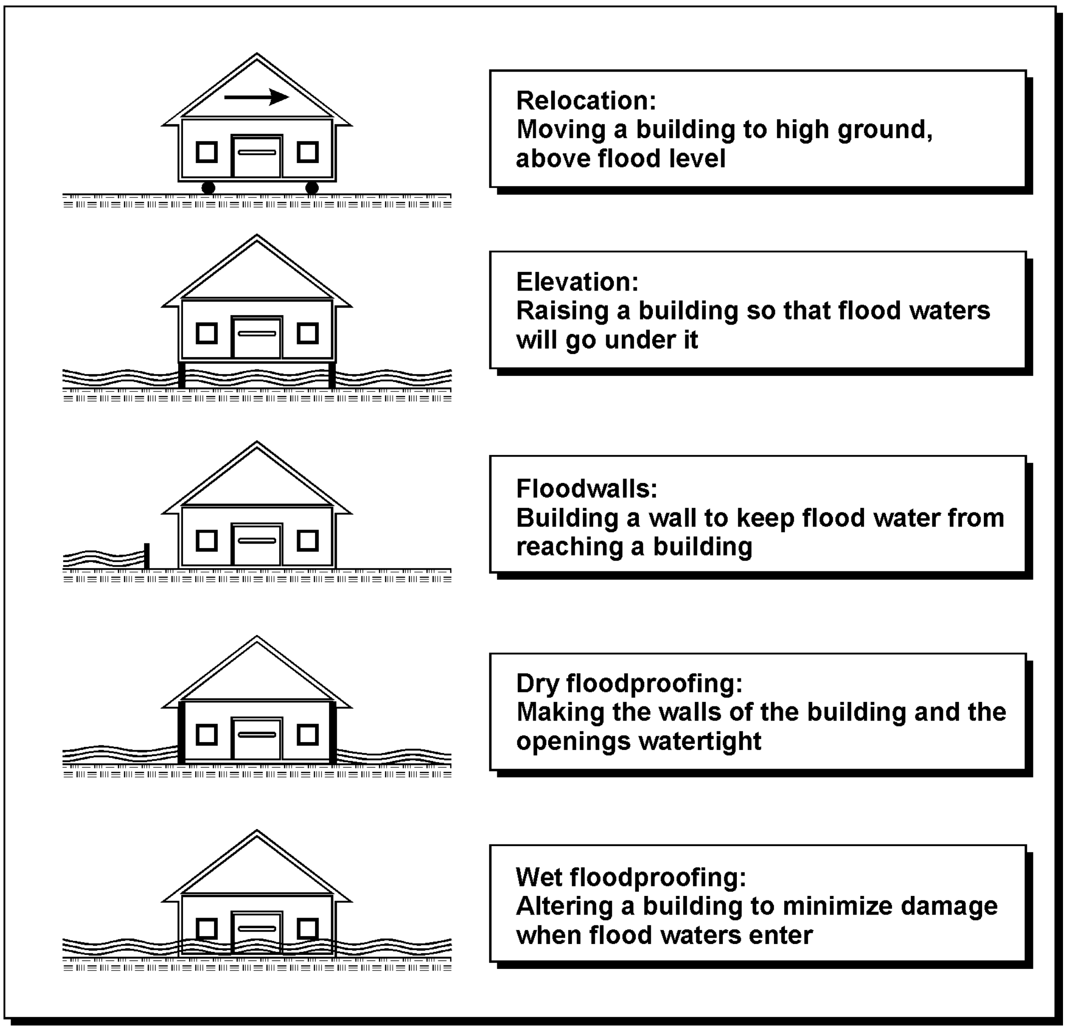


Fig. 7.1. Examples of flood proofing (UNESCO, 1995)

8. Legal and institutional issues

8.1. Role of governments

It is universally accepted that the national government with some degree of shared responsibility with regional or local authorities must bear the main responsibilities for managing disasters. The organisational structure needed for managing disasters is best founded on the existing government structure. It has been proven rather ineffective to create ad hoc arrangements for disaster purposes, as compared to a comprehensive body of legislation that should be enacted.

One of the roles of government in formulating a flood policy is to draw attention to the hazards of life, health and property in those areas where flooding has occurred and will occur again.

Master planning tasks are usually shared between various levels of government having different authority and responsibility. State government usually develop technical guidelines, designate which watersheds are to be studied, prepare model ordinances, provide technical assistance to local agencies, and provide financial assistance.

The county government prepares and adopts stormwater management plans for each watershed. A watershed advisory committee, at the county level, includes a representative of each affected municipality.

The municipal government adopts and implements ordinances for regulating zoning, subdivision of land, building construction, grading and site preparation, consistent with adopted watershed plans.

Governments in large cities and urban areas establish goals, policies and program development objectives. Ideally, they should be based upon the consideration of the needs in entire watersheds. There should be some accountability to a superior jurisdiction, often a state agency, to assure some degree of compatibility among areas where there may be consequential effects of one's action upon another.

The dissemination of information to the public is another important governmental task. Since floods are recurrent phenomena, authorities play an important role in keeping the collective memory on these events alive.

The local government is the focal point for urban stormwater management. It is the local government that best understands and must be responsive to the needs, desires, and requests of the local public. The local government is better informed than others are concerning planned urban growth, community goals, life-styles, and the financial programs that the local public can be expected to support. A major administrative problem may happen at the local government level when local political boundaries do not coincide with natural catchment boundaries.

The choice of institutional structure is less important than the requirement of providing a co-ordinated approach on a catchment basis.

The variety of flood mitigation measures should not be an obstacle for local governments to sort out the required activities and measures in time and among various institutions. At least four principal documents should be prepared and regularly updated, such as:

(1) *An urban stormwater drainage, flood and pollution control plan*, based on the catchment principle and environmental sustainability, aiming towards controlling future development or solving already existing problems

(2) *A flood preparedness program*, which determines what needs to be done before flooding occurs, featuring programs for raising public awareness, regulating land use and development policies, flood forecasting and warning, institutional strengthening, emergency situation simulation and training, etc.

(3) *A flood disaster plan*, which determines emergency response measures that need to be executed when flooding occurs and during its action, including mobilisation and evacuation, search and rescue co-ordination, medical care, food and supply management, information dissemination maintaining communication, etc.

(4) *A flood recovery program,* which includes measures and activities that need to be offered to or may be used by the public after flooding is over, such as insurance, financial assistance, rehabilitation measures, health and shelter programs, employment programs, etc.

All four documents should have organisation schemes and responsibility matrices, as well as allocation plans of needed resources, particularly including financial and human resources. It is also advisable to prepare an umbrella-type document, known as " A Guide for Public Officials", which would enable unification of the interpretation of local drainage and flood control policies. Among those listed documents the first two are very site-specific and are therefore expected to be fully supported financially, institutionally and legally by local governments. The other two documents require co-ordination with national flood mitigation programs, and cannot be planned or implemented without certain outside assistance.

Non-governmental organisations may also make important contributions in relief, rehabilitation and reconstruction, as well as in raising public awareness and providing training.

One of the principal questions that comes up in preparing a flood preparedness program concerns the number and sizes of tasks into which the work should be divided. In order to illustrate the work needed in developing such a program, an example is given in table 8.1 (UNESCO, 1995)

Table 8.1 (UNESCO, 1995)

Task No.	Description
1:	Collect Meteorological Data
2:	Collect Hydrological Data
3:	Design Flood Scenarios
4:	Select Scenarios for Planning
5:	Identify Evacuation Areas
6:	Identify Numbers and Characteristics of Evacuees
7:	Identify Time Requirements for Evacuation
8:	Evaluate Potential Flood Damage
9:	Identify Available Resources
10:	Identify Emergency Response Tasks
11:	Identify Threshold Flood Value
12:	Existing Flood Threat Recognition System
13:	Emergency Plan
14:	Evaluate Existing Mass Warning Arrangements
15:	Design Any Needed Site-Specific Warning Systems
16:	Design Public Information Program
17:	Formulate Maintenance Program
18:	Formulate Implementation Program
19:	Prepare Documentation

8.2. Role of local agencies

The institutional arrangements with respect to responsibilities and control of urban waters are typically fragmented in the cites all around the world. One institution is responsible for municipal wastewater collection and treatment, another for land drainage and flood control, and yet another for the drainage of highways and urban traffic arteries. This fragmentation and overlapping of authority results in a dilution of powers, brings potential conflicting interests and prevents the application of integral watershed management.

The overall co-ordination of flood management activities should be entrusted to one leading organisation that assumes responsibility for legal, administrative and financial matters. The organisation should also have the necessary technical and institutional expertise for the setting of standards, provision of technical advice and to ensure that the optimum mixture of both structural and non-structural measures is applied.

Stormwater management, including design and design approval, should be a responsibility of the department of public works. Construction is carried out by private contractors under contracts to the local jurisdiction or land developers. Inspection of construction is performed by the local public works department as well. The operation and maintenance of publicly-owned facilities comes under the department of street and sewers.

Sewer agencies are primarily responsible for the sanitary sewer system and wastewater treatment facilities. Because there are combined sewers in some areas, those agencies also may have stormwater management responsibilities. Besides runoff control, many agencies have responsibility for protection and development of water supplies, recreation, conservation and protection of natural resources, wildlife protection, navigation, general enhancement of urban environment. Combining stormwater control facilities with parks and recreational developments, green-ways, forest and wildlife preserves, groundwater recharge is also possible.

Large metropolitan areas require an area-wide approach to enhance and supplement the capabilities and activities of local governments. The public works department should review and approve all stormwater drainage plans and subsequently inspect construction for conformity with approved plans.

8.3. Special stormwater management agency

Watershed areas often extend over more than one community. Many of the existing and potential physical problems may impact two or more local jurisdictions. In such situations, all needed planning, design, financing, co-ordination and regulatory functions may be directed by an agency established by the state government on behalf of the local governments. This agency may be organised for the single purpose of stormwater management, or it may have multiple functions, such as wastewater disposal and flood control.

Generally, a stormwater control agency may perform one or more of the following activities:

- monitoring, data acquisition and processing
- planning
- policy co-ordination
- policy making
- financing
- construction
- operation
- maintenance
- updating databases

The dominant approach these days toward providing stormwater control through independent agency is the single-purpose agency. Once the decision to create an area-wide organisation has been made, the single purpose rather than the multiple purpose agency is preferable.

A drainage agency's responsibility needs to be defined in terms of a specific geographical area, known as the catchbasin, not coinciding with existing municipal boundaries. The agency's programs are subject to approval by the local government. However, countries and cities that adopt non-structural measures as the primary means of their flood management program may encounter difficulties in the policy formulation stage, and in the implementation stage as well. It has been proved successful in practice that multi-agency, multi-discipline, committees that review and update guidelines would be useful in resolving the problems of efficiency and unification of proposed measures.

The framework for drainage agency activities may be summarised as follows:

- serving as a central management organisation
- co-ordinating drainage activities of local agencies related to the management of soil, water and vegetation resources, to effect the best possible results on the area-wide basis
- determining final policy, after consulting the local jurisdictions
- being responsible for the maintenance of major outfalls for storm drainage systems under their jurisdiction

8.4. Legislation

Legislation that needs to be enacted in order to provide legal basis for implementation of stormwater directives and programs should include:

- provisions for stormwater pollution control
- provisions for temporary storage of excess runoff
- provisions for disconnection of roof drains from sanitary sewers - provisions for floodplain zoning and regulation
- provisions for flood-proofing of buildings
- provisions for development of a compatible and co-ordinated stormwater drainage system.
- provisions for implementing the source control

The extent to which the basin-wide management approach can be applied will depend largely on the nature of the ownership of land (government or private) and the authority that can be imposed by the drainage agency over development.

Experience has shown that voluntary regulation of the development on floodplains does not provide good results in either urban or rural situations. It is necessary to have legislative powers to achieve management goals. In some countries that operate under the English system of common law, flood organisation is not protected against claims for damage resulting from their issuing advice or granting approval for flood-liable areas. The issue of whether to provide employees the legal immunity against claims for damages or not, is still open.

9. Direct public involvement

9.1. Social effects of flooding

The social disruption caused by floods is one of the most significant effect to be considered. Other consequences are of medical nature and are generated by the trauma of flooding and the destruction of essential services. Social problems include:

- dislocation and disruption of transport, public and commercial services, food supply and medical services
- public health and housing of evacuees in unsanitary conditions
- emergency preparedness in activating food and power supplies, medical services and transportation
- care of disadvantaged social groups
- loss of employment
- temporary accommodation
- effects of involuntary relocation of flood affected residents
- safety aspects

9.2. Public participation

Public and community participation are two important elements of an effective social mobilisation and public awareness program. This program should be community-specific, based on assessment of information needed, integrated with existing disaster warning and response systems, focused towards information on prevention, mitigation and long-term recovery, established as on-going process, and addressed towards the most vulnerable people.

Co-ordination between the community agencies, representing its citizens and the municipal authorities is essential. Specific tasks are vested with the community, while others belong to the domain of municipal authority, as described in chapter 8 of these Guidelines. The capacity of the community determines how much should be executed by outsiders.

Once co-ordination is established, all concerned need to develop knowledge and skills that can reduce the possibility of damage and death during floods. The practice of learning while doing is accepted in community participation, but formal training programs are preferable.

The following participants may be expected to take part:

(i) at community level

- local leaders
- voluntary fire brigade
- Red Cross/Crescent societies

- various community groups (youth organisations, environmental groups, etc.)
- religious organisations
- local builders and craftsmen
- housing cooperatives
- volunteers

(ii) in local government

- town or district planners
- architects and engineers
- building inspectors
- contractors
- public health officers
- medical staff
- public utility staff
- social workers
- media
- police
- army

(iii) at national level

- politicians and lawmakers
- civil servants
- mapping agencies
- development planners
- university faculty
- research institutes
- professional organisations
- trade unions
- non-governmental organisations
- media
- banks
- insurance companies
- hydro-meteorological services

(iv) at international level

- international banks
- relief agencies
- investors
- multinational corporations
- charity organisations

Community participation should be ensured in several domains such as:

- establishing own goals and priorities
- clarifying the problems
- public debating on proposed solutions
- monitoring the process of master planning on the basis of two-way communication
- physical survey of the area and its structures

- surveillance (including data acquisition)
- socio-economic survey, followed by mapping the socio-economic conditions of the community
- administrative and managerial skills of the community leadership
- providing contributions in kind such as labor, building material and transport
- identification of local community requirements and resource mobilisation based of self-assessment of each community. Those are items such as sand, bags, labor, pumps, boats, generators, funding contributions etc.

The objective is to create a partnership between the government and the people so that disaster preparedness is recognized as a joint responsibility

9.3. Public information and education

Every community in a flood-prone environment should be "flood-adapted", based on acceptance of the fact that living in a floodplain must inevitably bring the consequences of sporadic flooding.

One of the most useful activities of is an active participation of general public, officials and planners in information campaign, tailored to the needs of the community. A variety of media can be used, such as local radio and TV stations, Internet, newspapers, pamphlets and posters, schools and exhibitions. In developing countries, use of warning boards and different illustration, placed or distributed at local community centres or main road intersection, may prove to be the most efficient communication medium.

The messages are more easily believed when they are repeated on regular basis and transferred to community members through channels they trust. It has been recognized that by disseminating the risk information, confidence and a sense of security among the people is established.

The following messages should be included:

- what is the hazard
- how will the hazard affect the community
- what are the vulnerabilities of the settlement
- how can the vulnerabilities be reduced
- what damages can be expected
- what actions are to be taken immediately after disaster
- how to act in response to flood warning
- how can the residents protect themselves in a disaster
- how to get safe drinking water if supplies are interrupted
- how to access help
- where are buildings in less vulnerable locations
- where are alternative food supplies

Dissemination of public information on a regular basis is very important. General public should also be knowledgeable on how taxes and other local revenues are allocated and used to provide solutions to problems associated with urban flooding.

One of the most convenient and efficient ways in communicating with public is through public workshops and hearings. When date, location and subject become known, organisers should request written comments to be submitted on a comment form developed for that occasion and distributed through public libraries, agencies involved in organisation or at the hearing itself. Written comments in other formats should be accepted as well. After considering all written comments and testimony from the hearings, a final decision can be made by the authorities. People expressing interest in being informed should receive a copy of the final decision by mail.

Another way of communicating with the public is by using contemporary electronic means such as electronic bulletin board, mail box and web site with a page on frequently asked questions (FAQs). Users of open electronic communication means should agree to abide by the rules of electronic communication means, meaning not to use profanity, not to advertise or promote any product or services, and not to change the purpose of discussion.

One of the examples of communicating with the local people is shown on a leaflet hereafter. Flooding fact sheet for individuals can be disseminated through different media, but can be incorporated in the local educational system as well.

Floods do not necessarily need to have disastrous consequences. Local flooding sometimes only disturbs traffic or maintains water for several days in basements. However, in many homes the water does not just stay in the basement. Urban surface water can be a nuisance to the local community. This fact may be used to attract the local people to support a proposed stormwater drainage program. An example of a public message is presented in fig. 9.1

Fig. 9.1. Example of a public message (King County, 1986)

FLOODING FACT SHEET FOR INDIVIDUALS

Before flood

Find out if you live in a flood-prone area from your local authorities responsible for emergency situations. Ask whether your property is above or below the flood stage level and learn about the history of flooding for your region.

Learn flood warning signs and your community alert signals.

If you live in a frequently flooded area, stockpile emergency building meterials, such as plywood, plastic sheeting, lumber nails, hammer and saw, shovels and sandbags.

Have check valves installed in building sewer traps to prevent flood water from backing up in sewer drains. As a last resort, use large corks and stoppers to plug showers, tubs, or basins.

Plan and practice an evacuation route. Contact the local emergency management office for a copy of the community flood evacuation plan. This plan should include information on the safest routes to shelters. Individuals living in flash flood areas should have several alternative evacuation routes.

Have disaster supplies on hand, such as flashlights, battery-operated radio, extra batteries, first aid kit, emergency food and water, sturdy shoes, non-electric can opener, essential medicines, cash and credit cards.

Develop an emergrency communication plan. In case family members are separated from one another during floods, have a plan for getting back togather. Ask an out-of-community relative or friend to serve as the "family contact". Make sure everyone in the family knows the name, address, and phone number of the contact person.

Teach all family members how and when to turn off gas, electricity, and water. Teach children how and when to call police, fire department, and which radio station to tune on for emergency information.

During a flood watch

Listen to a battery-operated radio for the latest storm information and be prepared to evacuate.

Fill bathtubs, sinks, and jugs with clean water in case water becomes contaminated.

Move valuable household possessions to the upper floors or to safe ground if time permits.

If you are instructed to do so by local authorities, turn off all utilities at the main switch and close the main gas valve.

(TURN OVER) →

During a flood	**If indoors, turn on battery-operated radio, get the latest information, and if told to leave, do so immediately.** **If outdoors, climb to high ground, stay there, and avoid walking through any floodwater, since even water 15 cm deep can sweep you off your feet.** **If in a car, turn around and go another way. However, if your car stalls, abandon it immediately and climb to higher ground.**
During an evacuation	**If advise to evacuate, do so immediately by following recommended evacuation routes. Shortcuts may be blocked. Evacuation is much simpler and safer before flood waters become too deep.**
After flood	**Flood dangers do not end when the water begins to recede. Listen to a radio and do not return home until authorities indicate it is safe to do so.** **Remember to help your neighbors who may require special assistance such as infants, elderly people, and people with disabilities.** **When entering buildings inspect foundations for cracks or other damage. Examine walls, floors, doors and windows to make sure the building is not in danger of collapsing. Watch for loose plaster and ceilings that could fall. Take pictures of the damage.** **Watch out for animals, especially poisonous snakes, that may have come into your home with the flood waters.** **Look for fire hazards, such as broken or leaking gas lines, flooded electrical circuits, submerged electrical appliances, flammable and explosive materials coming from upstream.** **Throw away food, including canned goods, that has come in contact with flood waters.** **Pump out flooded basements gradually (about one-third of the water per day) to avoid structural damage.** **Service damaged septic tanks, cesspools, pits, and leaching systems as soon as possible. Damaged sewage systems are health hazards.**
Inspecting utilities in a damaged home	**Check for gas leaks. If you smell gas or hear blowing or hissing noise, open a window and quickly leave the building. Turn off the gas at the outside main valve if you can. If you turn off the gas for any reason, it must be turned back on by a professional.** **Look for electrical system damage. If you see sparks or broken or frayed wires, or if you smell hot insulation, turn off the electricity at the main fuse box or circuit breaker. If you have to step in water to get to the fuse box or circuit breaker, call an electrician for advice.** **Check for sewage and water lines damage. If you suspect sewage lines are damaged avoid using the toilets and call a plumber. If water pipes are damaged, contact the water company and avoid the water from the tap.**

10. Financing flood management

10.1. Traditional financing

Traditionally, municipal utilities include water supply, irrigation, sanitary sewerage, solid waste, gas, and electricity. All depend on a physical "system" to deliver a service or commodity and the cost of providing services is distributed among customers. Each utility should be able to exist self-sufficiently by charging for the service or commodity it provides, and should function without subsidy from municipal taxes. The prerequisites for self-sufficiency are a suitable rate structure to be developed and bills to be regularly and fully collected. Charges to individual ratepayers must be fair and reasonable in terms of the value of the service provided. Clients who place similar demands on the utility operation should be charged similar amounts.

Since the facilities for the management of stormwater are essential parts of the urban infrastructure and as such contribute substantially to the economic well-being of the entire community, therefore the most reasonable way of financing capital improvement is from general tax revenues and street improvement funds. The decision on how to utilize a capital improvement fund is made within the political process of the local government.

Public officials usually ask for an approval from the residents, property owners and voters, expressed in forms of referenda, consent or public hearing testimony on proposed capital improvements.

However, any acceleration of current flood management requires an increase in the provision of public funding at a time when there may be increasing pressures for public funding in other communal areas. There is always competition between public systems that provide service to people, such as transport, health care, education, etc. Additional mechanisms are needed for funding flood protection.

10.2. User charge concept of financing

If one examines the stormwater drainage in the context of other utility features, one can conclude that stormwater is also handled through a physical system, serving each property and discharging stormwater into the system. The costs of stormwater management can be quantified, although in the past they have usually been buried in street development and improvement funds.

A utility is an enterprise, a public "business". Ratepayers and taxpayers are not necessarily the same, and a utility responsibility is to its ratepayers. Municipal utility does not have a profit motive but rather a long-term stability and quality of operation.

In the conversion of land from rural to urban, the increase in value of land is made mostly from public investment. Any gains in the land are made at the expense of the ultimate purchaser and the taxpayers. Therefore, a community that obtained the capital increment resulting from land use change can apply a levy to any ratable land that had increased in value by belonging to the flood protection scheme. The proceeds of the levy should be directed towards the costs of further capital improvement. A levy is imposed only on flood-affected properties and its collection ceases on completion of the project. User charges still remain after completion of the capital improvement to cover the costs of operation and maintenance.

The purpose of the drainage utility would be to manage stormwater drainage. Expenses of the utility have to be divided so that each property owner contributes to the cost of solving drainage problems to the same extent that he contributes to creating those problems. Monthly drainage fee for each property should relate to the amount of stormwater that runs off the property. This differs substantially from the most commonly used concept of charging stormwater drainage service through water and wastewater bills.

Traditional municipal utilities analyse their cost of service in terms of the unit cost of delivering a commodity (such as water) or providing a service like treatment and disposal of waste. The key to a proper cost of service analysis is not simply to determine how much the program will cost, but to identify the origin of demands for services which create the costs.

The most appropriate approach to origin of drainage costs is to base stormwater rate concepts on each property's "contribution to runoff", even though precise metering of runoff is not feasible. That concept, capable of replacing traditional general taxation funding, is known as user charge funding at the local level. Land owners that voluntarily agree to implement source control measures at the level of their property should be given financial incentives.

There are several possibilities in developing the user charge funding concept in a city. All methods deal with estimating the degree of development, either by using (a) land use classification and zoning or (b) coefficient of runoff corresponding to the rational formula, as measures of the rate of development, or by determining the contribution to runoff from each property on the basis of gross area of each property and the area of impervious coverage or the percentage of impervious cover.

Numerical values for the degree of development are assigned to each property, along with a numerical value for the gross area. The data are then processed through an algorithm that generates a number of billing units for every property. The amount charged per billing unit is determined by dividing the total number of billing units into the total revenue requirement.

The user charge concept covers much more than just flood control. It provides financial means for managing stormwater drainage as well. A property owner who lives on a hill may not understand how the construction of a storm drain in a low-lying area is a benefit to him. Proper stormwater draining in a low-land keeps streets open to emergency vehicle traffic, maintains ponds and open channels so they do not become health and safety hazard, and promotes the use of drainage facilities for recreational purposes. All residents and property owners are served when a drainage system prevents flooding of streets, parks and public facilities.

On the other hand, the property owner on the hill has, by converting the natural groundcover to streets, concrete, and rooftops, increased the stormwater runoff and contributed to the drainage problems of his low-lying neighbors. Such a property owner's potential risk of liability is reduced by provision of an adequate drainage system that prevents downstream flooding. The owner in the middle of a drainage basin is protected from uncontrolled runoff from uphill areas, and also has a potential downstream liability risk reduced. The person at the bottom of the basin, while not having as great liability risk, benefits by the protection a drainage system affords.

11. Environmental impacts caused by flooding

11.1. Water quality alteration

Stormwater drainage and flooding cause significant environmental disturbances both in rural and urban floodplains. These impacts on the environment can alter various components of the floodplain environment in both the short and long term, which may prove to be beneficial in some cases and adverse in others. One of the major impacts is the degradation of water quality as compared to regulatory standards for surface and underground waters and to the tolerances of organisms using the water body as a habitat. Surface stormwater and stream water pollution may be attributed to:

- overland flows, contributing dust and soil particles
- vegetation and animal activities, contributing wastes
- road surfaces, collecting inorganic solids, sand, road material salt and other de-icing chemicals
- motor traffic ,contributing oil, exhaust gas, petrol and particles from tires
- factories, being sources of dust and gasses
- human activity, leading to accumulation of litter, bacteria, detergent from car washing, garden fertilisers and organic waste
- gully pot storage, leading to pollution in septic and anoxic conditions
- overflowing of illegal and wrongful sewerage system connection
- construction sites, contributing eroded soil and debris
- corrosion
- urban agriculture and gardening, contributing eroded soil, herbicide and pesticide pollution

There is a marked difference between surface water running over an urban surface and the same water after passing through a piped drainage system. In combined sewerage systems approximately half of the storm runoff pollution load arises from the catchment surface and the remaining half from pipe and gully deposits.

Unlike wastewater discharges, the sources of stormwater pollution are diffuse and highly variable. Pollutants come from roads, parking lots, residential, commercial, and industrial activities within each municipality. Each water pollution control program should mandate permits for municipalities that discharge any kind of urban water into natural water bodies. Permits are a primary foundation for obtaining adequate environmental protection.

Combined sewer systems are considered as point (discrete) polluters due to the frequent spills at overflow structures during wet weather conditions. Therefore, control of municipal stormwater, both in separate and combined drainage systems, should be fitted somehow to the traditional wastewater discharge permit requirements. Authorities should include groundwater concerns in the permit as well.

The long-term goal of the permits is to control the pollutants and flow rates of stormwater discharges so that the water quality standards in the rivers, lakes and groundwater are not violated. The primary requirement of the initial discharge permits is the development and implementation of stormwater drainage programs aimed at moving existing stormwater programs further towards the long-term goal. It is a difficult challenge for municipalities, and therefore, permit conditions should allow a phased approach to watershed-based stormwater control during all wet weather-related discharges, that will take many years to implement.

The measures of general health of a water body that are frequently employed are the amount of dissolved oxygen (DO), the temperature, and the number of bacteria. However, assessment is usually made indirectly using the biochemical oxygen demand (BOD) test, which gives the amount of organic matter that is degradable under standard conditions. A similar chemical oxygen demand (COD) test is available for assessment of total organic content.

Another widely applied criterion of water quality is the content of solids, characterised by dissolved solids (DS) and suspended solids (SS). Suspended solids provide the transportation medium for various constituents such as lead, cadmium, mercury and hydrocarbons. Thus the concentration of SS can serve as an indicator of the presence and quantity of other constituents.

11.2. Environmental assessment

Flood control management is a part of the universal environmental protection policy. Key word related to reducing adverse environmental impacts is mitigation.

Mitigation is defined by environmentalists as a purposeful implementation of decisions and activities that are designed to reduce the undesirable impacts of a proposed action on the affected environment. Mitigation includes avoiding impact, minimising impact, rectifying impact, reducing impact and, finally, compensating for impact.

The definition of the environmental setting defines the study area and provides the baseline for the impact analysis. When flooding effects are in question, the following categories should be taken in consideration:

- topography
- soils
- groundwater resource
- surface water resource
- aquatic communities (flora and fauna)
- environmentally sensitive areas (wetlands, flood plains)
- land use
- infrastructure services
- project economics

For proper environmental planning and control, an inventory of the community principal environmental values should be developed. Those include wetlands, fish and wildlife habitat, natural and scenic beauty, water quality, and historic places.

Environmental assessment of urban stormwater drainage and flood control is the systematic and interdisciplinary evaluation of the potential effects of a proposed structural measures and their practical alternatives on the physical, biological, cultural and socio-economic attributes of a particular geographic area. Assessment is a preventive activity that reduces potential risks to the well-being of the natural environment. It is an early warning process based on regular review.

Environmental flooding-related issues are numerous. Some of them are listed below:

- mutual effects of agriculture and flooding
- migration disturbance in fish spawning areas
- protection of archaeological sites
- preservation of landscape and major trees
- improvement of downgraded land
- avoiding sewerage effluents and limiting overflows
- avoiding damage to habitats in urban streams
- creating new habitats for wildlife
- developing green belt zones in flood plains
- unauthorised development of site
- fostering and protecting the visual amenity of rivers and floodplains
- reducing risk of landslide and mud flows

Natural disasters cause not only massive death but also social disruption, epidemic diseases and famine, which leave survivors dependent on relief. In recent years the health profession has developed new approaches and new mechanisms, referred to as disaster medicine or disaster health management.

Most common effects on environmental health are shown in fig. 11.1.

11.3. Medical response to flood disasters

Floods are very damaging to man and material (UNESCO, 1995). During a major flood many deaths, caused by drowning, may occur, mostly among the weaker sections of the population such as infants, elderly and sick. Among the survivors, the most common medical problem is hypothermia, meaning loss of body temperature due to long immersions in water exposure to wind.

Immediate effects are not likely to last more than several days. Secondary effects are then likely to begin and more likely to last for a longer time, characterised by the emergence of communicable diseases, water-borne infections and food shortages. The diseases that are to be feared of are various diarrhoea diseases, acute respiratory infections, measles, tuberculosis and malnutrition.

It had long been believed that epidemics almost obligatory follow disasters. The truth is that diseases can be prevented by simple hygienic methods and should be kept under constant surveillance.

The immediate medical response to a flood disaster consists of several elements: search and rescue, triage and tagging, disposal of the dead, and the management of the casualties and the medical supplies.

Triage is a response technique that can be defined as the selection and categorization of the victims according to the degree of severity of illness or injury and the availability of medical and transport facilities. Whenever possible, each casualty should be given an identification tag at the triage stage.

Sound flood planning must anticipate the problems associated with providing, delivering and managing medical supplies. Standardisation of medical emergency supplies is an absolute necessity.

A considerable proportion of the damage to health and health service caused by floods is preventable and can be mitigated. Prevention includes provision of water tanks, setting of health facilities on high ground, immunisation, public health education and distribution of water supply and sanitation compact units.

Most common effects of floods on environmental health

Water supply and waste - water disposal	Damage to civil engineering structures	●
	Broken mains	◒
	Power outages	◒
	Contamination (biological or chemical)	●
	Transportation failures	●
	Personnel shortages	◒
	System overloading (due to shifts in population)	●
	Equipment, parts and supply shortages	●
Solid waste handling	Damage to civil engineering structures	◒
	Transportation failures	●
	Equipment shortages	●
	Personnel shortages	●
	Water, soil and air pollution	●
Food handling	Damage to flood preparation facilities	◒
	Transportation failures	●
	Power outages	◒
	Flooding of facilities	●
	Contamination / degradation of relief supplies	●
Vector control	Proliferation of vector breeding sites	●
	Increase in human-vector contacts	●
	Disruption of vector-borne disease control programs	●
Home sanitation	Destruction or damage to structures	●
	Contamination of water and food	●
	Disruption of power, heating, fuel, water supply, waste disposal services	●
	Overcrowding	○

● Severe possible effect

◒ Less severe possible effect

○ Least or no possible effect

Fig. 11.1. Flood effect matrix (UNESCO, 1995)

Within days of inundation, the emphasis shifts from life saving to restoration of normal life lines. Rehabilitation covers the weeks and months following the floods and aims towards restoring the community's health structure and services.

To ensure national capacity to deal with health problems in floods, all levels of government must prepare themselves for prevention and for cure. Possibly, an emergency committee or a civil defense agency attached, should assume the overall co-ordination. Well-trained local health personnel are key actors in the medical response following a flood.

Epidemiology of floods is the medical discipline that studies the influence of life style, biological constitution and other personal and social determinants on the incidence and distribution of disease caused by floods.

Poor sanitation is without any doubt the main danger in flooded areas and represents the greatest of environmental health hazards. Safe sanitation can only be achieved when participation of people with developed awareness is very high. The main concerns in sanitation are to:

- assess the performance of the existing system during floods
- provide back-flow valves in sewage systems
- isolate and treat human sanitary waste
- isolate and treat toxic chemicals and sources of pollution
- identify emergency systems for use during the flood itself

The prevention of flood waters from entering wastewater and solid waste treatment facilities should have high priority in flood prevention programs. When wastewater treatment plant are flooded, the effluent and even sludge may be flushed out, containing undigested organic matter. Low-lying sites are commonly used for treatment plants in order to enable wastewater to flow from the city to the plants by gravity. These locations are the most flood prone sites in the settlements and special care should be taken to protect those areas against flooding.

Organisation of the health sector on an affected territory may be as shown in Fig. 11.2

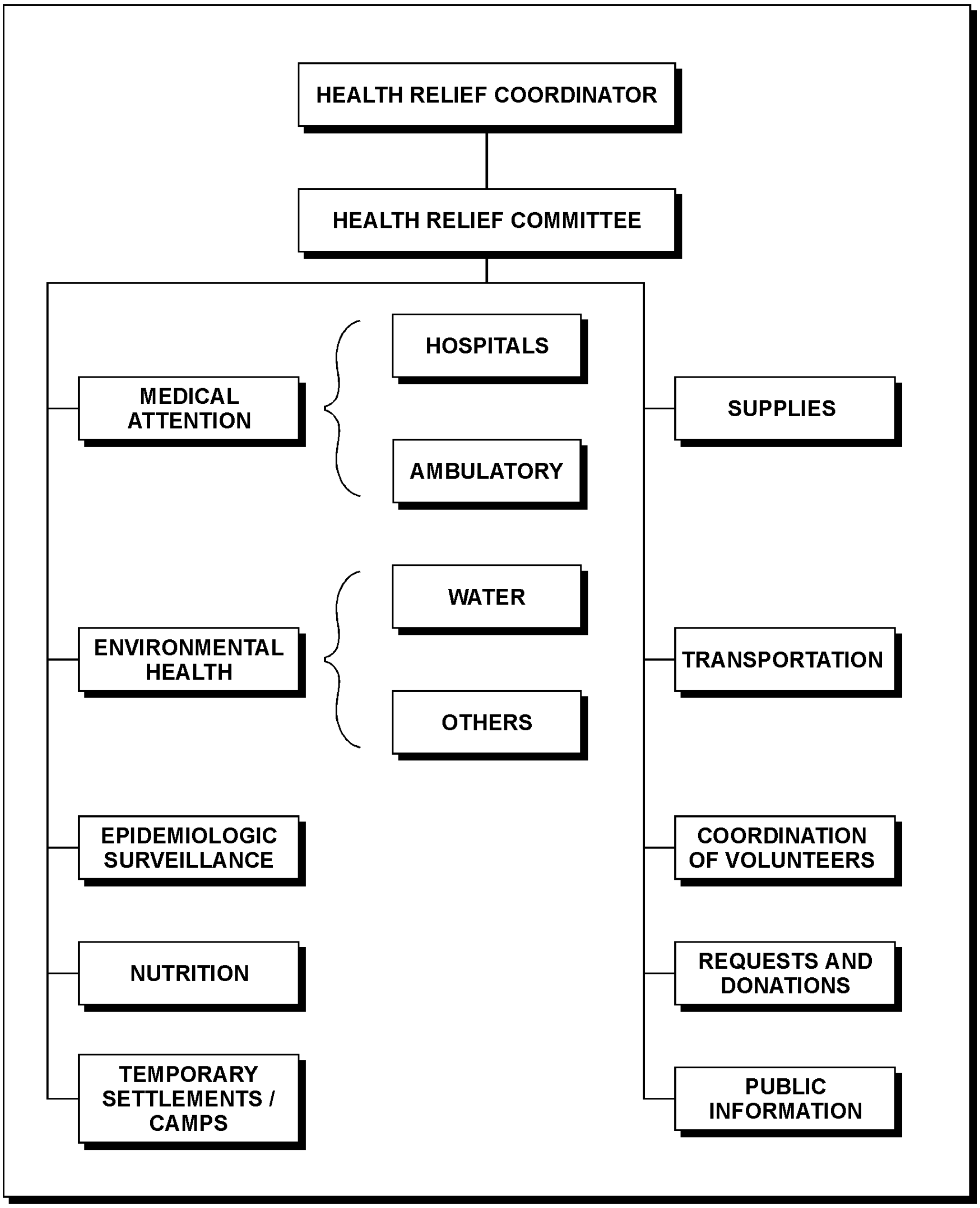


Fig. 11.2. Co-ordination of health relief activities (UNESCO, 1995)

12. Summary

Non-structural flood control measures attracted public and professional attention after conclusive reports were made by local and national governments that more money was being spent on remedying consequences of flooding rather then on preventing it. However, there is still some hesitation on the part of various stakeholders in urban water management to accept and adopt these measures (UNESCO, 1998).

These Guidelines present a number of generally accepted concepts that have already proved useful. They are listed, but not limited to, as follows:

- stormwater management in urban environments is an integrated, multi-sectorial, process that includes, in addition to flood mitigation, stormwater drainage and pollution control as well
- traditional site-specific planning needs to be replaced with w atershed (river basin) or sub-watershed oriented planning
- regionalisation has to be based on hydrologic principles rather than on administrative ones
- flooding does not necessarily need to be disastrous, which gives to the pollution aspect the same significance as physical destruction already has
- stormwater in cities is a resource to be managed, and proper linkage to the land use planning process has to be established
- the four cornerstones of a comprehensive management process are: *fact finding* (through contemporary data acquisition, database updating and exchange), *master planning* (preventive or remedial), an *unified action policy* effected by the authorities (through guidance documents, codes of practice and adequate legislative support), and *changing public attitude* (by raising awareness, building capacity and setting up involvement in planning, decision-making and implementation)
- data gathered by public funding have to be made fully available, which would enable building the trust of people and their participation in possible alternative concepts of financing, such as user charge
- an optimal engineering solution may not be the best because of social and institutional constraints, which means that traditional engineering codes reflect criteria which are not anymore politically permissible

The origins and consequences of flooding have to be fully understood, particularly in developing countries, in order to propose and justify adequate institutional strengthening (regulatory agencies, conservation authorities) which should overcome existing institutional and political barriers. Broad multi-media promotion of non-structural urban flood management measures should be carried out particularly at the level of local communities where flood protection facilities are exposed to atrophy due to globally experienced budgetary cuttings (UNESCO, 1998).

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GLOSSARY OF TERMS RELATED TO NON-STRUCTURAL FLOOD MANAGEMENT

Average annual flood:	The mean of the annual floods over a number of years
Base flood:	A flood with pre-selected probability-of-occurrence
Bonding:	Public borrowing method whereby money is obtained to pay for an improvement, equipment, and/or associated services such as construction management, and repaid in future years, with repayment guaranteed by the full credit of the city issuing the bonds
Evacuation:	Removal of people and property at risk following a warning
Encroachment:	The advance or infringement of uses, plant growth, fill, excavation, building, permanent structures or developments into a floodplain which may impede or alter the flow capacity of a floodplain
Flood:	a body of water, rising, swelling and overflowing land not usually thus covered. Also, overflowing of the bank of a stream, lake or drainage system of water onto adjacent land as a result of storm, ice melt, tidal action and channel obstruction.
Flood control:	The use of techniques to change the physical characteristics of floods
Flood control benefits:	*Direct:* Reduction in flood damage to land and property in terms of cost of restoration to pre-flood condition; *Indirect:* Higher grade use of land formerly flooded in terms of increased earnings, and reduced interruption of business, industry and commerce, traffic, communications and other activities both within and outside the area subject to flooding
Flood forecasting:	Prediction of the characteristics of an imminent future flood
Flood management:	The organisation of responses to flood problems
Floodplain:	Area susceptible to inundation by a base flood including areas where drainage is or may be restricted by man-made structures which have been or may be covered partially or wholly by flood water from the base flood
Floodplain acquisition:	Purchase and demolition by public authorities of properties in risk areas

Floodplain regulation:	Laws defining acceptable use of land in defined areas, thus controlling the extent and type of future development
Flood proofing:	Any combination of structural and non-structural additions, changes or adjustments to structures, made well before a flood event, which reduce or eliminate flood damage to real estate or improved property, water and sanitary facilities, structures and their contents
Flood zoning:	Definition of areas, based on flood risk, within floodplain appropriate for different land uses
Flood relocation:	Voluntary or compulsory movement of people and property out of risk areas
Flood protection:	Protection against the damaging effects of floods
Flood risk:	The chance of experiencing a flood, expressed in terms of the return period
Flood warning:	Issuing the result of a forecast to the public or public authorities
Flood stage:	The elevation of the water surface above which the stream is considered to be in flood
Floodway fringe:	Area of a floodplain adjacent to the floodway where encroachment may be permitted
Floodway:	The channel of a watercourse and those portions of the adjoining floodplain which are reasonably required to carry and discharge the floodwaters of a selected probability-of-occurrence flood.
Flood hazard zone:	Any land area susceptible to flooding or flood related damage as designated on the floodplain management maps. Such flood hazard zones may include but not be limited to areas highly susceptible to erosion, stream meander sensitivity, moveable bed, scour, wave action, and subsidence.
Flood insurance study:	The official report provided by the insurance authorities that includes flood profiles and base flood elevations
Insurance:	Purchase of guaranteed financial relief by means of a regular payment made before a flood
Insurance rate map:	An official map on which insurance authorities has delineated both the special flood hazard areas and the risk premium zones applicable to the community
Land use planning:	Control and supervision of land use in floodplain (zoning,

	regulation, acquisition, relocation)
Management:	Entire process of planning and intervention for reducing disasters, as well as the response and recovery measures
Mitigation:	Action taken to reduce the effects of a disaster on a nation or community
Non-structural measures:	The measures which alter the exposure of life and property to flooding
Policy:	Established uniform approach
Preparedness:	Measures which enable governments, communities and individuals to respond rapidly to disaster situations to cope with it effectively
Prevention:	Measures for impeding a disaster event, or preventing it from having harmful effects on people, their property and settlements
Response:	Measures directed towards saving life and protecting property and to dealing with the immediate danger and other effects caused by the disaster
Relief measures:	Actions taken immediately following the occurrence of a disaster
Rehabilitation:	The interventions taken after a disaster with a view to restoring a stricken community to its normal living conditions
Reconstruction:	The actions taken to reestablish a community after a period of rehabilitation subsequent to a disaster
Risk:	The expected loss due to a particular hazard
River basin development:	The orderly marshalling of land use and water resources of a river basin for multiple purpose to promote human welfare.
Source measures:	A series of mitigation measures undertaken as close as possible to the origin of surface runoff or pollution in urban environment
Structural measures:	The measures which alter the physical characteristics of the floods
Vulnerability:	Difficulty to cope with stress. Also, potential loss of people and goods from a damaging phenomenon