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ASSOCIATED PROGRAMME ON FLOOD MANAGEMENT

The **Associated Programme on Flood Management** (APFM) is a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP).

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To the reader

This publication is part of the *"Integrated Flood Management Tools Series"* being compiled by the Associated Programme on Flood Management. The *Health and Sanitation Aspects of Flood Management* Tool is based on available literature and draws on the findings from relevant works wherever possible.

This Tool addresses the needs of practitioners and allows them to easily access relevant guidance materials. The Tool is considered as a resource guide/material for practitioners and not an academic paper. References used are mostly available on the Internet and hyperlinks are provided in the *References* section.

This Tool is a *"living document"* and will be updated based on sharing of experiences with its readers. The Associated Programme on Flood Management encourages flood managers and related experts engaged in the evaluation and auditing of flood management programs around the globe to participate in the enrichment of the Tool. For this purpose, comments and other inputs are cordially invited. Authorship and contributions will be appropriately acknowledged. Please kindly submit your inputs to the following email address: apfm@wmo.int under Subject: *"Health and Sanitation Aspects of Flood Management"*.

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1 INTRODUCTION

1 Flood events are known for their profound capacity to positively or negatively affect humans. Floods improve overall human well-being by providing services such as groundwater recharge, surface-water replenishment, soil-fertility enhancement and a general increase in the value of social–ecological systems. Equally, however, flood events pose a series of diverse health threats, ranging from contaminated water sources to decreased agricultural productivity, especially when communities are vulnerable and lack the capacity to effectively respond to, and recover from, the adverse effects of floods.

2 In the past decade (2004–2013), 62,879 people lost their lives and about 1 billion people were affected by floods globally. Lives lost in 2013 alone amounted to some 9,816, which was recorded as the highest number of annual deaths owing to floods during the entire decade (CRED, 2012). Most vulnerable are those living in least developed countries, where resilience is hindered by adverse socioeconomic conditions. Poor populations generally tend to occupy places that are normally left unsettled, such as flood-prone areas or steep slopes, increasing their exposure to flooding (or flash flood). The capacity of these populations to cope with floods, depicted by their weak flood-management policy or complete lack thereof, is usually either non-existent or inadequate because of insufficient resources and means. Coastal and urban settlements are also under increasing pressure from climate change and extreme weather events. More than 50% of the global population is found in densely populated urban settlements and 44% of the global population inhabit the coast (UN Atlas, 2012). These areas are highly exposed to flood hazards. In addition, many people are disproportionately affected by extreme weather events, especially vulnerable groups, which are more likely to suffer damage and have limited capacities to cope with hazardous events (IPCC, 2007).

3 Flood-related health risks are not limited to injury and loss of life but also trauma, increased incidence of communicable disease, loss of livelihood and disruption of basic services (water supply and sanitation systems) that exacerbate population vulnerability and hinder sustainable development. The changes in water quantity and quality associated with flood events can be influenced by agricultural and urban runoff, sediment loading and chemical, biological and even

radioactive agent intrusion. These changes alter the availability of clean water – the most basic environmental determinant of human health – and its ability to be used every day: drinking-water supply, domestic use, bathing, recreation, agriculture, aquaculture, energy and industry.

4 Flood damage to critical infrastructure, such as water supply and sanitation **(WSS)** systems, transport routes and health facilities, disrupts the provision of basic human supplies. WSS systems are critical determinants of human health. Non-existent, failing or compromised services therefore pose a significant health risk that reaches beyond local and national borders. Pathogens can invade water sources with a pervasive effect on catchment activities, ecosystems and health. If drinking-water sources become contaminated and no effective treatment can be provided through the water-supply facilities, then flood victims do not have access to safe water and this increases the risk of infection and disease. Where hygiene among displaced populations is poor, water- and vector-borne diseases require special attention to prevent outbreaks and control epidemics. Furthermore, food security is threatened because agriculturally productive floodplains are vulnerable to soil erosion and greater runoff rates during floods, which could result in decreased agricultural productivity and potential contamination of water and food supplies by heavy chemicals, metals, pesticides and animal dejections carried by runoff. Adequately coping with such challenges requires flood planning, preparedness, response and recovery activities that are supported by government and local communities.

5 The World Health Organization **(WHO)** defines environmental health as *"…all of the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviours. It encompasses the assessment and control of those environmental factors that can potentially affect health."* (WHO, 2012(a)). In this sense, floods can be interpreted as a natural hazard that generates physical, microbial, chemical and radiological environmental health hazards due to disruptions to the environment. Public-health management should, therefore, be considered within the broader context of flood resilience (see **Box 1**), given that flood-adaptation and mitigation measures that increase flood resilience have greater capacity to protect and improve health outcomes.

Box 1 — Concept of resilience *(CARRI, 2013)*

Resilience (derived from the Latin *resalire*, to spring back) has become an important term in the language of many disciplines ranging from psychology to ecology. Unfortunately, there is no commonly accepted definition of resilience that is used across all disciplines. The term resilience was first used in the physical sciences to denote the behaviour of a spring. In the 1970s and 1980s, resilience was adapted by the ecological and psychological communities to describe somewhat different phenomena.

In psychology, the term was used to describe groups that did not change behaviour in spite of adversity.

In ecology, the term was used to describe ecosystems that continued to function more or less the same in spite of adversity.

Resilience began to be used in terms of disasters, especially by the engineering community (particularly referring to physical infrastructure), in the 1980s and was related to the concept of being able to absorb and recover from a hazardous event. Since that time, hybrid definitions have arisen that combine the engineering with the ecological, or the ecological with the behavioural.

6 In practice, the critical linkages between flood management, water resource management, public health, WSS systems, climate change and disaster risk reduction are ill defined and remain compartmentalized. A need exists to fill the knowledge gap of public-health vulnerabilities in existing flood-management practices and integrate health and WSS systems before, during and after the flood event. Integrated flood management (IFM) supports this discourse and facilitates flood planning, preparedness, response and recovery activities to reduce environmental health hazards and protect human well-being.

2 INTEGRATED FLOOD MANAGEMENT

7 Integrated flood management is a dynamic and participatory approach to flood management that integrates land and water resource development in a river basin, within the context of integrated water resource management (IWRM) (see **Box 2**). It aims at maximizing the net benefits from the use of floodplains and minimizing loss of life and livelihood from flood events (WMO, 2009). An integrated – versus fragmented – approach shifts from traditional flood-control practices to proactive participation and collaboration among river-basin stakeholders, holistic management of the water cycle and reduction of risk and uncertainty.

Box 2 — Integrated water resource management *(GWP, 2000)*

Integrated water resource management is "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems".

8 The requirement for stakeholder engagement integrates all actors in the river basin to reduce flood risk collectively, not just those living directly on the floodplain. Various water users, service providers, planners and policymakers across different levels of the public, private and non-governmental sectors engage to develop and implement flood planning, response and recovery activities. This serves the ultimate goal of sustainable development by reducing vulnerability and increasing community resilience in view of the rising risks of flooding and uncertainties that climate change generate.

9 Due to the complex nature of floods and their hydrological uncertainty, no single or combined measure(s) can provide absolute protection from flood risk. Flood risk is defined by three

variables: the frequency and severity of the flood hazard, the people and assets potentially exposed to the flooding, and the vulnerability of those people and assets (WMO, 2006) (see Error! Reference source not found.). Given that floodwaters do not respect geopolitical borders, risk-sharing between local, municipal, national or transboundary actors is unavoidable in flood-management practices.

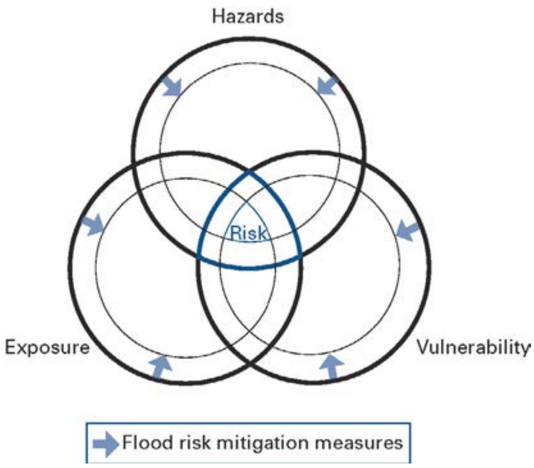


Figure 1 — Flood risk and its reduction (WMO, 2006)

10 Human behaviour and the built-up environment are two significant aspects that influence vulnerability to floods. While floodwater itself is a major cause of death and injury, the spread of disease and availability of safe water in affected communities is largely influenced by the vulnerability of WSS systems and effective health-system management to cope with it. Strong and responsive institutions that protect public well-being are vital ingredients to reduce flood- and health-related risks during emergency situations. Efficient management involves a multisectoral approach, integrating stakeholders from a variety of agencies (environment, water and sanitation provision, education, health, transport, infrastructure, etc.) which collaborate and communicate effectively to mitigate and manage risk.

11 Since no single or collective measure(s) can provide absolute protection from floods, emergency preparedness and response plans are essential to manage residual risk. Various levels of government should coordinate to plan and prepare for flood disaster appropriately. More broadly, implementation of national disaster-risk reduction programmes and adoption of an integrated multi-hazard approach can reinforce preparedness, response and recovery activities in the flooded region. The multidisciplinary nature of IFM is pervasive in the sustainable development agenda; linking flood hazards to the larger attainment and consideration of economic, social, cultural and environmental goals (see **Box 3**). In the context of health and sanitation, mitigation of flood risk thereby mitigates associated health and environmental risks.

Box 3 — Hyogo Framework for Action *(UNISDR, 2005)*

One of the key activities cited in the Hyogo Framework for Action (within the context of the World Conference on Disaster Risk Reduction) is to "implement integrated environmental and natural resource management approaches that incorporate disaster risk reduction, including structural and non-structural measures, such as integrated flood management and appropriate management of fragile ecosystems".

12 This Tool divides health and sanitation aspects of IFM into three main stages (see **Figure 2**):

– **Flood planning and preparedness:** measures to mitigate the adverse impacts of floods on human health and environmental health services (WSS, food hygiene, vector control);

– **Response:** operational plan to assess damage and ensure emergency operation of WSS systems and health-care services during a flood;

– **Post-flood relief and recovery:** action to reinstate water quality, restore essential health services and rehabilitate critical infrastructure in the aftermath of a flood.

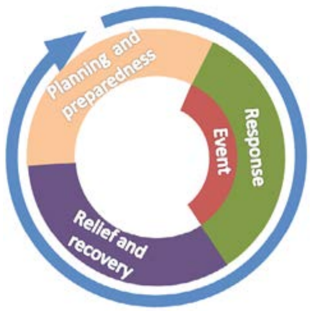


Figure 2 — Health and sanitation stages within IFM

3 FLOOD PLANNING AND PREPAREDNESS

3.1 Pre-flood baseline health

13 Human health plays an overarching role in hazard preparedness and emergency response. All other considerations being equal, healthy communities are more resilient to the adverse effects of floods than communities with poor health and limited access to health-care services. While the health-care system itself is important when considering flood preparedness, minor differences in demographics or socioeconomics can result in large variances of health outcomes. Numerous competing factors, such as the physical environment, socioeconomics, infrastructure, education, institutional accountability and governance contribute, among others, to health vulnerability. Understanding the initial susceptibility of an area or region to health hazards contributes to both mitigation and adaptation measures during an extreme event. Identification of those already threatened by public-health issues, without the presence of hazardous events (flood), is preliminary for fostering preparedness and developing effective response plans when an event does occur.

14 An initial Baseline Health Assessment (BHA) serves to provide meaningful information on the general health status and critical needs of any given community. Baseline health is the current health status of a given population, based on data gathered from existing health-care information systems or local branches of the Ministry of Health for a selected geographical region (municipal boundaries, catchment areas, floodplains). In countries where health data and financial and human resources are limited, a basic BHA can be carried out by designated members of the community (nurse practitioners, community-based officers, water-user association members). Relevant variables may include age, sex, life expectancy, disabled and injured persons, child health (under-five mortality rate, immunization), nutritional health, presence and incidence rates of communicable and non-communicable diseases, including HIV/AIDS, mental-health patients, routine health practices, vaccinations and proximity to environmental health services

(access to WSS). Confidentiality must be maintained when collecting any demographic or health-related information.

15 The critical analysis of the health, socioeconomic and environmental variables contributing to BHA will provide a baseline health profile. The profiles will add value to the design and implementation of structural and non-structural measures essential to IFM, regardless of how preliminary or elaborate the results are. As a minimum, the analysis should assist in identifying the most vulnerable groups and planning health systems. For instance, when flood-hazard maps incorporate baseline health information, they can be used as a tool to identify those susceptible to flood-related health risks (such as persons living in flood-prone areas with extensive malnutrition and limited water and sanitation coverage). Otherwise, the identification of vulnerable groups should be made against the baseline health status and further incorporated into flood-related health planning and preparedness measures. Launch of flood-awareness and flood-related health campaigns to reduce vulnerability and protect public health in these areas should be the main priority (see **Figure 3**). Generally speaking, the most vulnerable are women, children, the elderly, disabled and mentally ill persons, the poor and marginalized groups.

Figure 3 — Cholera prevention signboard
(Sustainable Sanitation Alliance Secretariat (SuSanA))
www.flickr.com/photos/gtzecosan/5268484475

16

17 The multidisciplinary nature of IFM makes the content of BHA relevant not only to flood practitioners but also health-care professionals, local governments involved in strategic planning, infrastructure development and upgrade, land-use planning, development strategy, etc. Information-sharing between all stakeholders will encourage dialogue on priority needs and build institutional capacity.

3.2 Need for a health risk assessment

18 The impacts of a flood are unevenly distributed. It neither poses singular health risk nor is everyone affected equally by floods. Floods can also exacerbate many pre-existing health conditions and create new ones. The protection of human health, therefore, requires an understanding of the

associated health hazards that put persons at risk. Flood-related health hazards and health outcomes are largely influenced by the physical, geographical and socioeconomic conditions, basic services (shelter, health care, water and sanitation coverage), baseline health and hygiene practices, combined with the flood characteristics (type, severity, duration). A flood-related health risk assessment evaluates population exposure and vulnerability to the adverse effects of floods.

19 Since it is not possible to eliminate floods and thereby eradicate health impacts, a main objective of the risk assessment is to characterize and prioritize health risks. This will assist in the development of mitigation measures that increase the resilience of exposed populations. For the purpose of the assessment, hazards are defined as events that have the potential to cause adverse health effects. Additionally, risk characterization evaluates the vulnerability of populations against flood-management practices or lack thereof. In this regard, the outcomes of the assessment encourage the risk-management process and simultaneously enhance flood, community and health resilience. The following risk-assessment paradigm (WHO, 2001(b)) has been adapted to assess flood-related health risks (see **Figure 4**):

- Hazard identification: Identify health hazards associated with flood events. Baseline health data can be used to identify existing health vulnerabilities that will be exacerbated by flood events.
- Hazard characterization: Qualitatively and quantitatively describe the hazard(s), including properties involved (agent, element, matter), source (point/direct, nonpoint/diffuse), transmission route(s) and resulting health impacts (direct and indirect).
- Exposure assessment: Determine the size and characteristics of the population at risk and estimate the expected amount and duration of the exposure (water requirements per day, sanitation, health-care services). Exposure can be assessed using flood-hazard maps that incorporate health (e.g. malnutrition) or environmental health (WSS, vector control, food handling, etc.) attributes.
- Risk characterization: Integrate the information from the hazard characterization and exposure assessment to estimate the magnitude of health outcomes against existing IFM practices. Preliminary estimates of direct and indirect morbidity and mortality may be used as indicators in this process. Estimates informed by health-surveillance data, flood-disaster reports or other sources for the defined area will be more reliable.

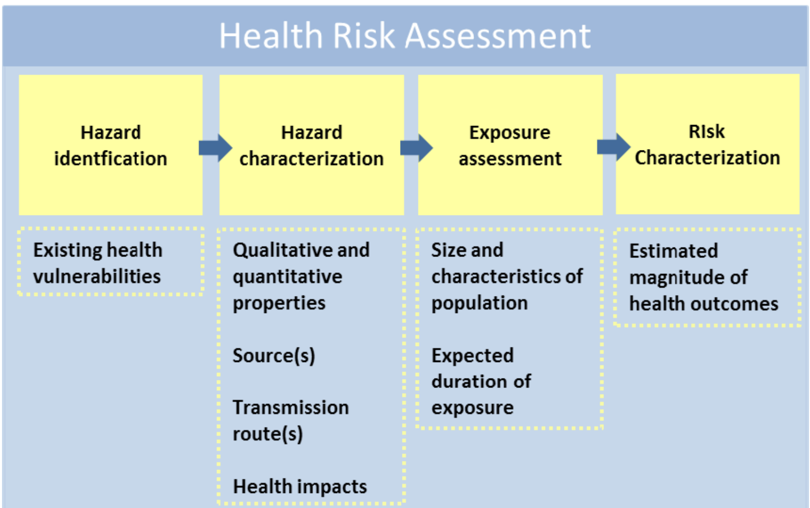


Figure 4 — Health risk assessment steps (WHO, 2011(b))

20 Risk characterization presents a major opportunity to mainstream health objectives and outcomes into IFM and, thereby, increase flood resilience and associated health resilience. The significance of structural and non-structural measures and flood-related health hazards are presented in **Annex 1**. In this regard, human behaviour is analogous to public-health protection. The identified weaknesses provide an opportunity to reduce health impacts by addressing the flood rather than the health-care systems. For example, the characterized risk of morbidity from contaminated floodwater is lower if the critical infrastructure is flood-proofed; similarly, the risk of drowning or death can be reduced if early warning systems and evacuation orders are effective.

3.2.1 Health risks associated with flooding

21 The hydrological changes associated with floods alter the water quality and quantity essential to life. These changes are pervasive in their reach and even if IFM measures are well designed and implemented, floods still have the capacity to impart an individual and aggregate risk of physical, biological, chemical and radiological hazards that can compromise public-health security. These risks occur over various spatial and temporal scales that vary according to the flood characteristics (severity, duration and frequency), population, exposure and vulnerability. For instance, local impacts can be tremendous in high-density urban slums, where flood events will be extensive and affect the population en masse. Special attention must also be paid to vulnerable groups, including women, children, the elderly and physically and mentally challenged persons. These groups are more likely to be disproportionately affected by flood events, because their ability to access health-care systems and essential resources is often limited and undermined, these groups being undervalued in a number of societies. The purpose of this Tool is not to identify all possible health outcomes for every geographic and demographic setting but to introduce the major flood-related health risks that normally threaten human health.

Health risks can be categorized as follows:

A | Physical

22 The physical hazard of floodwater itself endangers human life and sustainability of basic services. Risk of drowning or injury is greatest at the onset of the flood, when waters may rise unpredictably and rapidly. Floodwaters can carry large volumes of debris and sediment, particularly in downstream regions, that may cause fatal or non-fatal injuries (cuts, scratches, broken bones, lacerations).

23 Any injuries sustained before, during or after a flood can quickly turn into a life-threatening ailment if not treated quickly, especially in the face of biological flood hazards. The hydraulic force and erosive power of floodwaters can also cause physical damage to infrastructure and disrupt essential services (transport systems, health care, WSS, communication, public building, homes and electrical supply).

24 When these basic services are no longer operational or operate at reduced capacity, human well-being is again at risk. Direct and indirect implications are not just limited to physical health but also to mental and social health. Those living on the floodplain in basic shelters, especially the vulnerable groups composed by the elderly, mothers, children and minority groups are

typically at greatest risk. Food and safe water for consumption become scarce, which affects not only the vulnerable groups but also the overall displaced populations, extending the physical effect of floods.

B | Biological

25 Biological safety is one of the most critical aspects of public-health security during floods. The major public health concern is the deterioration in water quality and reduction in available safe water quantity that might increase exposure to communicable diseases, including waterborne and vector-borne disease (WHO/WMO, 2012).

26 Microbial hazards, a subset of biological hazards, involve microorganisms, particularly pathogens that increase the risk of communicable diseases and outbreaks. Floodwaters can quickly become polluted with dangerous pathogens (bacteria, viruses, parasites, protozoa, fungi) from the natural and human environment. Tropical and temperate climates provide warm, moist breeding environments that promote the growth and nourishment of water- and vector-borne pathogens and enhance this hazard.

27 Risk of acute infection is further exacerbated by population displacement, overcrowding and disruption of WSS systems (WHO, 2005(a)).

28 The vast majority of water-borne diseases originate from pathogens found in human or animal faeces (WHO, 2011(b)). These harmful pathogens can be ted directly via the faecal–oral route or indirectly via contaminated food and drinking water. Risk of disease is further enhanced by poor hygiene, most notably the lack of hand-washing and safe food-handling practices. Faecal-derived pathogens can easily be transferred to food, kitchen utensils and drinking-water vessels and slowly invade the human body. Zootoxic pathogens from animal husbandry (livestock waste), domestic animals or wildlife can also contaminate water bodies used for drinking-water supply, recreation, agriculture and aquaculture when heavy precipitation or riverine floods increase pathogen loads because of excess runoff.

29 WSS systems are inherently vulnerable to physical damage and microbial hazards following floods. If they are not properly planned beforehand, the large-scale alteration in hydraulic capacity associated with flood events can lead to damage or disruption. Hydrological changes can damage water and sanitation infrastructure (intakes, piped distribution systems, wells, latrines), contaminate safe drinking-water sources (breached well walls), pollute waterways and cause overflow/backflow in water-treatment facilities. Moreover, excessive sediment loads may cause silting and reduce efficiency of water- and wastewater-treatment processes or block pipelines. Any damage or disruption of service requires WSS systems to operate under extreme pressure, especially poorly built and managed systems. As a result, inadequate water quality and quantity leave populations vulnerable to disease and outbreak when service is compromised.

Box 4 — Some epidemological definitions *(WHO, 2011 (d))*

Water-borne diseases are caused by the ingestion of faecally contaminated water. Cholera and typhoid fever are classical examples of waterborne diseases, where only a few highly infectious pathogens are needed to cause severe diarrhoea.

Water-washed diseases occur due to the lack of adequate water supply for washing, bathing and cleaning. Pathogens are transmitted from person to person or by contact with contaminated surfaces. Eye and skin infections as well as diarrhoeal illnesses occur under these circumstances. Waterborne pathogens include bacteria, viruses, protozoa and helminths.

Vector-borne diseases are caused by bites from insects that breed in water. Insect vectors such as mosquitoes transmit diseases such as malaria, Chikungunya and other diseases.

30 Floods can lead to a number of water-related diseases, which are discussed in the literature (Gleick, 2002). Common flood-related, water-borne diseases and their relative pathogens include cholera (*Vibrio cholera*), typhoid fever (*Salmonella Typhi*), leptospirosis (*Leptospira*) and Hepatitis A (*Hepatovirus*) (WHO, 2005(a); WHO, 2011(b)). When diseases such as cholera or typhoid are left untreated, the results can be a devastating increase in morbidity and mortality rates (WHO, 2011(b)). Cholera and typhoid are also classified as enteric disease, those that affect the gastrointestinal tract and are transmitted by the faecal–oral route (WHO, 2011(b)). Enteric pathogens increase the risk of diarrhoea, a major killer of over two million people per year; four billion cases are reported annually, particularly affecting the developing world and children under five (WHO, 2013(b)). Several other human- and animal-derived enteric pathogens threaten an outbreak of water-borne disease following floods. Common examples include *E.Coli*, *Campylobacter*, *Cryptosporidium parvum*, *Cyclospora*, *Gardia*, *Norovirus* and *Rotavirus* (WHO, 2011(b)).

31 Some enteric diseases, such as bacillary dysentery (*Shigella*), are mutually inclusive to both water-borne and water-washed disease. Water-washed diseases arise from insufficient water for basic sanitation and hygiene (WHO, 2011(d)). When clean water for bathing, hand washing, toilet flushing and household use (cleaning utensils, clothes washing) is limited because of flooding, then the risk of water-washed disease increases. For example, *conjunctivitus* (pink eye) infection is a highly contagious infection associated with floods that spreads from person to person or when in contact with contaminated food, in the absence of water available for hand-washing (WHO, 2011(d)).

32 The spread of water-related vector-borne disease is influenced by ecological changes and an alteration of the natural environment following flood events. Depending on the flood characteristics, either existing habitats are washed away or new ones are created. An increase in vector habitats and population growth promotes outbreaks of disease and epidemics. For example, standing pools of water can become larval breeding sites and enhance potential exposure of disaster-affected populations to malaria, dengue and West Nile virus *(WHO, 2005(a))*. Rodent-borne pathogens can be influenced by the availability of food sources and displaced rodents seeking refuge. Temporary or long-term population displacement associated with flood events may attract rodents seeking new habitats and promote their rapid growth. Leptosporia bacteria hosted in rodents such as rats can cause leptospirosis when transmitted via the urine of infected hosts (WHO, 2011(b)). Humans can become infected by direct contact with urine or contaminated environments via abraded skin, wounds or mucous membranes *(WHO, 2011(b))*.

33 Recreational water environments, used for bathing, swimming, water sports, fishing or any other activity where human contact with water is made, require particular attention for biological hazards following a flood. Public-health impacts are largely dependent on the properties of the water body (type, size, depth, flow, circulation patterns, sedimentation) and the ability to absorb the increased runoff and pathogen loads (from sewerage outfalls) following floods. Flash floods, for instance, directly impact the physical and biological water properties of recreational waters that can become a public-health threat *(WHO, 2001)*. Increased nutrient runoff deposited in adjacent water bodies can create favourable environments for algal blooms and the proliferation of toxic cyanobacteria. Cyanobacteria are non-faecal-derived bacteria with the ability to produce harmful "cyanotoxins" in aquatic environments *(WHO, 2011(b))*. These photosynthetic bacteria may be known as blue-green algae but they exist in a range of different colours. They are most common to freshwater lakes, reservoirs, ponds and slow-flowing rivers but can also be found in seawater and can infiltrate soil. High-toxin concentration levels can produce a range of adverse health effects that vary, depending on the toxin form. Immediate ingestion induces gastrointestinal and respiratory illness, including flu, that may damage the liver, spur tumour growth and cause neurotoxicity (WHO, 2011(b)).

34 Flood damage to critical infrastructure and environmental health services such as wastewater-treatment plants is highly correlated with adverse health outcomes in recreational waters. The capacity of treatment plants to maintain operations directly influences the water quality of recipient water bodies. A clear link has been established between water-borne diseases, heavy precipitation and sewerage outfalls when treatment facilities are overwhelmed and sewerage is discharged into the natural environment or upstream portions of a river following a flood (WHO, 2011(a)). Finally, people must also attempt to avoid encounters with dangerous marine predators (sharks, crocodiles, eels, etc.) and venomous species (snakes, jellyfish) in inundated and aquatic environments.

C | Chemical

35 The natural and man-made environment is filled with stored chemicals that may be released during a flood event. Increase in basin runoff from agricultural, urban and industrial areas, which discharges into waterways, leads to chemical contamination and potential eutrophication of those waterways. Chemical contamination can infiltrate soil and aquifers and compromise safe drinking-water sources, agricultural production and ecosystems as a whole. People living near large agricultural areas, industrial zones or waste sites are at risk of toxic exposure to heavy metals, hazardous chemicals, agricultural chemicals (pesticides, fertilizer) and by-products of mining and manufacturing processes. Domestic dwellings can also release heavy metal from household chemicals into waterways. Without proper wastewater treatment processes, these chemicals can make their way into drinking and bathing waters.

36 Many exposure routes exist for hazardous chemicals, including ingestion of drinking water or food, direct contact with skin or mucous membranes, or inhalation (WHO, 2011(b)). Depending on the hazardous properties of the chemical (toxic, corrosive, carcinogenic, irritant), health effects may vary with the degree of exposure. Exposure may increase the risk of non-communicable diseases (cancer, neurological disease) and impairment of major organs (Alderman et al., 2012). Although only a few chemicals have been proved to cause adverse health effects in drinking water through long-term exposure, a large release of chemicals from a landfill or mining site during a flash or coastal flood can be unexpected and costly to exposed populations. A common

flood-related contamination source is nitrite and its more toxic form, nitrate, from agricultural runoff or sewerage pollution (WHO, 2011(b)).

37 Major microbial and chemical hazards can lead to endemic/pandemic conditions within the catchment. The risk of water contamination and subsequent health outcomes varies according to the concentration of agents, point of entry (point source/nonpoint source, direct/diffuse), transmission route and extent of effluent treatment (untreated, primary, secondary), if applicable. Nonpoint source pollution often occurs in lower concentrations but is more difficult to identify, quantify and control than point-source pollution. The eventual load of pathogens from nonpoint source can be much greater in the long term, however, which may later present a grave danger to human health.

D | Radiological

38 Radioactive risks are normally small compared to physical, chemical and microbiological risks because of their lower occurrence probability. If a release of radioactive material happens, however, severe consequences are to be expected. Radioactive materials (radionuclides) are present in the air, soil and water from natural processes or are artificially produced during industrial and medical processes. Harmful radionuclides can contaminate waterways, infiltrate soil or directly emit radiation to those in close proximity when critical infrastructure is damaged or inundated by floods. For example, nuclear power plants are typically constructed in coastal areas or inland near waterways to satisfy water requirements necessary to cool reactors. Floodwaters can easily become radiologically contaminated if the facilities are inundated and radioactive materials (nuclear fuel of fission products) are transported. Similarly, temporary or emergency health-care facilities must exercise due care in medical waste planning to prevent the release of radioactive by-products into the environment and waterways. Both long-term exposure or exposure to acute large doses can harm human health. Personal exposure limits vary according to geographical location, diet, medical treatment and lifestyle.

3.2.2 Direct and indirect morbidity and mortality

39 Many direct and indirect health impacts are associated with flood events (see **Table 1**). Direct contact with turbulent and quickly rising floodwaters often claims lives. Drowning is still the leading cause of death during flash and coastal floods (WHO, 2013(a)), yet this is one of the most preventable outcomes (WHO, 2008). Cardiac arrest, hypothermia and acute trauma further contribute to mortality rates in the immediate onset of floods (UNECE, 2000; Alderman et al., 2012; WHO Regional Office for Europe, 2011). Direct contact with, or ingestion of, contaminated floodwater is the major cause of acute morbidity.

> **Box 5 — Morbidity *(WHO, 2011 (d))***
>
> *Morbidity* describes the proportion of patients with a particular disease during a given year per unit of population. (…) This includes all cases, both fatal and non-fatal.

40 Mental well-being almost always suffers in the aftermath of a flood event. The loss of life, personal assets, cultural or heritage sites, livelihood or burden of disease that often accompanies floods can bring stress, anxiety, depression and post-traumatic stress disorder to the affected populations (Friel et al., 2011). Severity of the flood, disaster preparedness, socioeconomics

status, baseline health and sense of community are contributing factors to the development of psychological disorders.

41 Flood damage to infrastructure, loss of personal assets, economic hardship (raised market prices and reduced commodities), reliance on external assistance, and food insecurity indirectly impact human well-being. For example, damage or disruption of WSS, transport, health care and public spaces can exacerbate chronic disease or related conditions, especially when health care is lost or becomes limited. Broken transport systems threaten the delivery of timely supply (water, food, medicine) and manpower. Moreover, where poor baseline health exists, any additional water-borne disease can directly or indirectly increase the environmental burden of disease. For instance, poverty-ridden households, burdened by malnutrition and disease, typically suffer the most. Where vulnerable groups are affected – especially female-headed households – any additional socioeconomic burden may be tremendous. Loss of shelter also increases exposure to the elements (wind, water, sun), further contributing to illness and disease.

42 Floodwaters are an additional threat to agricultural activities. Prolonged inundation of fields and crop loss lead to higher rates of malnutrition and nutrient deficiency in already vulnerable communities. Agricultural production on contaminated land further threatens food security by limited or delayed harvests. Care must be exercised to monitor the equitable price of food staples following a flood, rather than tolerating inflated prices that people cannot pay. Food-network actors (farmers, food vendors) may take advantage of the economics of emergencies and drive up food prices and transport costs to the detriment of affected populations and vulnerable groups. These consequences, individual or aggregate, contribute to the increased susceptibility and reduced resilience to non-communicable, infectious diseases and overall poor health (Friel et al., 2011). As a result, the ability of those affected to withstand and recover from hazards becomes limited.

43 Although it is widely acknowledged that floodwaters pose many direct and indirect environmental health risks, there is far less empirical evidence to support this statement (Alderman et al., 2012; WHO, 2013(a)). Localities typically lack the capacity, expertise and coordination to conduct enhanced epidemiological research or sanitary surveys that are required to link health impacts directly to the flood event. Moreover, it becomes difficult to capture holistically environmental health risks due to flooding because the burden of disease reaches far beyond local and national borders. Good baseline health data, together with public health surveillance, can start to provide some answers.

Table 1 — Direct and indirect impacts of floods on human health (adapted from *(UNECE, 2000)*)

Direct impacts		
Flood-related health hazard	**Causes**	**Health Implications**
Physical	– Deep floodwaters; fast-flowing and turbulent waters carrying boulders and fallen trees; multi hazards (landslide, mudslide) – Contact with water	– Drowning; non-fatal injuries (cuts, scratches, broken bones, lacerations, electrification) Respiratory diseases; shock; hypothermia; cardiac arrest

Direct impacts		
Flood-related health hazard	Causes	Health Implications
Biological	Contact with polluted waters; encounter with marine predators, venomous species	Wound infections; dermatitis; conjunctivitis; ear, nose and throat infections; communicable disease; fatal and non-fatal bites, stings
Physical, biological, chemical, radiological	Increase of physical and emotional stress	Increase of susceptibility to psychosocial disturbances and cardiovascular incidents
Indirect impacts		
Physical	Disruption of communication (telephone, Internet, social networks); loss of property, jobs, family members and friends	Possible psychosocial disturbances; anxiety, stress
Physical	Damage to health services; disruption of "normal" health service activities	Decrease of "normal" health-care services, insufficient access to medical care
Physical, biological	Damage to water-supply systems, sewerage and sewage disposal damage; insufficient supply of drinking water; insufficient water supply for washing; power outages; overcrowding; underground pipe disruption	Water-borne disease (enterogenic E. coli, shigellosis, hepatitis A, leptospirosis, giardiasis, campylobacteriosis, typhoid, rotavirus); water-washed disease (dermatitis and conjunctivitis)
Physical, biological	Clean-up activities following floods	Electrocutions; injuries; lacerations; skin punctures; growth of mould
Biological	Rodent migration	Possible diseases caused by rodents; leptospirosis
Biological	Standing waters; heavy rainfall; expanded range of vector habitats	Vector-borne diseases; malaria, dengue, West Nile virus
Physical, biological, chemical	Destruction of primary food products; disruption in agriculture and animal husbandry	Food insecurity; malnutrition; nutritional deficiency
Physical, biological, chemical	Dislodgment of storage tanks; overflow of toxic-waste sites; release of hazardous chemicals and heavy metals; agricultural runoff of pesticides and other industrial chemicals	Potential acute or chronic effects of chemical pollution, including methaemoglobinaemia and gastrointestinal irritation
Radiological	Release of radionuclides; damage to nuclear power plants	Potential acute or chronic effects of radiological pollution, such as certain cancers (thyroid, stomach, digestive) and mental-health effects

3.3 Prepardeness programmes

3.3.1 Disaster-risk reduction

45 Floods are a naturally occurring hydrometeorological hazard with the potential to become a disaster. In fact, floods are one of the greatest high-impact disasters known to mankind. In 2011 alone, floods and mass movements represented the largest portion of disasters globally (Guha-Sapir et al., 2012). Disasters impair a community's ability to cope with risk and result in a serious disruption of capacity that involves widespread human, material, economic or environmental loss. The potential cascading effects of floods (landslides, mudslides, electrocution and epidemics) should be considered as part of a wider risk-management system rather than a hazard-specific approach, because multiple related hazards often result in catastrophic events.

46 The disaster-management cycle aims to reduce hazards and prevent disasters, prepare for emergencies and facilitate recovery in the aftermath of an event (WHO, 2002). This process is illustrated in **Figure 5**. Prevention and preparedness are critical components of disaster-risk reduction wherein persons have the knowledge and resources to protect themselves from the hazards they face. Increasing the capacity of people to cope with flood disasters involves their own ability to address environmental health concerns by engaging in the risk-management process. Identification of hazards and development of mitigation measures to reduce impacts serve to reduce risk to an acceptable level. Local ideas should be encouraged to increase ownership and mobilize risk-reduction efforts.

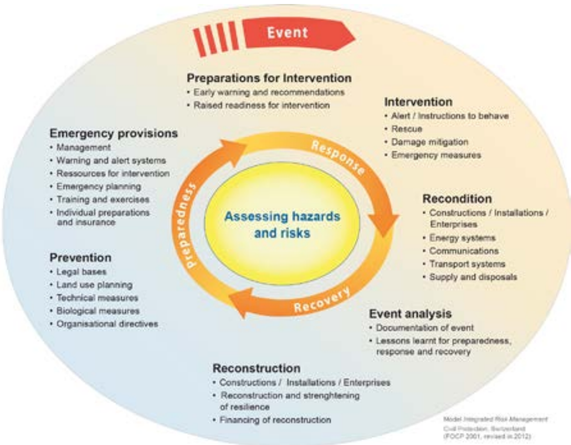


Figure 5 — Integrated risk management (Swiss FOCP, 2012)

47 The mitigation strategy and emergency preparedness of the target population will largely determine if the event will become an emergency. Support of national governments to develop and adopt disaster management and sustainable development policies is critical to this process. Clear roles and responsibilities between key institutions and levels of government need to be defined to facilitate effective communication, coordination and relief during an emergency.

48 Disaster planning and preparedness must consider the risk of damage to critical infrastructure or processes that could release harmful amounts of radioactive material and chemicals into the environment and leave the population exposed to risk. Mapping industrial facilities, reservoirs and dams, intensive agricultural activity and nuclear power plants in the catchment and in

proximity to settlements should be made with particular attention to the contamination of air, soil and water. **Annex I** defines the significant relationship between disaster risk reduction, IFM and health hazards. Risk reduction should be accepted as ongoing learning that requires the evaluation of outputs and updates, especially in the post-disaster phase, to contribute to institutional learning.

3.3.2 Health-system management and medical planning

49 While flood planning and preparedness largely dictate the susceptibility of people to flood emergencies, health-sector planning and preparedness are a critical component of emergency response to reduce flood-related health risks. Health-care systems act as the backbone of relief operations during emergencies, and equitable access for all persons to quality medical care remains a high priority in the event of a flood. These systems, however, are vulnerable to damage, disruption of service, interruption of water supply and excess medical demand without any notice. Health-sector policymakers and operators committed to flood-risk reduction and health-system management increase the probability that essential health services will remain accessible, operational and reach those most in need during a flood event.

50 The design of health-care infrastructure and systems will impact the delivery of services during a flood. As a precaution, land-use regulation should specify that all health-care facilities be built away from the floodplain or flood-prone areas (low-lying areas). Buildings with built-in or retrofitted flood-proofing measures reduce the risk of inundation and breakdown of essential services. This is particularly important for emergency facilities designated as safe shelters which host and service large volumes of people. The use of additional non-structural measures, such as flood-hazard mapping (see **Figure 6**) and contingency planning, can illustrate the probability of flood-damage exposure and number of flood-affected persons. Medical contingency planning for flood events, especially in flood-prone areas, should be an implicit component of health-care system management. Contingency planning is a means of disaster preparedness that anticipates medical demand and develops detailed plans to meet those requirements in the event of an emergency. These plans should be informed by health data, past reports, public-health expertise, the baseline health profile and the flood health risk assessment.

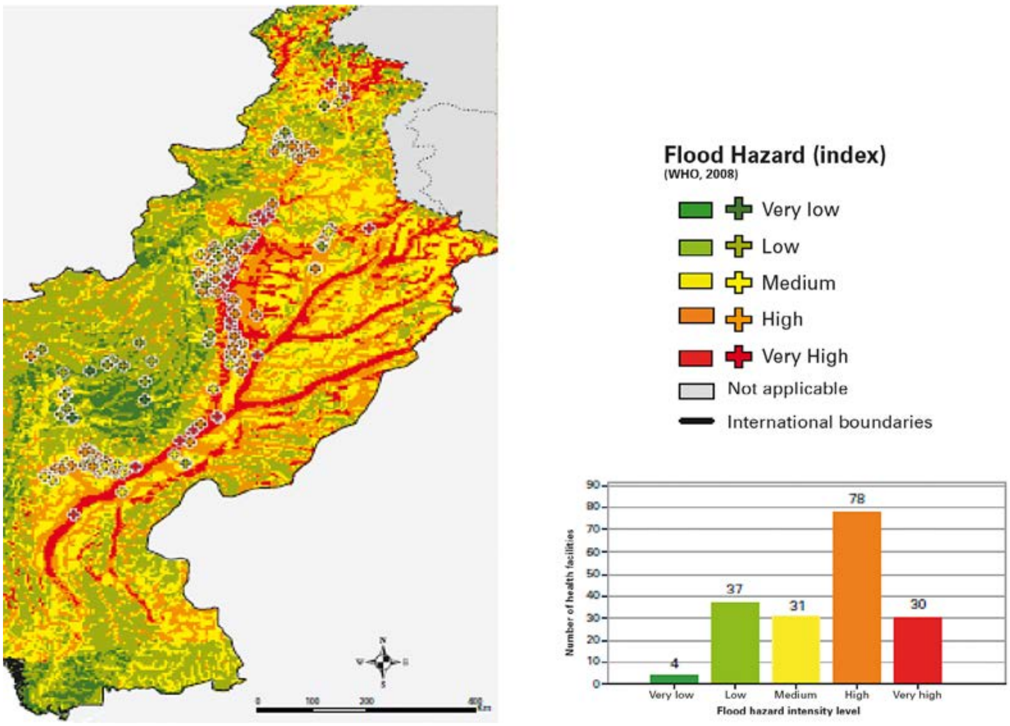


Figure 6 — Map indicating flood-hazard-prone areas and graded exposure level of health facilities

51 When large volumes of in-patients stress the health-care system and disrupt normal services during an emergency, a mass casualty incident exists (PAHO, 2001). National government, including the Ministry of Health, plays an overarching role in emergency preparedness and mass casualty management (MCM). Planning and preparedness for such incidents is not limited to death and injury but a "whole-of-health" approach, including treatment for disease (communicable and non-communicable), as well as mental, maternal and environmental health needs (WHO, 2007). A dedicated team within the Ministry of Health should be assigned responsibility to plan and prepare for mass casualty events, as well as to coordinate with other sectors and health-system components (international, public, private, military and non-governmental organization (NGO)) (WHO, 2007). This Ministry should also be charged with the development of a National Mass Casualty Management Plan, in collaboration with key stakeholders and based upon existing health-care system resources and needs, using a multi-hazard approach. The Plan should be consistent with emergency and disaster-management plans and compatible with other levels of government planning (provincial/state, local), known as a tiered approach. Efficient planning involves clearly defined roles, responsibilities and communication plans among all stakeholders. Communication plays a central role in emergency management (WMO, 2015(b)).

52 At the local level, health-care facilities play a key role in first response to the community and are a vital ingredient of emergency management. Every facility must anticipate surplus demand and estimate its institutional and workforce capacity required to provide essential services. Key capacities and needs to consider in health facility MCM plans include:

- Maximum patient load and medical staff-to-patient ratio (doctors, nurses, specialists);
- Medical protocol, including standard triage and patient prioritization (early discharge of persons with non-life-threatening illnesses);

- Access to, and stock of, essential medicines and medical supplies according to established standards;
- Establishment of emergency health facilities, including alternate care facilities, mobile clinics and field hospitals to service populations with limited access to health care;
- Availability of well-trained emergency medical staff, local health workers and resources (sanitary supplies, curative care, essential drugs, equipment, etc.), including location, type, quantity and accessibility;
- Capacities of nearby health facilities (30 km radius) and formal agreements to share resources (equipment, staff);
- Trained emergency medical personnel and supplies required to prevent and respond to outbreak of disease or any other identified health risks, including patient referrals to other facilities;
- Water needs and supply (quantity per patient and facility operations, quality requirement for different needs, segregating water for designated use);
- Water safety plans (provision for clean water supply in the eventuality that existing systems become damaged or contaminated) (see **Section 3.4.4**);
- Alternate transport routes for public access to transfer patients and deliver medical resources;
- Provision of medical waste management;
- Mechanisms and materials for prompt repair of equipment for essential services.

53 Estimates should be consistent with population demographics, baseline health condition, health assessment and re-evaluated during the actual emergency. They should also be made over a specific timeframe (minimum of 15 days; 90 days for outbreak) and kept up to date.

Box 6 — Mass casualty management during flash floods *(Gupta et al., 2002)*

The citizens of Leh, the largest town in the Ladakh region of northern India, faced torrential rain at midnight on 6 August 2010. The ensuing flash flood claimed the lives of more than 200 people and significantly disrupted normal health-care services.

Over 800 injured and missing persons were unable to receive medical attention at the government's civil hospital, which was severely flooded and deemed inoperable. Rapid response led by the Government of India alongside the Indian Army, state government and police forces launched prompt rescue and relief operations and mass casualty management **(MCM)**.

Search-and-rescue operations were activated by dawn and the Army Hospital, a nearby facility, accepted the surge of incoming flood victims and patient transfers from the civil hospital. Salvageable medical equipment and supplies were transferred from the civil hospital to an alternate building, where casualties were also received.

Meanwhile, tertiary patients and those in a severe condition were transferred by air to the Army Command Hospital in Chandigarh. Damaged transport infrastructure, including collapsed bridges, flooded roads and airport runways, was quickly dealt with by army and civil officials. Medical staff from the two local hospitals joined forces and additional medical staff were flown in from "stand" cities, such as New Delhi, to cope with the emergency. The still functional mortuary of the civil hospital handled the bodies of the deceased.

Deployment of these efficient and effective disaster-management activities and MCM strategies saved lives and quickly restored normality in the aftermath of this high-impact event.

54 Service delivery at medical facilities should not be compromised by the lack of a basic water supply or access to the facility. Understanding water use and demand at these sites is essential to the planning process, as is identification of alternate access routes. Hand-washing stations for first-aid workers and medical staff should be available to ensure that hygiene standards are maintained by medical service providers. Wherever possible, at least one female health practitioner should be assigned at hospitals or other temporary health facilities (mobile units, field hospitals) as, for cultural reasons, it may encourage increased access to health serviced by vulnerable groups. Waste management is another critical component of health-care facilities, especially those that produce large quantities of medical refuse, including hazardous chemical, bio-contaminated and radiological waste harmful to human health. Due care must be exercised to segregate, store, collect and dispose of various types of waste appropriately.

55 Health-care service providers must comprehend the potential consequences of flooding and be given the best possible preparedness tools and resources to handle emergencies. A prerequisite for medical planning is appropriate training for health-care staff on the nature of floods and related health risks. Training programmes should be based on the level of responsibility and category of health-care workers and prioritized according to needs and health-facility competence gaps (Sphere Project, 2011) (see **Section 3.3.4** for further details). Government investment in national, provincial and local health-training programmes and national flood policy requiring strong risk management of health-care systems will benefit any emergency situation.

56 Where flood mortality is widespread, human corpses and animal carcasses can become breeding sites of flies and increase the risk of disease transmission and contamination of water supply from insect faeces. Management of the dead should be handled in a prompt, safe and dignified manner, in consultation with public-health authorities and other responsible agencies (Sphere Project, 2011). Search-and-rescue teams, organized by existing community groups and local volunteers, can assist with procedures. Those involved must be informed and aware of the circumstances they face, including the likelihood of trauma and distress. Mental health and support services should be readily available to them.

57 The loss of life, assets and economic hardship following a flood will test the psychosocial resilience of individuals and communities. Mental-health services should be available to distressed flood victims burdened by social and mental-health problems. Floods may exacerbate existing issues or create new ones in the immediate onset or aftermath of events. These can lead to ongoing psychological disorders, including post-traumatic stress and depression. Helpful community-based services can provide a solid foundation for support in the short and long-term. Adequate planning for counselling, treatment and education should be accounted for in local health planning.

58 Hygiene and sanitary products may be lost or ruined during a flood. Medical planning should consider distributing hygiene packages and reproductive health kits to vulnerable groups, including women and children, and to community centres, especially in the immediate term. As a minimum, soap should be included in the kit. Distribution of jerry cans or water vessels may also be necessary to ensure people have safe containers to treat and store water. Emergency medical kits (first aid, clean delivery kits for pregnant women) should also be available to trained staff (community members, public-health authorities, volunteers) capable of administering medicines and providing basic health advice.

59 Engagement and planning of the health sector with other key sectors (water resources, disaster-risk reduction, education, development) and stakeholders will facilitate the most practical approach to well-coordinated relief efforts essential to flood emergency response or any other disaster. For example, where floodwaters cause severe damage to roads and bridges, maintaining access to health services will require communication and coordination of water resources, transport and public works to rehabilitate infrastructure or develop alternate routes for the timely delivery of supplies.

60 The significance of long-term medical planning, including public-health promotion, education, vaccine administration and nutritional programmes aimed at eradicating disease and improving overall health, also requires attention. Effective planning in these domains will increase health resilience, reduce vulnerability to environmental change and enhance the capacity of communities to prepare, prevent and respond to hazardous flood events.

3.3.3 Disease-control programmes and outbreak preparedness

61 Since flood-affected regions are vulnerable to communicable diseases, especially where environmental health services are disrupted and population displacement is widespread, they require supportive disease-control programmes and outbreak preparedness. Outbreaks are dangerous because of their endemic/epidemic potential. The baseline health of the population, capacity of the health sector and related institutions, population exposure and vulnerability to health hazards, hygiene practices and climate (warm, moist environments) all contribute to the risk of disease and outbreaks.

62 Disease prevention lies at the root of disease control. Maintenance of a healthy environment with a nutritious diet, safe water, adequate sanitation and good hygiene is the best defence against microbial hazards (WHO, 2002). Floods, however, disrupt the natural and built environment and increase pathogen loads. The health sector must prevent, plan for and respond to, pathogen influx and potential outbreaks. In this regard, important elements of public-health protection during floods are:

- Adequate personnel (public health authorities, doctors, volunteers) capable of delivering medical services to the affected population, especially vulnerable groups;
- Identification and characterization of the disease to control (transmission route, exposure, case definition, epidemiology);
- Standard medical protocol for investigation, early treatment of key symptoms and identification of medical conditions;
- Emergency medical supply for diagnosis and treatment of water-related disease (testing kits, oral rehydration therapy, mosquito nets, chemical spray for vectors);
- Distribution of hygiene kits;
- Mapping control facilities (quarantine or isolation). If none exist, plans for temporary quarantine shelters to contain disease and endemics should be developed;
- Public outbreak-awareness campaigns recommending early care for key symptoms (fever, diarrhoea) and immediate treatment at designated health facilities that reach all persons, including vulnerable groups;
- Prevention of overcrowding along evacuation routes and at temporary shelter sites;

– Public-health education and hygiene-awareness campaigns aimed at adopting behaviours that promote healthy and sanitary environments for the prevention of water-related disease (water-borne, water-washed and vector-borne);
– Identification of an alternate laboratory able to assist with testing and confirmation of an outbreak;
– Real-time surveillance, evaluation and monitoring of disease and outbreaks.

63 Outbreak preparedness constitutes a system of early detection, investigation, confirmation and response to disease. Proper training in disease definition, identification and risk assessment is critical to this process. Designated health staff record incidents by type of disease, history of patient, recent contact/potential transmission and source of disease (epidemiology), if known. Local or municipal tally sheets and graphs are useful tools to track disease-incidence rates and monitor disease progress. These should feed into an amalgamated public-health surveillance system devised to monitor epidemics according to pre-established thresholds. Thresholds are informed by baseline health data, expertise, knowledge and historical trends of disease, assigned outside the scope of spatial (specific population, geographic area) or temporal expectations. All health authorities should be alerted when incidents are near threshold levels or an outbreak is suspected. When pre-determined thresholds are surpassed, an outbreak must be reported and protocol followed until incidence rates recede. Public-health surveillance should record classification of the outbreak (endemic, epidemic), spatial and temporal scale, thresholds, number of incidents, disease definition and type of diagnosis (laboratory, clinical, principal). Information should be readily available and shared with all appropriate stakeholders.

64 Outbreaks have a tendency to disguise diseases and promote multiple infections that make diagnosis and treatment more difficult. Several communicable diseases have an incubation period, which can disguise the illness or present it in another form (see **Annex II** for a list of common flood-related diseases, their features and incubation period). Testing and accurate diagnosis can prevent or contain an outbreak. Mass immunizations (e.g. for Hepatitis A) are not recommended as a short-term protective measure during emergencies to control an outbreak (WHO, 2005(a)). Targeted immunizations to high-risk and vulnerable groups can, however, contain a rapid spread of disease. Standard protocol to prevent further incidence of disease includes immediate curative care (e.g. oral rehydration therapy) for any suspected cases, regardless of whether diagnosis is confirmed, and isolation of patients to minimize transmission. Untimely test results should not impede efficiency in administering treatment, especially in endemic-prone regions. In this sense, preventive and curative measures are taken concurrently. Further, sanitation conditions and hygiene practices should be re-evaluated and promoted to prevent the spread of infection.

65 Timely collection and analysis of health information is an integral part of health-information management and central for investigation and control of communicable disease and outbreaks. Routine public-health surveillance should include (WHO, 2002):

– Ongoing data collection and monitoring of mortality and morbidity, including identification and case definitions of communicable disease;
– Epidemiological investigation and outbreak detection (early warning systems);
– Disease and outbreak trend analysis (short, medium and long term);
– Geographic and demographic analysis;

– Feedback to other sectors (water authorities, environmental health authorities) and levels of government.

66 Such analysis facilitates comparison against baseline health conditions and begins to fill in much needed and demanded research gaps. Documentation of the environmental burden of disease and critical determinants of health can then be used to inform policies and strengthen institutions.

3.3.4 Training of responsible staff

67 Well-trained personnel at various levels of government (national, regional, district, local), private actors, the public sector and the community are essential to flood mitigation and emergency preparedness. This includes all those affected by the flood and those critical to the development and implementation of response activities. Training of selected personnel should be done well in advance of the flood season to clearly define roles and responsibilities that will provide structure to relief efforts, supported by local capacities and clear lines of communication. Roles and responsibilities vary greatly from high-level policymakers, health care/environmental health practitioners, river-basin authorities, water-service providers and utility managers to volunteers who will require tailored, flood-hazard-specific or multi-hazard training programmes based on local resources.

68 There is generally a shortage of resources to deliver timely relief during an emergency situation. Proper training of those involved is essential to maximize output from the available personnel. Training results should yield competent persons able to identify risk, evaluate response options and respond appropriately. Effective programmes capitalize on previous experience, integrate innovative and participative training methods and are financially feasible. Integrated training programmes are structured to simulate real-life emergencies and bring together actors who will play an integral part in relief efforts (community workers, municipal authorities, public-health authorities, volunteers, support professionals). For instance, mock MCM training exercises should be led by hospital authorities in association with the public sector (police, civil defence, firefighters, transport authority, utility), private sector (water operators), local NGOs and community volunteers. Relevant components include, among others, establishment of temporary health facilities, management of the dead and communication mechanisms (more information on communication is available in (WMO, 2015(b)). Planning is crucial to well thought-out training and exercises that foster trust and collaboration among participants. New ideas can tackle existing vulnerabilities and minimize risk, while providing practical information and utility. For example, community members can simulate efforts to repair a breached embankment and, in the process, strengthen it or be trained in how to disinfect the local well after a flood and install flood-proofing measures to protect it against contamination.

Box 7 — Potential flood-related health training for relevant stakeholders
(adapted from (Jha et al., 2012))

– **Design and implementation of structural and non-structural flood-management measures:** River-basin authorities, flood policymakers, government officials, water resource managers, engineers, community leaders, water and sanitation operators, health-care operators, NGOs

– **Assessment design** (baseline health, health risk assessment, initial damage assessment)**:** Policymakers, government officials, community leaders, NGOs

Box 7 — Potential flood-related health training for relevant stakeholders *(continued)*

- **Conduct assessment** (baseline health, health-risk assessment, initial damage assessment)**:** Public-health authorities, flood practitioners, health-care authorities, utility managers, WSS operators
- **Local medical planning** (including distribution of hygiene kits) **and medical first response:** Health-care workers, medical staff, selection of community members
- **Disease identification** (water-, vector-borne)**, treatment protocol and outbreak control:** Public health authorities, health-care operators and workers, selection of community members
- **Mass Casualty Management:** Ministry of Health, medical staff, health-care workers, public-health authorities, police; firefighters, civil defence, transport authority, NGOs
- **First aid, basic resuscitation and wound management:** Selection of community members
- **Mental health and psychological first aid:** Health-care workers; community members
- **Identification of priority action and medical action response:** Community leaders, public-health authorities, flood managers
- **Search and rescue:** Police, firefighters, community volunteers
- **Basic WSS service provision during the flood:** Community members, public-health authorities, utility managers, water and sanitation operators
- **Monitoring and reporting:** Government officials, public-health authorities, community leaders, community members

3.3.5 Flood-related health campaign

69 The level of perceived risk largely determines a community's capacity to cope with, and respond to, a flood event (WMO, 2015(a); WMO 2015(b)). Where risk is perceived to be high, management practices and incentives to build community resilience exist. Those living in flood-prone areas typically have a greater understanding of flood risk and are more likely to invest in measures to protect their livelihoods rather than those found in low-frequency but historically high-impact areas. In the latter case, preparedness measures are typically non-existent, especially for unanticipated flood events (flash flood, storm surge).

70 A pre-flood health campaign is a vital ingredient to prepare communities for anticipated changes in public health during and after a flood. The goal of the campaign is to generate awareness of flood-related health risks and thereby motivate action to protect and enhance community well-being. It provides the platform to share and build upon community knowledge and explore mitigation and adaptation activities that are best suited for flood events. This campaign is considered more technical than the broader flood-awareness campaign aimed at encouraging people to embrace the risks associated with floods (floods are inevitable). Wherever required or most feasible, it can serve the dual purpose of creating awareness of flood and flood-related health risk. Further, the health-awareness campaign acquires greatest capacity to mitigate risks when reinforced by the response: a post-flood hygiene promotion campaign designed to preserve public-health security during a flood (Jha et al., 2012) (see **Section 4.7**). Most specifically, but not exclusively, campaigns should be targeted at reducing the risk of communicable

disease, one of the major public-health threats associated with floods. This preparatory work will have large benefits for affected communities when a hazardous event occurs. Otherwise, even a small-scale flood could be devastating. Participative campaigns that reach all community members, including vulnerable groups, have a tremendous capacity to increase resilience.

71 For any campaign to be effective, it must be based upon, and tailored to, local needs and empower communities. Two critical components are involved in the design of successful campaigns:

– Introduce relevant hazards to those at risk (contact with turbulent floodwaters may cause drowning; floodwater can inundate and contaminate water sources such as wells, ponds, reservoirs); and
– Propose realistic measures to reduce the risk (keep distance from floodwater; protect water sources).

72 Those charged with campaign formulation must have a good understanding of local culture, community perceptions surrounding health issues (transmission routes, types of disease, vulnerable groups, etc.), sanitation and hygiene practice (service provision, hand-washing, open defecation, etc). This will ensure that the target audience will engage in, and contribute to, campaign formulation during community participation.

73 Needs are better determined using a participatory approach than one based on existing cultural belief systems, perceptions and motives. Health-care needs also vary with the geographical location of flood incidence (tropical, semi-tropical, temperate, semi-temperate, alpine, etc.). Campaign development and selection of priority messages should therefore:

– Be informed by the findings of flood-related health-risk assessment; tailored to local flood risk (type of flood involved, severity, duration);
– Incorporate community participation. Community members must take part in problem identification and problem-solving. When general attitudes and beliefs of the target population are incorporated, ownership and motivation of those involved to adopt a specific behaviour increases (WHO, 2002). Special attention needs to be paid to vulnerable groups to ensure that they participate in the required dialogue;
– Be guided by stakeholder engagement, using a multisectoral approach. Ideally, the campaign should be incorporated into national flood-management programmes, otherwise it could also be combined with other health campaigns and development strategies (general flood-risk awareness, disaster-risk reduction, water, sanitation and hygiene (WASH) strategies, maternal health education).
– Targeted campaigns have the greatest capacity to reap considerable benefits where flood risk is significant. An increasing trend in global urbanization continues to put pressure on urban flood management, and health-awareness campaigns are becoming essential to adaptive management (Jha et al., 2012). Where WSS coverage and hygiene behaviour are limited, any additional water-related stress on already vulnerable systems threatens delivery of service when people need it most. Campaigns targeting informal settlements, rural areas, women and children, can be particularly promising.

74 The communication medium plays an integral role in generating public understanding, acceptance and behaviour change (WMO, 2015(b)). A combination of robust tools and methods should be used to transmit clear messages that reach the target audience. These include individual and

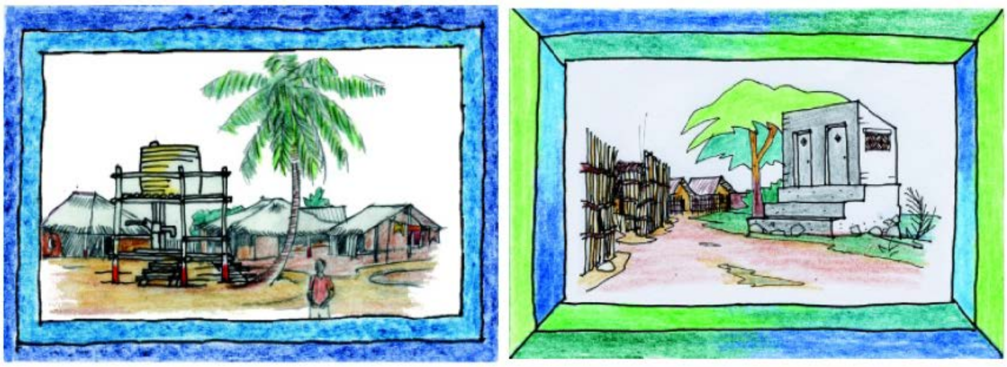
group interactions (role-playing, story-telling, demonstration, plays and discussion), visual aids (posters, brochures, illustrations) and mass media, such as TV, print, radio and electronic media. While this list is not exhaustive, the most important issue is that methods selected reinforce one another and the communication is diversified. The selection of methods will depend on characteristics of the audience (poverty, literacy level, age, gender), available technology (TV, print, audio, mobile phone, Internet) and time pressures. For example, communication through mobile phones could be an effective means of informing and preparing the community for an imminent flood. According to the International Telecommunication Union (ITU), in 2014 cell phones reached a global penetration of 96.1%. Communicating by mobile phone could, therefore, reach large populations (ITU, 2015). Effective campaigns are consistently monitored to assess success of behaviour change, evaluated to inform evolution of the campaign and sustained over time.

Box 8 — Case study: Flood campaign in Mozambique *(Lumbroso et al., 2008)*

After the devastating 2000 flooding in Mozambique that affected a quarter of the population (4.5 million people), the United Kingdom Department for International Development and the United Nations Human Settlements Programme (UN-HABITAT) partnered with local communities to produce educational material aimed at urban and rural areas to reduce their vulnerability to flood risk.

The materials focused on strengthening flood planning and preparedness by introducing non-structural flood measures (flood awareness, early warning systems, flood-proofing, etc.). Access to safe drinking water and safe storage of seeds during the flood were priority mitigation measures identified by community members. In one out of three villages, implementation reaped significant benefits: a flood-proofed water tank and rainwater-harvesting facility were constructed, using local resources and manpower.

These efforts were complemented by health education in each pilot area and the creation of local management committees to monitor and ensure sustainability of the projects. Collectively, the projects provide enough safe drinking water to the community for the entire year.



Educational cards illustrating examples of flood proofing of rural water supply and sanitation infrasctructure

3.4 Management of water-supply and sanitation systems

3.4.1 Context of water-supply and sanitation systems

75 It is critical to acknowledge the underlying complexities between flood hazards, WSS systems and sustainable development. Public-health security is intricately linked to the development of WSS systems (WHO, 2009). The immediate risk of communicable disease following a flood is limited, unless WSS systems are disrupted and/or populations are displaced (WHO, 2005(a)). Any hazardous event (flood) that disrupts or damages the system therefore poses a direct threat to public health, if not adequately planned or prepared for.

76 WSS systems are engineered to deliver safe water, remove sewerage and treat wastewater to protect and improve human well-being. As a minimum, humans have to be provided with drinking water essential for life and for support services such as food production and consumption. Moreover, one tenth of the global burden of disease can be prevented by improving water management capacities in WSS systems (WHO, 2008). Poorly designed, maintained and managed systems undermine development, lead to collapse and increase this burden. WSS actors (managers, private operators and community-led suppliers) are continually challenged by flood events and are thereby called to enhance system resilience against the anticipated effects of environmental health hazards. Traditionally, they have been excluded as actors in flood management and ignored in policy development.

77 In many parts of the developing world, systems already operate under pressure without the presence of external hazards due to limited capacities and resources, inadequate access to reliable water supply and poor or non-existent sanitation systems. Countries with low access rates to clean water and improved sanitation are extremely vulnerable to floods (WHO/WMO, 2012; WHO, 2009). For instance, surface water is a primary source of drinking and household water for 10% of the population in least developed countries (UNICEF/WHO JMP, 2012). Their susceptibility to infectious disease signifies a great need for improved water supply in these areas and protection against flood-related health risks. Furthermore, open defecation in fields, bushland, water or other spaces is common practice among 15% of the global population and another 27% rely on unimproved sanitation technology (UNICEF/WHO, 2012). The risk of surface-, groundwater and soil contamination remains extremely high in these communities because excreta are directly exposed to floodwater. Flood risk in these regions is therefore significant and action must be taken to mitigate risk and build resilience.

78 Moreover, public-health protection is deeply rooted in sanitation and hygiene behaviour in parallel to provision of environmental health services (WSS, food hygiene, vector control) (WHO, 2002). The sole existence of WSS services does not directly imply that people will engage in behaviour that improves their health. For example, basic water supply does not guarantee safe water when open defecation upstream of the water source is common practice. Hygiene promotion and education must not, therefore, be separated from WSS systems and flood management. This background is preliminary to the scope of this Tool and is synonymous with increasing improved WSS technologies and education, rather than improving coverage rates.

3.4.2 Vulnerabilities of systems to flood events

79 It should not be assumed that WSS systems are easy to manage during a flood event. These are complex systems that require technical expertise and resources to maintain and restore when service is disrupted. For example, water supply consists of extraction, source protection, collection, treatment, storage and distribution. Sanitation systems include collection, storage, treatment and disposal. The scale of systems and their effective management play a central role in defining and reducing vulnerability of any of these components. Any damage that disrupts service can also be a source of contamination when harmful biological agents or chemicals (heavy metals, pesticides) enter the systems and pollute water sources, recreational waters, aquifers or soils.

80 Without adequate planning and preparedness, floodwaters can damage or disrupt WSS systems by several means across numerous components of the system. The hydraulic force of floodwater can rupture or wash out water-supply components (wells, hand pumps, valves, structures, pipelines) or create gaps or wide-open spaces in distribution/collection systems. Saturated soils or soil erosion can similarly displace wells, pipes and intakes. This type of damage will have significant implications for service provision and leave water systems extremely vulnerable to contamination. Inundation of simple latrines, septic tanks and cesspools can cause sewerage seepage into soil and additionally contaminate groundwater sources, as well as surface water. Raw-water sources can also become contaminated when floodwaters breach well walls (dug wells, boreholes, tube wells) or when flooding occurs in reservoirs and dams with insufficient overflow.

81 Further, high sediment loads transported by floodwaters can reduce the efficiency of water-treatment plants or cause system-wide failures when particles get trapped and clog the system components (pipelines). Facilities may otherwise experience increased loads of key processes due to failure of the surrounding facilities they have committed themselves to support. When water- and wastewater-treatment plants are stressed, their risk of inundation increases – either directly or by backflow from surrounding areas – and operations are threatened. Finally, any flood damage to power lines or major infrastructure (transport systems) will likely impact WSS activities, especially where back-up generators and pumping stations are damaged and communication or access is compromised. These immediate system impacts and their adverse effects on public health can take weeks, months or even years to be redressed.

82 Due to the close relationship between floods and the vulnerability of WSS systems, water-borne and water-washed diseases are at increased risk following a flood. Direct contamination of water sources or system components can quickly become an outbreak of infectious disease. A shortage or rationing of safe water can limit sanitary and hygiene practices and, where water quality is compromised, harmful pathogens increase the burden of disease. For example, when service is disrupted, open-defecation practices may increase, further inducing surface-water contamination and spread of water-borne disease. While human and animal excreta are major sources of disease-causing pathogens, some microorganisms can grow in piped-water distribution systems or waterways (e.g. guinea worm *Dracunculus mediensis*, *Legionella*) (WHO, 2011(b)). Overall, pathogen transmission is highly influenced by contaminated water sources, open defecation, and overflow of wastewater treatment facilities. The risk of pathogen transmission is enhanced by inadequate sanitation and poor hygiene, most notably inadequate hand-washing and food-handling. When systems are disrupted, early detection

and monitoring of water quality will prevent widespread contamination. Microbial changes in source and surface waters, especially coliforms (faecal indicators), must be monitored closely, together with chemical indicators.

83 Investment in, and maintenance of, WSS systems increase resilience and mitigate risk. The vulnerability of facilities and execution of site-protection plans will determine the likelihood and extent of flood damage. In this regard, flood mitigation and adaptation measures (land-use planning, flood-proofing, hazard-mapping, early warnings, etc.) are central to the protection of WSS systems. Management priority should be to identify vulnerabilities and make the necessary adjustment to minimize external disturbances and deterioration. For example, water-treatment plants located in low-lying areas with few pumping stations are more vulnerable than those with gravitational discharge and back-up pumps. Management should arrange infrastructure so as to minimize the effects of the flood.

84 A "whole-of-site" flood-mitigation strategy should be applied across the entire system, using a multi-hazard approach, targeting the key components of the system, which are source protection, abstraction, collection, treatment, storage and distribution. This process should be documented concurrently with the development of water safety plans (see section 3.4.4). Water assets (buildings, equipment, intakes, wells, etc.) can be strengthened by structural and non-structural measures. Flood forecasting, for instance, can play an essential role in operator preparedness and coordination with other stakeholders during emergencies. Minor design modifications (flood-proofing), such as headwalls around wells or use of slab covers in latrines, will also significantly reduce the risk of environmental health hazards. Where the age of the building and networks is a significant limitation, regular system maintenance and testing of emergency procedures can compensate for economically unfeasible investments to major improvements. Trade-offs between the cost of implementing hard and soft interventions and the expected severity of the flood will have to be factored into decision-making.

85 Pro-active maintenance of the system (cleaning of well platforms, drainage channels and pipes, chlorination procedures) will help maintain maximum hydraulic capacity during the flood and mitigate the risk of contamination. Flood forecasting and hydraulic simulations can help identify system vulnerabilities and a starting point where maintenance should commence (where it is most required). Operational damage to equipment and materials, as well as personnel safety and evacuation plans, should be accounted for. It is good practice to test standby generators, pumps, pumping stations and electrical supply to proactively mitigate risk. Regular testing and maintenance of generators with varying load-demand scenarios should be conducted to understand equipment capacity and prevent breakdown by overload or overflow of the facility if loads become unmanageable.

86 Detailed and accurate maps of WSS providers and their assets can significantly aid emergency situations in adapting to extreme weather events. Knowledge of existing network connections and creation of cross-/interconnections can save hundreds of lives and promote public-health security. For example, interconnections can quickly provide secure alternate water sources or, conversely, can be turned off to contain the risk of any contamination. Mapping exercises are largely dependent on available resources and expertise (personnel, funding, transportation, access to the community, etc). Water-user associations, funded by national/local government and public-health authorities, may assist in this exercise. When combined with flood-hazard-mapping, most vulnerable components of the system can be identified.

87 There is a need for water-supply and system operators to liaise with other agencies to optimize flood planning and preparedness measures. Communication between system operators and other stakeholders is essential for effective management and to ensure continued service during a flood event. Not only should operators be included in disaster-risk reduction plans but they should also be empowered to make emergency decisions that will benefit their communities. Meteorological and environmental agencies should work closely with operators, advising them about changes in weather, climate and catchment conditions that impact their operations. Early warnings, for example, can significantly assist operators in preparing for floods and activating timely response to coordinate efforts with nearby municipalities and their operators. Mutual aid between stakeholders such as engineers, contractors, national agencies, medical operators and electrical suppliers should be agreed upon and documented to provide timely relief (WHO, 2011(a)).

3.4.3 Urban versus rural systems

88 The responsibility of the water and sanitation sector is often fragmented between various actors (utility, private operators, community-based organizations, individuals), who separate in urban and rural areas. Globally, small-scale, decentralized water suppliers serve large fractions of the population rather than large utilities with piped distribution systems typical of urban areas (WHO, 2009). The exact definition of a small-scale supplier is ill defined; the arrangement is most common in rural areas but is also prevalent in urban and peri-urban settings (WHO, 2002).

89 Overall system design and technology are the major factors in distinguishing urban and rural systems rather than demographic definitions. Low-cost technology and simple, decentralized systems managed by private individuals (water users), collectively by communities (cooperatives) or a public utility (WHO, 2011(a)) are typical of rural settings, whereas large water- and wastewater-treatment plants with extensive infrastructure and varying types of service providers (conventional utility, public-private partnerships or community-based) are more often found in urban areas. Rural areas typically lack the capital and labour-intensive sewerage systems and water-treatment plants that serve urban areas. Instead, households may rely on household or community latrines, simple cesspools, septic tanks, small-scale community wastewater treatment plants, built-in latrine design (aqua privy) or may lack any means to treat human and household waste.

90 A major challenge for urban systems is matching supply to demand (WHO/UNICEF, 2012). Rapid urbanization and the widespread establishment of large, informal settlements in urban and peri-urban settings increases flood risk and vulnerability of these groups that often lack formal service provision, infrastructure and regulation. Excessive demand strains the functioning capacity of water systems to produce reliable and equitable supply. Similarly, treatment plants and distribution systems are typically unable to outgrow their expectations. Theoretically, the most resilient systems are well managed and supported utilities with ample expertise, training and capital that plan and protect them against floods or other extreme events. In reality, utility operation is often delimited by intermittent supply, illegal pumping and poor maintenance.

91 Urban runoff, a nonpoint source of water pollution is another pressing issue. Impervious surfaces found in urban areas enhance water volume and flow rates during floods and can transport a large amount of microbial and chemical wastes along the route that eventually terminate in waterways. Industrial hazards that leach chemicals and radioactive pollutants into soil and

groundwater further increase the risk of threats to public health. If separate systems do not exist for sanitary wastewater and surface waters (stormwater), then heavy precipitation events exacerbate public-health risk as combined sewerage overflows transport household sewerage and highly concentrated urban runoff into recipient water bodies. In this case, wastewater treatment plants reach capacity and backflow sanitary sewerage and stormwater, producing combined sewerage overflow pollution. The risk is reduced when stormwater-retention tanks/reservoirs are installed at wastewater treatment plants to store first-flush rainfall (initial 2–3 hours of rain) that can later be treated at the plant, instead of being released directly into the receiving waters. To mitigate this risk, separate sanitary-sewer and storm-drainage systems are highly encouraged. Large-piped connections combined with other point-source suppliers further complicate urban systems. For this reason, urban floods are more costly and complex to manage, given large populations and asset densities. Urban settings are also the core of economic and cultural activities, making them more vulnerable to the impacts of floods.

92 Conflicting agendas between service providers and their relative service areas hinder effective planning, rapid response and coordination of relief during a breakdown in service. Urban areas typically have more disposable resources and personnel to evaluate individual system components than rural areas, whereas the large distances among distributed populations living in rural areas increase the timeframe required to assess damage and coordinate relief following floods. Clear lines of communication must be established for an effective and comprehensive evaluation that enables rapid response in each setting.

93 Small-scale service providers face many management constraints (financial, equipment, personnel), which are compounded by flood events. They are typically untrained, unremunerated and inherently vulnerable to a disruption of service, given limited access to expertise, materials and support from institutions. System technologies range from small piped systems delivering water to individual dwellings or point sources, such as traditional dug wells, hand pumps, tube wells, boreholes or springs used for water collection and distribution (see **Table 2**). Although decentralized water-supply and treatment systems often have low operating capacity and are vulnerable to overflow during floods, they can deliver safe drinking water, should other sources become contaminated. The network of numerous point sources can effectively play a large role in outbreak relief, while at the same time posing a great risk of outbreak. Low levels of flood-risk awareness in rural areas support the latter case. Locally managed assets can further increase accountability and accessibility.

94 The major concern of rural WSS systems is the simplicity of design and level of protection for a water source to mitigate the risk of contamination. The majority of households served by unimproved sources are those living in impoverished rural areas (WHO, 2009) with little regulation of water standards. Water treatment at the household level is rare in rural areas, even if a piped system exists (Mahmud et al., 2007).

Table 2 — Water supply and sanitation technologies

Improved water supply	Unimproved water supply
Protected dug well or spring	Open surface water (river, pond, lake, channel)
Piped system	Unprotected dug well or spring

Improved water supply	Unimproved water supply
Rainwater harvesting	Mobile source or water vendor (tanker truck, cart with drum)
Public tap or standpipe	Tube well or borehole

Improved sanitation technology	Unimproved sanitation technology
Pit latrine with slab	No facilities (open defection)
Flush/pour pit latrine	Simple pit latrine without cover
Ventilated improved pit latrine	Hanging latrine/toilet
Ecological toilet	Bucket/pan latrine
Septic tank, cesspool	Public or shared facilities
Piped sewer system	

96 Improved systems are designed to reduce the risk of point-source contamination, especially against faecal-derived pathogens and are more resilient to flood pollution. Women and girls – the primary providers and managers of household water and hygiene – benefit most from improved systems. Equally, however, they suffer from low-priority water investments and are further burdened by flood events. Wherever possible, therefore, an attempt to improve supply and sanitation technologies should be made. For example, springs or wells can be quickly improved by building a protective headwall above the ground to prevent inflow of rising floodwater or by lining the upper 3m (10ft) of the well to protect the aquifer from surface- and groundwater contamination from flooding. Further upgrading of a shallow hand-dug well to a tube well or borehole with sealed well walls (lining), casing or other structural measures should be taken to improve the water source. These technologies are considered to be most climate-resilient and, although capital costs may be high, they are more efficient and will protect the communities they serve (WHO/UNICEF, 2012). Provision must also be made for adequate spacing between water sources and sanitation facilities to mitigate the risk of groundwater contamination. It is highly desirable that sanitation facilities are located at least 9m (30 ft) from water sources and in downstream areas.

97 Human behaviour also plays a critical role in reducing health risks associated with hazardous events (floods). Wells should be fenced in and covered with a slab to protect against livestock and other debris from entering. Use of a basic hand pump or a more advanced electrical pump is the preferred method to restrict human contact and also enables water to be pumped out of the well in the case of flooding. Such improvements in the design and implementation of controls over water-supply inputs and processes are referred to as water safety plans (see section below).

3.4.4 Water safety plans

98 The adaptation and mitigation of environmental health risks are a major challenge for water-service providers, regulators and policymakers. The responsibility of due care and diligence of safe drinking water rests ultimately with the water supplier (utility, private operator) but standards are set and enforced by the government. In the context of floods, water safety plans **(WSPs)** are contingency plans which use a comprehensive, risk-management approach to

"consistently ensure the safety and acceptability of a drinking-water supply" from catchment to consumer (WHO, 2005(b)) (see **Box 7**). WSPs focus on holistic identification and management of hazards by implementing control measures that increase the overall resilience of water-supply systems. In this sense, they can be used as a primary vehicle to reduce the water-related burden of disease, enhance microbial and chemical water quality and protect communities from hazards, including floods.

Box 9 — Water safety plans *(WHO, 2011b)*

Water safety plans are normally comprised of three components:

- **System assessment:** determination of the existing system capacity to fulfill the required water quality;
- **Effective operational monitoring:** monitoring of the existing system-control measures that play a vital role in securing the safety of water;
- **Management:** management of the plans that are to be executed from normal conditions to extreme events.

99 Ideally, each water-supply system should have its own WSP, although WSPs can be specific to (a) particular process(es) if an entity is involved in one or more aspect(s) of service provision. The latter arrangement is more relevant to small-scale decentralized systems (hand-dug wells, community-based supply), where the generic or guided WSPs are more appropriate (WHO, 2005(b)). In the former case, large-scale utilities are the supply-chain provider charged with developing, implementing and updating the WSP for their relative service area. A multi-stakeholder approach, integrating major players who influence water quality, is deemed necessary when preparing a WSP (WHO, 2005(b)). For example, industrial activities in the catchment can produce water pollution if not properly managed. All relevant stakeholders should therefore be consulted to understand their practices and capacities to protect the quality of the water. Communication among actors promotes collaboration and capacity-building that can be capitalized upon during an emergency situation.

100 Bearing the multi-stakeholder approach in mind, the first step in formulating a WSP is to designate knowledgeable and experienced personnel, familiar with the water-supply process and its vulnerabilities on the WSP team. A range of diverse actors – water operators, hydrologists, geologists, public-health officials, engineers, water-quality control staff, technical staff and, especially in rural areas, the community representative – form the team and are led by a senior utility manager (WHO, 2005(b)). They should create a detailed description and flow diagram of the entire system, traced from catchment to the consumer. This critical step will guide the risk-assessment process to identify any potential hazards (physical, biological, chemical, radiological) at every critical step (water source, extraction, treatment, storage, transport and distribution, wastewater treatment). Hazards are evaluated within the framework of WSP objectives, which aim to ensure safe drinking water by (WHO, 2005(b)):

- Preventing contamination of source water;
- Treating the water to mitigate or reduce contamination to a residual level; and
- Preventing re-contamination during storage, distribution and handling of drinking water.

101 All hazards/hazardous events must be documented, assessed in terms of risk and prioritized for effective management. Key assumptions regarding likelihood, timeliness and severity of the hazard are inferred, using historical data, expertise and informed estimates based on population vulnerability and institutional capacity.

102 Once hazards are prioritized, control measures must be developed to reduce risk to a tolerable level. Many water-supply systems already have established controls – mitigation measures – in place. These are essential components of a WSP and are directly or indirectly linked to the IFM approach. For example, regular maintenance (cleaning) of piped distributions prevents silting during floods, thereby reducing the risk of contamination from backflow/overflow. Another, broader, example is land-use planning in the catchment to protect the quality of water sources. Wherever possible, actual functioning of the system and identified control must be validated and monitored to ensure that they work as intended. Facts can be corroborated by visual inspection, field and site visits, conducting control tests, simulations and independent third-party evidence (externally prepared water-quality audits).

Box 10 — Examples of water safety plan control measures to mitigate flood-related health hazards for different activities within the water-supply system *(WHO, 2005(b))*

Source water and catchments

- Land-use planning procedures and control of human activities within the catchment
- Diversion of local stormwater flows and runoff interception
- Protection of waterways

Water extraction and storage systems

- Use of available water storage during and after periods of heavy rainfall
- Appropriate location and protection of intake
- Proper location and construction of wells, including casing, sealing and wellhead security

Water-treatment system

- Process controllability of equipment
- Availability of backup systems (pumps)
- Alternative treatment

Distribution systems

- Distribution-system maintenance
- Availability of backup systems (power supply)
- Cross-connection and backflow prevention devices implemented
- Fully enclosed distribution system and storages

103 Formal monitoring of controls and ongoing risk assessment is critical to ensure continued effectiveness of the WSP over time. Three additional activities facilitate this process (WHO, 2005(b)):

- Compliance monitoring. Verifies controls are functioning effectively and corrective action is taken for any controls that do not adhere to set standards (water quality);
- Internal and external aud of operational activities. Independent and unbiased audits attest to water quality and effectiveness of controls while further assessing risk;
- Monitoring consumer satisfaction. Ensures customers accept and are satisfied with water-quality standards.

104 Finally, management needs to take a hands-on approach to water safety. The WSP is not a static document but a robust tool designed to ensure that adequate water quality (and quantity) is consistently delivered to consumers. Standard operating procedures need to be devised for any detected deviations, remedial action and communication of incidents to key staff members. Ongoing support programmes that enrich the WSP include training, customer-support services and research and development of the plans themselves (annually or after a major incident). Effective communication among all personnel and relevant actors is a prerequisite to foster commitment and develop capacities to mitigate risk and build system resilience.

Box 11 — Water safety plans in rural Bangladesh *(Mahmud et al., 2007)*

Bangladesh is one of the poorest, most densely populated countries in the world and faces extreme pressure from climate change. Recurrent floods and the threat of sea-level rise challenge the water-supply system, particularly dug wells, which are used in arsenic-affected areas across Bangladesh (WHO, 2009).

In response, WSPs were piloted in 82 rural communities by three NGOs over a 10-month period in 2006. WSP training was delivered to water caretakers to mitigate microbial and chemical contamination of small-scale systems and was reinforced by hygiene education aimed at water-point management committees, caretakers and communities.

This dual effort strengthened the implementation and delivery of the WSPs through the entire water chain, ending at consumers. In several cases, caretakers took the initiative to improve their water source, repair damaged infrastructure and relocate away from animals and sanitation facilities.

Improvements translated into enhanced sanitary conditions and reduction in microbial contamination, especially for individual technologies (dug wells, tube wells) and improved health outcomes (12% reduction in diarrhoea incidence against baseline).

National support for WSPs in Bangladesh has now been given: major water-supply projects are committed to implementing WSPs in their projects and WSPs have been identified in major sector documents, as required.

105 Recent experience has shown that WSPs have been primarily adopted by utilities in developed countries. They are slowly emerging in developing countries and are in their infancy at the small-scale supplier level, where the greatest potential to increase resilience exists (Mahmud et al., 2007). Similar to the process described above, WSPs designed for small-scale providers are based on a thorough understanding of the system and the potential hazards it is exposed to. Building this fundamental knowledge and expertise in the community is central to risk reduction and serves as a transition from untrained and vulnerable operators to technically oriented and resourceful suppliers. Due to limited initial capacities, external assistance or guidance is necessary to guide

development of a WSP. Educational materials should be developed with community members that capitalize on their existing belief systems and resources. Identification of hazards and controls to mitigate risk should be as specific as possible for every technology used. For example, use of a slab cover over well walls, safe distance of wells or boreholes from sanitation facilities and livestock, headwalls and aprons around wells and elevated sanitation facilities all reduce the risk of contamination. Using this approach, all sources are improved in some measure. Beyond physical improvements and upgrades, management of the water system is drastically altered. The water supplier becomes responsible for verifying the effectiveness of the WSP, including validating and monitoring the controls and reporting any deviations. These activities promote a dynamic approach to water management that builds health, climate and flood resilience. It also provides an important opportunity to incorporate and empower women, since they are typically responsible for the household water supply.

3.5 The need for a participatory approach

3.5.1 Stakeholder engagement

106 Successful IFM design and implementation are largely dependent on engaging and mobilizing river-basin stakeholders and their resources to manage flood risk. Flood awareness and awareness of flood-related health risks are a prerequisite in this process. Individuals must understand the complexity of floods and their impacts through effective dialogue that promotes their personal and collective interests. Communities that are aware of risk are more motivated to design and implement flood-mitigation and adaptation measures. Engagement in IFM effectively becomes a tool of ownership, investment in public-health protection and sustainable development.

107 Stakeholder participation contributes to the development of a holistic IFM strategy with an underlying attempt to balance conflicting priorities. Stakeholder involvement is essential at the onset of the planning process, because it allows for groups to expose their vulnerabilities and contribute to capacity-building. Stakeholders include all those who reap any socioeconomic, environmental or cultural benefit from the river basin and are generally categorized into eight main groups (WMO, 2006):

- Government ministries, departments and agencies (Water Resources, Environment, Natural Resources, Civil Defence, Health, Rural Development, Land Management, Agriculture, Public Works, Transport, Communications, Education, Disaster Management);
- Flood-prone communities;
- Other basin organizations (water-user associations, watershed-management committees, river-basin organizations);
- Scientific institutions and professionals (hydrologists, meteorologists, water and sanitation engineers, climate change and hazard related institutions, health specialists);
- Registered NGOs;
- Voluntary organizations (youth groups, women's organizations);
- The private sector (private supply and sanitation-service providers, telecommunications, waste management);
- The public.

108 Every group should have an equal opportunity to voice its concerns and be viewed impartially in order to foster trust and build commitment. The local environment and socioeconomic context strongly influences flood-risk management practices, rather than generic national standards. A tailored approach that incorporates traditional knowledge into monitoring and management of floods and health hazards is, therefore, a winning strategy.

109 Participation methods range over a broad spectrum with varying degrees of responsibility, motivation and risk-sharing. Success of the process depends on continuous dialogue complemented by consultation, collaboration, partnerships or self-mobilization mechanisms (WMO, 2006). The inclusion of relevant stakeholders rather than every stakeholder should be planned for in order to minimize redundancy and enhance efficiency. At the national scale, it is important to define the roles and responsibilities of each group in order to maximize synergies that will permeate down to local levels.

3.5.2 Community participation

110 IFM strategies are reinforced by community efforts to actively prepare, respond to and recover from flood events and their multidimensional impacts. Community participation facilitates ownership and action for disaster preparedness and risk reduction akin to stakeholder engagement as the platform for IFM development and implementation. The principles of community participation are widely applicable to the underlying goal of sustainable development and should be applied in the management of floods and health-action priorities. Commitment is largely reflected in a community's sense of ownership and perceived benefit of the outcome (reduction of risk and use of floodwater). Locally tailored, inclusive strategies build resilience by planning their own level of residual risk and devising action (problem solving) to achieve it.

111 When community members collaborate in an inclusive and equitable way to inform and create disaster-mitigation and adaptation programmes, they are better prepared to respond and recover in the absence of external assistance. Strong community leadership and organization is central to effective action during a flood emergency. Participation does not come without challenges and community members must collaborate equitably to balance conflicting priorities. Priorities must take into account the collective interests of the group, rather than be biased by political or economic intentions. Overall, community participation in flood management contributes to (WMO, 2008):

- Efficient coordination of individual efforts;
- Synergy building and cost reduction in an emergency situation;
- Solidarity and effective cooperation among community members;
- A platform for consensus and conflict resolution;
- Reinforcement of national and local government efforts;
- Synchronization of flood-management efforts with other development activities (health action, WSS).

112 Finally, participation is an ongoing process that is expected to build resilience over time and vulnerable groups must not be excluded from the process.

4 HEALTH EMERGENCY RESPONSE DURING THE FLOOD EVENT

113 The ability of communities to cope with and manage changes in water quality and quantity are key determinants of flood-related health outcomes. These changes are subsequent to an increased number of pathogens or chemical agents, damage to critical infrastructure, failure of WSS systems or additional stress on existing/new resources due to overcrowding at relief or medical facilities. Flood-mitigation and adaptation measures are designed to protect the public by planning and preparing for environmental health hazards. The extent and effectiveness of planned measures will be tested and validated during the actual flood event. Significant weaknesses will quickly reveal the immediate impact on basic human needs, including safe water supply, adequate sanitation, shelter, food security and access to health/medical care. All these issues will require remedial action or alternate solutions to maintain services during the flood. While the type, duration and severity of the flood cannot be ignored, the capacity to respond to even the largest scale of floods is largely a reflection of planning and preparedness efforts.

114 During and in the aftermath of the flood, information must be quickly collected and analysed in order to launch relief efforts on the local, catchment or national levels, based on actual needs and available resources. Any assumptions should be corroborated by sufficient evidence or expertise to enable an effective and real-time decision-making process. Otherwise, irrelevant assumptions counterproductive to actual needs will likely be made. Open lines of communication between key stakeholders will ensure that information is capitalized upon and coordination mechanisms are functioning effectively.

115 The following list provides key emergency-response activities essential to protect public health during a flood:

– Needs assessment and intervention strategies;

- Public warning and timely evacuation of high-risk areas;
- Search and rescue;
- Access to health-care facilities and medical treatment (including first aid, referral cases);
- Disease control and outbreak programmes;
- Mass casualty management, including establishment of temporary health facilities wherever necessary;
- Public-health surveillance;
- Provision of clean water supply and safe sanitation;
- Household action and safety;
- Hygiene promotion.

4.1 Rapid needs health assessment

116 A rapid needs health assessment, conducted by the local government authorities, is the first step in evaluating immediate needs of flood-affected communities. While this step is focused on quantifying actual flood-related health impacts, non-structural flood management measures (early warning systems, flood forecasting) can assist in alleviating further adversity and informing intervention strategies. For example, flood-hazard maps can identify severely flood-affected areas that require priority action or safe areas (safe havens) to evacuate to. In this regard, the health assessment provides quick access to relevant information for emergency decision-making. Quantitative and qualitative aspects to include in this assessment are:

- Geographical location and extent of floodwater (localized or widespread, changes in flow regimes duration, depth and intensity etc.);
- Number of people affected, their general demographic characteristics and vulnerable groups (women, children, the elderly);
- Baseline health condition, vulnerability(ies) of the affected population and those who require ongoing medical treatment (persons with mental health disorders, non-communicable diseases, HIV/AIDS);
- Immediate environmental health hazards (physical, biological, chemical, radiological) at risk;
- Basic survival needs (water, food, shelter, medical care);
- Damage to infrastructure (private dwellings, public buildings, roads, etc.), including medical facilities and flood shelters;
- Human capacity and resources available for emergency response (technical support staff, community-mobilization mechanisms, technology, emergency preparedness and training, local supplies and material, etc.);
- Barriers to relief efforts (logistics, transport, physical environment, culture, politics, operational control and coordination);
- Medical preparedness and capacity to reduce morbidity and mortality (medical supplies, staff, facilities, training, disease and outbreak control, health and sanitation campaigns, public-health surveillance).

117 Once information is collected, it must be analysed and interpreted to identify immediate health priorities and create objectives. Effective response strategies that yield the greatest

benefit can then be formulated. For example, disease control and outbreak preparedness should commence where significant risk of disease has been prioritized or food-supplement programmes where floods have devastated rural villages. Early warning systems, evacuations and provision to satisfy basic needs (safe drinking water in adequate quantity, food supplies, clothing, shelter, medical care) remain among the top flood-related interventions to address public-health security. The outcome of the rapid needs health assessment is therefore a tailored action plan of relief efforts based on the following steps (Twin Cities Metro Advanced Practice Center, 2007):

- Identify hazards and potential threats;
- Assess public health risks and determine priorities;
- Develop short-term objectives and long-term goals;
- Strategize response interventions;
- Decide whether external resources are required;
- Perform intervention strategies;
- Follow up with public-health surveillance;
- Reassess hazards and potential threats.

118 Rapid needs health assessment is an ongoing process and, although designed objectives may be short term, long-term goals provide guidance for continued action and strategies to achieve continued and sustainable results. The results should be passed up to provincial/state and national levels to facilitate information-sharing and the best coordination of response wherever necessary. Following the initial assessment, more technical information should be gathered to inform detailed response plans. For example, an immediate objective may be to ensure the safety of all persons from floodwaters, while a long-term goal may be to protect all water technologies from inundation and thereby minimize the risk of water-related disease. Bearing in mind that disaster management is an ongoing process with no panacea, taking a step back to objectively evaluate the situation may be the key to a fast-paced and dynamic problem-solving approach during emergency situations.

4.2 Displaced population health protection

119 High-risk populations may be ordered to evacuate flood-prone or flood-affected areas as part of preparedness or response activities. The role of flood forecasting, early warning systems and hazard-mapping cannot be undermined as a precursor to timely and successful evacuations. Characteristics of the flood (intensity, severity, duration) and mitigation measures will largely dictate when warnings and evacuation orders should take effect. Public authorities are responsible for disseminating precautionary messages that protect people from floods and trigger mass action. In response, community members must mobilize quickly to execute plans and anticipate action for impending flood damage (activate local contingency plan that includes search-and-rescue teams). The levels of community trust and flood awareness are significant aspects of effective evacuations. Otherwise, people may disregard warnings or lack the means to mobilize without external assistance.

120 Evacuations may be temporary or lead to permanent displacement (flood refugees), especially where significant flood damage exists, institutional capacities are weak and external aid is limited. Emergency displacements threaten public health due to high population densities, large masses of people being evacuated along a single route, poor planning of WSS systems, overcrowding and poor hygiene. These factors often lead to an increased risk of biological hazards, particularly communicable disease (WHO, 2002). Populations become highly susceptible to pathogen transmission (faecal–oral, person to person) and exposed to vectors that quickly exploit new habitats. Poor baseline health and malnutrition further exacerbate the incidence of disease and outbreaks.

121 Safety and security precautions should be taken to mitigate the risk of human-induced secondary health hazards during displacement emergencies. For instance, women and children are at heightened risk of gender-based violence, abuse and exploitation following natural disasters, including floods, because social norms and legal protection are often weakened or break down (Inter-Agency Standing Committee, 2005). As a starting point, any available information should be collected about existing physical or sexual based violence. Casual discussions with the community can serve as an entry portal for intervention and awareness-raising. A plan of action for coordination, prevention and response to violence and discrimination should be developed, using a participatory approach that includes victims, vulnerable groups and those who suffer from inequality and discrimination, who also require special attention. Designated public-health authorities or trusted members of the community should be assigned to these groups to ensure they are accounted for and have equal access to quality water, sanitation and health care services.

122 Well-coordinated evacuations and properly planned settlement sites are central to protect public health of displaced persons. Critical components include:

- Timely early warning systems, accompanied by clear and concise evacuation orders and protective health care;
- Messages that are communicated in local languages and understood by a non-technical audience;
- Planning for the number of displaced persons and their demographics, displacement term (temporary, permanent), settlement site selection and capacity;
- Evacuation management (steady, continuous flow of persons rather than high-density, discrete movement, access to water resources and emergency health-care services along route, trained staff);
- Planning of WSS systems at settlement sites (population water requirements, water source and sanitation facilities management, water-treatment processes, wastewater disposal etc.);
- Hygiene education and supplies (soap, food utensils, water vessels, sanitary and reproductive health kits);
- Vector control (waste management, local management committees dedicated to vector control);
- Inclusion of the whole population (gender equity, social inclusion, vulnerable groups) in health campaigns and settlement-support activities (provision of mental-health support);
- Training in gender-based violence prevention and response action for relief staff, including men and women at shelter sites.

4.3 Relief shelters and temporary health facilities

123 Adequate facilities to protect displaced flood victims from flood-affected areas, as well as temporary medical facilities, must be arranged. Establishment of relief and health facilities should be accompanied by timely evacuation orders that assign people to alternate facilities in their proximity. A few temporary sites should be pre-planned to factor in uncertainty of flood severity and impacts. If necessary, impromptu facilities can be established and, wherever possible, should start functioning before distressed flood victims arrive. Alternative health facilities (mobile clinics, field hospitals) should be avoided unless existing hospitals and health-care units are inoperable, an outbreak has occurred or if populations have limited access to health services due to displacement or isolation (Sphere Project, 2011). Otherwise, it is typically more effective to reinforce nearby hospitals and other health-care facilities by transferring medical resources and staff from the dysfunctional units.

124 Large public buildings, including schools and community centres, can be designated as safe shelters. In chronic flood-prone areas, temporary shelters can be created using portions of embankments that should be strengthened, raised and widened (WMO, 2005). Proximity to affected populations, injury sites, accessible transport, multi-hazard proof design and suitability of existing buildings are all considerations to bear in mind when planning sites. Critical infrastructure (health-care facilities, community centres) and emergency storage facilities containing food, water and medical supplies should always be flood-proofed to provide refuge from rising water levels to ensure goods and services are not damaged or disrupted. The choice of flood-proofing method depends on expertise, local conditions and available resources. Additional measures to strengthen physical infrastructure go a long way during an emergency situation and, as a minimum, all selected sites should be situated in elevated areas. The ability to mobilize resources (human resources, supplies) quickly will pay off as the event unfolds; standby flood defences (e.g. sandbags) that provide emergency protection around the site and individual equipment should be taken where significant flood damage is expected. Regular maintenance will ensure that infrastructure remains resilient. Additional consideration should also be made for indoor air pollution in shelter camps and the related health consequences of biomass-energy use. Wherever possible, cooking and heating with biomass (wood, coal, dung, crop waste) should be avoided in indoor spaces to mitigate inhalation of particulate matter and avoid associated illness (respiratory disease, pneumonia).

125 Equitable distribution of drinking water and access to sanitation facilities will be required for displaced persons. Therefore, provision of water supply and waste disposal is equally important to plan at the sites or should be planned as soon as possible to minimize the risk of water contamination and disease. Priority is to serve these populations, as well as hospitals, long-term care homes and other medical facilities with an uninterrupted supply of water, food and medical supplies. Women and men should be equally integrated into decision-making over water and sanitation services at relief shelters and sites. Decisions that maximize the safety, privacy and dignity of women and girls, especially when planning communal facilities, should be made (Inter-Agency Standing Committee, 2005).

4.4 Water-supply and sanitation systems

4.4.1 Initial damage assessment

126 A supply of safe drinking water and adequate sanitation is at the top of the priority list during a disaster or state of emergency (WHO, 2011(b)). WSS systems, however, are inherently vulnerable to flood damage and service is too often compromised by floodwaters. Interruption of a water supply has a pervasive effect far beyond the communities living in flood-affected areas. Hence, the emergency plans to maintain or restore WSS systems cannot be taken lightly.

127 Public-health priority remains providing flood victims with safe drinking water in adequate quantity for survival and to reduce the risk of water-related disease. Local government authorities should conduct an initial assessment of WSS systems at the onset and throughout the flood event to quantify the extent of damage and develop an emergency response plan for service provision. Key community members may perform this task for small-scale community supply and where systems are managed by multiple actors: as is often the case in urban and peri-urban areas, collaboration is required to assess holistically the functioning of systems. Adequate training in answering the following questions is vital to the assessment and to prioritize response:

- What are the main geographical areas affected by the flood? Are they urban, peri-urban or rural communities, remote or accessible?
- Who are the main water users? What are their immediate water needs? Are their needs being met?
- What is the service provision for these areas (water supply, treatment, distribution, storage, collection, sanitation, waste and wastewater disposal)?
- Which components of the system are operational (fully, partially), damaged, contaminated or at risk? Can service remain operational, even to some extent? Are small-scale community supplies protected?
- Is the power supply compromised?
- What is the extent of damage to critical water assets (wells, water mains, pipes, reservoirs, plants, control systems, sanitation facilities)? Have any components been interrupted or shut down before the flood?
- Where is additional water-quality testing and treatment required?
- Are emergency water-treatment methods stocked at the plant and available to households (sodium chloride)? Are they locally available from a reliable source?
- Are there sufficient technical expertise and materials (generators, pumps, cement, mortar, spare valves, etc.) available to rehabilitate and regain water supply as soon as possible?
- Will any resources have to be outsourced?
- Has service in health care or relief sites been compromised?

128 The implications of damaged or disrupted systems must be examined in the greater context of immediate water needs, available resources and service recovery. Priority response can then be developed to relieve distressed flood victims having the greatest water and medical needs. During emergencies, people require 7.5–15 litres of water per day for basic survival,

while those with medical conditions require as much as 60 litres (Sphere Project, 2011). In this situation, water quantity overrides quality, bearing in mind that the responsible authorities will commence improvements imminently. Sites that lack alternative water sources, especially in densely populated and vulnerable areas, will require immediate attention. Special attention should also be given to both water supply and sanitary requirements for vulnerable groups, such as physically and mentally challenged persons, the chronically ill, the elderly, and children, to ensure their needs are fully met. Furthermore, it is important that supplies can be quickly sourced from local suppliers rather than stockpiled across various sites. Relief operations will be largely dictated by the extent of damage and remediation required to reinstate functioning of WSS systems to satisfy these water requirements.

4.4.2 Operational plan to protect public health

129 WSS system operators are a vital element of operational plans to ensure safe drinking water and excreta management during a flood. These actors should liaise closely with key stakeholders to anticipate external hazards and possible risks to consumers. For example, communication with health authorities may reveal significant system weaknesses (contaminated sites) and offer insight to the extent of damage. Any system damage or contamination must conversely be communicated to local authorities, who must then issue water advisories or restrictions. Findings of the rapid needs health assessment should also be shared with the operators. Excessive medical demands can be used as a proxy for the expected increase in water demand during an emergency. Water-supply authorities can use this information to plan for additional requirements and operating pressure of their systems.

130 The expertise of operators and their ability to collect/share information, as well as to mobilize resources, will guide the development of operational plans. In addition, water and sanitation operators should document the flood event and remedial actions taken as the situation unfolds. Follow-up can then be made during the recovery phase and long-term adjustments can be factored into the emergency planning process. Depending on the nature and extent of service damage or disruption, operational plans to maintain adequate service include:

- Isolation and protection of existing water sources;
- Use of alternate water sources and sanitation sites (nearby wells, springs, treatment plants, portable latrines or defecation sites);
- Linking water services to external networks and systems (cross- and interconnections of piped systems and reservoirs);
- Provision of uninterrupted supply;
- Use of standby system components (backup generators, pumps);
- Emergency repair to damaged components and power supply;
- Sustained operation of water and wastewater treatment works;
- Additional treatment to raw water;
- Water restrictions and segregated use;
- Use of mobile water tankers/storage units.

131 Intensified water-quality monitoring is essential for all existing, alternate and standby water sources during a flood. Biological and chemical monitoring will ensure that widespread

contamination is minimized by identifying and isolating any contaminated sites. If testing cannot be performed (small-scale community supplies), it should be assumed that waters are contaminated and additional water-treatment measures should be taken by the service provider, as well as individual households. (See **Section 5.1** for detailed information on water-quality control.)

132 If raw water has been compromised by floods, the immediate response should be to isolate fully functioning sections and bypass damaged or contaminated components. This will prevent further contamination, while continuing to deliver service. During remediation efforts, alternate sources should be identified to maintain an adequate supply. Due care must be exercised when identifying and planning alternate raw-water sources; nearby unprotected sources can be more harmful than protected ones compromised by the flood. For instance, surface waters should always be assumed to be contaminated and used only as a last resort, when groundwater sources are not available, insufficient or contaminated. If alternative sources are downstream of the settlement, it is imperative to relocate livestock beyond human source waters and demarcate animal watering areas (fence them in).

133 Where plans for new or standby sources are developed, extra effort in qualitative monitoring and a precautionary approach should be taken to maintain water quality at these sites. New springs or wells should be improved and protected against hazards by developing WSPs. Shallow tube wells or other water sources should be quickly constructed in emergencies under the leadership of those with technical expertise (local skilled workers). They should be constructed above the flood level and in accessible locations that yield maximum benefit for the flood victims. Where dug wells or open water holes exist, they should be deepened, lined and sealed with earth to increase yield and protect the source. Ideally, planning for available construction materials, sufficient expertise and site selection should be conducted, either in advance of the flood or coordinated on an ad hoc basis.

134 Linked water services can also serve as an efficient alternate water source. Knowledge and the mapping of inter- or cross-connections should be well documented during the design and engineering of systems (WHO, 2011(a)). This information should also be updated, whenever necessary, in order to use the knowledge of connections during extreme weather events (WHO, 2011(a)). Flooding can also alter available water inputs and, in response, systems may operate at reduced pressure or intermittent supply. In these situations, the risk of contamination by ingress or backflow from contaminated areas increases (WHO, 2011(a)). De-pressurized systems and those serviced by intermittent supply must be closely monitored to ensure drinking water remains safe.

135 The ability of operators to repair their systems will be tested during the flood. Any mechanical or structural damage to existing technologies should be repaired as soon as possible to prevent contamination of the water supply and avoid long-term maintenance issues. Immediate efforts should be to restore the system to its pre-flood condition rather than aiming for significant improvements. Emergency repair and replacement of pumps (hand and electrical), dug wells, tube wells (lining, headwalls), valves, intakes or pipes are contingent on local supply, resources and technical knowledge. Any repaired or newly installed components must be disinfected, for example with a chlorine solution, flushed out with treated water and monitored for contamination before use.

136 Mobile water-storage units should be used in the event that piped supply ceases or alternate sources are too distant to provide an immediate drinking-water supply. The capital, maintenance and operational costs of mobile water storage are very high and should be considered only when all other options are unsuitable. The quantity of water to be transported will depend on the number of people affected, daily drinking-water requirements and other immediate water needs (bathing, household). In the case that untreated water will be supplied through a piped system, the use of mobile units is highly recommended (WHO, 2011(a)). Any potential contamination caused by the untreated water to the piped system will be costly, timely and inefficient to remediate. Depending on available resources and emergency planning, a variety of water transport and storage units can be used, such as road tankers, pillow tanks or portable tanks. All units must be disinfected prior to use and water-quality tested before distribution.

137 Sanitary inspection can be taken as an initial step to prevent and control contamination (faecal) of water sources. It will give a first-hand idea with regard to the action that should be undertaken to protect water sources (WHO, 2011(b)). Sanitation priority lies in isolating and containing faecal matter to minimize contamination. This includes preventing sludge and waste from entering surface- and groundwater by inundation of household and public latrines, cesspools, septic tanks and protecting water sources (boreholes and wells) from polluted floodwaters. Interconnections can also be used to divert the flow of sewerage to other sites, wherever possible. Depending on the quality and quantity of the produced wastewater, it can be discharged into normal watercourses, infiltrated into soil, disposed off by evaporation or used in agriculture (WHO, 2002). Selection of these sites should be planned in advance, based on environmental and demographical factors. Coordination of emergency waste- and wastewater-disposal processes should be developed as a part of national disaster-risk-reduction plans.

138 Inundation of household or publicly shared latrines can pose a serious threat to human health, especially in rural areas where small-scale service providers have limited resources and expertise about flood risk. Human faeces contain pathogens that can enter the body via contact with contaminated food, water, kitchen and cooking utensils or other objects. Efforts should be prioritized to allow people to use their household latrines. In the event that household or community sanitation facilities are compromised, alternative facilities must be established. Existing community centres and schools can serve the general public if they are still operational. Otherwise, quick construction of emergency trench latrines (shallow or deep) or simple pit latrines is encouraged. Defecation in rivers and surface water, including the open sea, should be highly discouraged and, if necessary, allowed only in designated areas downstream of other human use. Cultural practices and gender equality must be factored into design and management of temporary facilities. A public-health committee in charge of managing sanitation facilities should be created to ensure latrines remain clean and safe.

139 Changes in river-basin flow and water chemistry alter the water quantity and quality available to different user groups with different water requirements. During floods, clean water often becomes scarce and availability should be prioritized, based on user needs, using a balanced approach. Water restrictions and voluntary usage reductions should be enforced in the catchment to reduce stress on already pressurized systems. Industrial and agricultural water users can play a large part in demand management, as well as private suppliers, who may unjustly increase price to reflect scarcity. Their commitment to water resource management and public-health safety should be reflected in stakeholder engagement and a participatory process. Clear and timely messages must be communicated to water users for their cooperation; reasons for the

rations, how the rationing system will work and when advisories are rescinded must all be explicitly stated (WHO, 2002).

4.5 Household action and safety

140 Floodwaters impact many household activities and create general safety concerns. Both damage to assets (livestock, crops, personal possessions) and inundation of dwellings threaten livelihoods, while changes in drinking-water supply and personal hygiene adversely impact physical, mental and social well-being. Resilient families that are prepared for floods will have the advantage with reduced health risks and the capability to protect themselves during the volatile times that ensue.

141 According to (WHO 2011(b)), "access to safe drinking water is essential to health, a basic human right and component of effective policy for health protection". Hence, following a flood, when water sources are contaminated, water consumers must exercise caution. Water consumers must be informed of deterioration in the water quality. The public also shares responsibility for keeping water safe and informing authorities of contaminated water sources. As a minimum, any changes in water turbidity, odour or taste can be an indication of water pollution. If water quality cannot be tested, it should be assumed that water is contaminated and individuals must treat the water prior to drinking. When ground- and surface waters are deemed contaminated, public-health warnings should come into immediate effect for all point-of-use drinking water and water used to prepare food. The risk of widespread water contamination and incidence of communicable disease can be significantly reduced if the public is attentive to public-health messages and follows guidelines for household-water treatment, safe storage and personal hygiene.

142 Clear and timely information detailing how to mitigate health risks must be communicated by health officials, bulletins, media or any other means. The messages should be in local languages and understood by a non-technical audience, especially vulnerable groups. Main components include:

- Water-contamination notice;
- Recommended household water treatment and safe storage method;
- Good hygiene practices (hand-washing, safe food handling and storage);
- Early disease recognition (less than 24 hours) and location of treatment facilities.

143 The extent of damage on WSS systems, degree of deterioration in water quality and available distribution channels are all important factors to consider when selecting a water-treatment method to implement. The most appropriate treatment method depends on effectiveness of the technology, availability and affordability (WHO, 2002). Distribution of water vessels should also be considered to ensure the technologies distributed or recommended are viable. Moreover, they must also be culturally accepted for sustainable use by the household.

144 Generally, those served by improved technologies are more likely to treat their water using basic methods such as boiling, filtering, disinfection or sedimentation (WHO/UNICEF, 2012). While some of the methods rely on outside aid and commercial production (filters), many methods are

simple, inexpensive and do not require any additional resources. The most widely implemented methods are:

- Storage and basic sedimentation of untreated water for 12–24 hours in a clean container with a lid. The longer the water is stored and the warmer the temperatures maintained (direct sunlight), the better the quality will be. As particulate matter settles to the bottom of the container, harmful pathogens are removed and die off. Clean water should then be decanted into a clean vessel.

  On a large scale, water samples should be taken to inform sedimentation-rate guidelines according to container size that can be communicated to the public.

- Boiling water provides the ultimate means of sterilization. In order to inactivate pathogenic bacteria, viruses and protozoa, water should be heated up to a rolling boil, after which it can be removed from the heat and left to cool naturally. It is important to protect water from post-treatment contamination, especially regarding the storage conditions (WHO, 2015).

  If water is turbid, settled particles can be removed using the sedimentation method described above or filtered prior to boiling. During emergencies, households often lack resources (fuel, firewood, stove) to boil water, so this method is not always feasible and can be costly.

- Solar disinfection is viable for households that have clear water vessels (glass or plastic) with a lid. Water is poured into the container, sealed, shaken and placed for six hours in direct sunlight or 24 hours in cloudy conditions. Pathogens are inactivated by the combination of heat and ultraviolet rays.

- Various filtration methods, such as sand filtration or ceramic-pot filters are effective at eliminating most microbial matter, harmful chemicals and unpleasant taste and odour. The rate of filtration depends on the type, porosity and depth of the filter material, as well as size and amount of pathogens. For example, ceramic-pot filters with small pores are very effective at filtering out any bacteria, protozoa, cysts and other suspended particles (CDC, 2012).

  Some microbial viruses however, can bypass the filter, posing the risk of ingestion. Use of locally produced filters should be encouraged, which, in turn, not only boosts the local economy but also receives greater acceptance through sense of ownership.

- Chemical disinfection is the most widely adopted treatment method (WHO, 2005). It is simple, cost-effective and efficient at destroying almost all water-borne pathogens, when applied properly.

  Chlorine or iodine powder/tablets – common disinfectants – are highly effective (99.99%) at inactivating enteric bacteria and viruses except for a few water-borne pathogens (*Cryptosporidium parvum* oocysts and *Mycobacteria* species) (WHO, 2005). The volume of water, as well as the level of pollution, dictates the amount of chemicals required.

  For disinfection to be effective, the water must be clear; unclear water must be processed for sedimentation and filtration process prior to disinfection. It requires a minimum of 30 minutes for reaction to occur. Some expertise and the ability to test the water after disinfection are also necessary. For example, after 30 minutes, a test for residual chlorine concentrations of 0.2–0.5 mg/l is required to ensure that enough active chemicals remain to destroy bacteria and that the water is safe to drink (WHO, 2005).

  Otherwise, physical properties of the water can be compromised if chemicals are over-dosed, making the water unpalatable. Households may be reluctant to consume water with an unusual odour and taste. Community-level training is a good idea to ensure that persons understand the disinfection process and are able to mix proper doses of the chlorine solution and, if necessary, test residual chlorine levels in their homes.

- **Coagulation/chlorination** is a slightly more complex method that can significantly enhance microbial water quality of turbid or polluted water. An agent called coagulant (aluminium sulphate, ferric sulphate) is stirred into raw water to stimulate coagulation followed by flocculation: merging of smaller particles which settle at the bottom of the container (WHO, 2002).
- Multiple containers are required to strain the water during various points in the process. Physical properties of the raw water determine the best coagulant agent and process to follow.

145 Social acceptability of safe drinking water should be kept in mind while dealing with household water safety. In the case of a disaster or emergency, some physical characteristics, such as colour, odour and taste, may not be treated. People rely hugely on the visual appearance of water, so even treated water, which may have a different colour, odour and/or taste, may be unacceptable. Instead, people might turn to sources which look clearer, without making a background check. In such cases, authorities must communicate with users regarding water safety and urge people to treat their water until further notice. Finally, when the overall quality of the supplied water is restored and advisories are lifted, the public must be informed. This will maintain the confidence of households in their local authorities.

146 Treated water must be safely stored, transported and handled to minimize the risk of recontamination and to retain the benefits of effective treatment. Households are prone to the introduction of microbes from unhygienic practices, such as inadequate hand-washing, contact with food, kitchen utensils, diapers, and other faecally contaminated sources. Water vessels with a narrow opening, tight-fitting, disinfected lid and dispensing devices (spout/spigot/ladle) minimize the risk of microbial intrusion at point of use.

147 Many hazardous chemicals are also found in the household: cleaning and disinfecting agents, paints and solvents, motor oil, fuel oil, pesticides and batteries. These substances, if exposed to floodwaters, can cause health problems and potentially affect the drinking-water supply. Early warning systems should be a trigger for households to remove the waste safely (not flushed down drains or storm sewers) prior to the flood. If it is not possible to remove the items, then they should be stored at a safe distance from floodwater or in elevated areas to minimize exposure. Any chemical spills or hazardous waste released into the environment should be reported to the relevant authorities.

4.6 Food handling

148 When WSS systems are disrupted and hygiene behaviour is impaired, the risk of food contamination and disease increases. For example: when a flood occurs, food can come into contact with surface water, which itself has been contaminated by sewerage water. Emergency planning and preparedness measures are the best defence against household food vulnerability. Wherever possible, adequate food stocks and their safe storage should be planned in advance of the flood. Household food safety depends on the type, severity and extent of flood, type of food stored (perishable or non-perishable), storage conditions (sealed metal can, polythene bag) or power availability. In the absence of electricity, perishable food requiring cold storage should be discarded after four hours or otherwise cooked and stored appropriately. As a general rule, where floodwater has, or is suspected of having, contact with

food, all items should be destroyed to mitigate the risk of ingesting biologically or chemically contaminated food (CDC, 2008(b)).

This includes any food stored in non-waterproof or non-resealable containers that cannot be sanitized using boiling water or a bleach solution. Food of any unusual odour or suspicious appearance should also be discarded. Non-perishable goods in sealed metal cans may be salvaged after inspection and disinfection. For example, cans that have come in contact with floodwater must be cleaned, using soap and water and disinfected in a bleach solution (one tablespoon of bleach to one litre of water) prior to consumption (CDC, 2008(b)). Items with any signs of leaks, bulges or rust may indicate contamination and should be discarded.

149 All salvageable food, including stockpiled dry food (rice, beans) and seed, should be safeguarded, stored in cool, dry places, such as elevated areas of the household, until floodwaters recede. Problems regarding food safety become astronomical in the absence of adequate food supply. Floods could inundate the agricultural lands, drown the animals, food-storage units and other parts of the food-supply chain. In such cases, households are compelled to survive on contaminated or damaged food items, making them highly vulnerable to epidemics of food-borne diseases. Storage of food items in waterproof polythene bags or plastic/earthenware containers that normally float will protect food and are easily transportable. Whenever possible, containers should be covered with a lid to minimize the risk of microbial contamination and food loss.

Owners of livestock and poultry should relocate their animals to elevated portions of their homestead or other nearby land (raised roadside) for safety. Large, makeshift floating devices or raised platforms constructed of local materials (wood, bamboo, water hyacinth) can also serve as temporary storage facilities for household items, including food, fuel, water and other personal belongings. In flood-prone areas, these can be constructed during the dry season in anticipation of flood events.

4.7 Hygiene promotion

150 Hygiene behaviour is critical to the protection of public health during floods, especially if WSS systems are disrupted and people are displaced (WHO, 2002). Previously launched flood-related health campaigns should be reinforced by hygiene promotion so that people can adapt to new circumstances and are given information on how best to mitigate the risks at hand. Hygiene promotion adds value to the resilience of communities by generating public-health awareness and reducing susceptibility to water-, food- and vector-borne disease. The spread of acute diarrhoea, caused by the presence of pathogens, is one of the greatest threats to safe drinking water during an emergency (WHO, 2002). Good hygiene practices such as hand-washing are key to reducing transmission and burden of disease. Hygiene promotion serves to achieve behaviour change that will reduce the risk of disease and the transmission thereof.

151 For any campaign to be effective, it must be based upon, and tailored to, local needs. Analogous to health campaigns, hygiene needs are best determined using a participatory approach that reveals and builds on existing cultural beliefs, perceptions and motives. In addition, the promotion should be informed by the results of the emergency assessment (rapid needs health assessment, initial damage assessment) and provide relevant and available solutions

to mitigate health risks. For example, promotion may be tailored to outbreak conditions and minimize disease transmission if outbreak thresholds are on alert or when water sources become contaminated. Creation of a hygienic environment may be necessary to facilitate hygiene standards, since personal items may have been lost or damaged by floodwaters or people simply lack these items. In this case, distribution of personal hygiene kits containing soap, diapers, menstrual pads, etc., as well as water vessels for household water treatment and safe water, is appropriate. There is little time to spare during emergency situations and people will rely on simple and clear messages. Selection of the most appropriate communication medium should be tailored to local resources that remain available during the flood and those that will reach the target audience, especially vulnerable groups (for more information on this topic, see (WMO, 2015(b))).

Box 12 — Typical hygiene promotion during floods *(IFRC, 2012)*

- Wash hands (with soap, if available) after defecation; after contact with sewerage; after contact with contaminated floodwater; before food preparation and eating
- Wash food with safe water prior to consumption
- Destroy any food in contact with floodwater
- Destroy any standing pools of water
- Cook food thoroughly
- Use safe water for cooking food
- Clean utensils with water after use
- Wash food-preparation areas with water and soap
- Clean open wounds or cuts with water and soap
- Follow instructions on household water treatment and safe storage (see **Section 4.5**)
- Encourage use of sanitary facilities such as latrines and defecation fields
- Discourage open defection, especially near surface waters (i.e. rivers)

152 Vector-borne disease control can also be achieved through hygiene promotion. Encouraging the management of household waste inside and outside the household can reduce rodent populations. Where diseases such as malaria or dengue are of significant concern, promoting the elimination of mosquito habitats by destroying standing-water areas and giving close attention to water-collection sites, can prove to be invaluable. Hygiene promotion should therefore be tailored to relevant community needs and focus on areas that require immediate attention and that yield the greatest health benefit.

153 Ideally, hygiene promotion should be a sustained activity akin to public-health education and WSS, rather than a single-dose intervention to mitigate disease outbreak during a flood emergency. In vulnerable regions with poor sanitation and minimal hygiene, emergency situations may be a gateway for hygiene promotion. People may more readily adopt the

intended behaviour consequent to the rapid change that follows disasters. Effectiveness of campaigns should be consistently monitored to assess the success of behaviour change and to inform the evolution of the campaign over time. Similar to flood-health campaigns, scaling up multisectoral approaches may prove to be a resourceful way of disseminating information and resources to the target audience. Hygiene promotion, disaster-risk reduction, child and maternal health can all be leveraged against flood-awareness campaigns and vice versa. This requires adequate coordination and planning between sectors to deliver clear, systematic and comprehensive messages.

Box 13 — Emergency response in Niger *(IFRC, 2012)*

Several international organizations collaborated to provide emergency relief to approximately 531,000 people affected by severe flooding due to heavy rains across Niger in September 2012.

Emergency health teams conducted disease-prevention and health-promotion activities in half of the flood-affected regions. Two hundred volunteers were trained in epidemic control and water-treatment methods. Their skills were used in community health education and awareness-raising campaigns on the prevention of water-borne and communicable diseases, including cholera and diarrhoea.

Water, sanitation and hygiene promotion further reduced the risk of water-borne and water-related disease in these areas. Household water-treatment technologies, as well as jerry cans, buckets and soap, were distributed to 10,500 persons. Outreach activities focused primarily on health and vector control by distributing mosquito nets, managing waste (garbage) and maintaining cleanliness at sanitation facilities.

During recovery, volunteers were provided with protective gear and waterproof apparel for sanitary cleaning and disinfection of public schools, latrines and health centers.

5 POST-FLOOD RELIEF AND RECOVERY

5.1 Water-quality control

154 Intensified monitoring of water quality must remain after a flood to ensure confidence in the safety of drinking water and recreational water environments. Responsibility of water-quality testing rests with the service provider and government authorities (health authorities), who test for bacteriological, chemical and radiological parameters, as necessary. The acute health impacts associated with microbial hazards are often weighted against long-term effects of chemical and radiological exposure to prioritize testing. Chemical or radiological hazards typically require extensive laboratory testing of specific elements (nitrite, sulphates, chlorides) and contamination should be evaluated against set guidelines (WHO, 2011(b)).

155 Since microbial contamination is a major concern to public health during floods, testing for parasites (indicator organisms) is the most important and widely used quality-control measure. Bacteriological testing examines the type and level of coliforms (total coliforms, thermotolerant coliforms) present in water samples. Commonly used indicator organisms are E. coli species, exclusive to human and animal faeces, or enterococci/faecal streptococci (WHO, 2002). Many indicators such as E. coli and other coliforms are present in the environment and are not necessarily harmful themselves; their presence in water, however, indicates recent faecal contamination (WHO, 2011). Indicator organisms can also infer the presence of other hard-to-detect and resistant pathogens such as enteric virus and protozoa *(Rotavirus, Norovirus)* (WHO, 2011(b)). When bacteriological testing is not possible or timely, enhanced monitoring of residual chlorine levels, pH and turbidity are valid water characteristics to investigate (WHO, 2002).

156 Another comprehensive measure to identify existing or potential sources of water contamination is to conduct a sanitary survey or inspection. Ideally, water-quality testing should complement sanitary inspection but, in some cases, it can also serve as a stand-alone method to assess the

likelihood of faecal contamination in the absence of scientific measures. During the course of the survey, any deterioration in water quality is evaluated against threats to public health and used to inform decision-making that protects health security. Sample sanitary and drinking-water household surveys are available (WHO and UNICEF, 2006). Routine and emergency sanitary surveys should be conducted by system operators and at recreational water sites. Results of the survey should identify where additional measures are required in order to protect source waters and update existing WSPs. The results should also be transparent and shared with government authorities and other stakeholders.

Box 14 — Sanitary survey *(EPA, 2012)*

According to the US Environmental Protection Agency (EPA), sanitary survey is an "on-site review of a public water system's water source, facilities, equipment, operation, and maintenance. Surveys point out sanitary deficiencies and assess a system's capability to supply safe drinking water".

157 Bacteriological, chemical or radiological water-quality testing is a discrete testing method; the results are only applicable to a sample collected at a certain point in time. Water-quality testing is carried out in a localized area at discrete time intervals. Water quality is dynamic in space and time, however, so proper spatial and temporal coverage of the water dynamics is essential to estimate the extent of contamination, especially for larger water bodies with several contamination points. Moreover, policies and procedures for routine and emergency water-quality testing need to be developed. This will establish standards for testing, acceptable levels of agents and appropriate action for anomalies.

5.2 Recovery and reconstruction of water-supply and sanitation systems

158 The need for well-organized recovery and reconstruction will be significant after floodwaters recede. Temporary fixes applied during the flood may last only a few days or weeks and require comprehensive measures to fully restore and rehabilitate systems. Similarly, heightened water levels can persist and interfere with natural flow weeks after the flood, causing damage to the entire catchment area. The long-term effects of floods typically persist well beyond the recovery phase and are causal to the severity of flood impacts. Rehabilitation of WSS, health care, agriculture and economic and transport systems can take years for remediation, when trapped in low-resource, malnourished and disease-stricken areas. It is imperative to start reconstruction as soon as possible and mobilize community members to assist efforts wherever practical. Governing bodies should allocate emergency funds on local, as well as national, levels to be used during the duration of a disaster. This reduces the financial pressure on the government during emergencies.

159 Once floodwaters recede, the key is to assess damage, prioritize critically affected areas and develop an action plan to recover and strengthen WSS systems. One of the main challenges during the recovery and reconstruction process is the planning of incremental improvements ("build back better") and availability of resources. Successful recovery depends on gradual improvement of water supplies, progressing from basic services during the emergency and

recovery phases, to more sustainable services in the long term, when installations should be more robust and less vulnerable to disaster (WHO, 2002). The immediate recovery agenda should at least be to restore systems to pre-flood conditions. Remediation of contaminated drinking-water sites should be prioritized during recovery. System operators should, no doubt, take initiatives beyond this minimum and investigate the vulnerabilities that led to the damage/ disruption in the first place. Documentation of the flood events can serve a useful purpose here. They can be used as a chronology to explore structural and management weaknesses that give rise to the system failure and identify critical areas that need strengthening.

160 The key to successful recovery and restoration is an increase in the capacity of systems to cope with the changes that caused the damage or disruption – the flood event. Since we know that floods themselves cannot be eliminated, efforts should be made to strengthen structural and non-structural measures designed to cope with the changes in hydraulic capacity and influx of pollutants due to flood events. System vulnerabilities should therefore be re-evaluated against IFM practices to determine where they need to be strengthened.

161 WSS systems are vulnerable not only to floods but also to several other hazards. The flood event may thereby serve as an opportunity to increase overall climate resilience, since adaptation measures for floods are readily applicable to other extreme weather events, as well. Where new systems are being designed or existing systems are being maintained or upgraded, a "no regrets'" policy should be adopted to ensure technologies are flood- and climate-resilient in order to protect public health when the inevitable strikes.

162 While emergency response efforts focus on maintaining service provision during the flood, recovery requires full remediation of affected components to make them operational again. For example, where alternative sources were used to provide source waters, the original source will require pumping and disinfection. A major component of recovery efforts is the cleaning and disinfection of water sources, facilities, collection, distribution and storage components once the floodwaters have receded. This should not imply that recovery is limited to disinfection. Where pumps or electrical systems have been flooded, components must be dried and cleaned of any sand or silt. Wiring should be checked before systems are reinstated to minimize the risk of electrical shock and further damage.

163 Operational risk must be examined at inundated or damaged water- and wastewater-treatment plants before the system starts up. Key treatment processes should be sequentially reinstated under close supervision by management until automatic operations are resumed and water-quality levels are tested and accepted. Any inundated water-treatment facilities and pumping stations should be pumped dry and followed by thorough disinfection. Electrical components and machinery must also be thoroughly dried or replaced to minimize the risk of electrical shock and damage to the system. Excess water captured in storage tanks should be treated and released into recipient bodies during non-peak bathing periods and in low-frequency doses. This will allow time for natural inactivation to take place. Small-scale system operators should coordinate with centralized system operators and other actors to assist with their recovery, as agreed upon by the parties during planning.

Box 15 — Key principles in recovering water-supply systems after a flood *(WHO, 2011(a))*

Regaining wells and boreholes: start with the most used critical supply first.

– **Assess damage:** check pump; check borehole casings/void (using clean steel rod or dip tube).

– **Rehabilitate:** clear borehole with compressed air; ensure headworks are above ground level and re-sealed; repair pump and ancillary equipment.

– **Test pump output:** pump out at least twice the borehole volume; check clarity and basic quality.

– If not acceptable, then re-assess and rehabilitate (or, if repeated, then consider abandoning).

– Check pump output with required demand/pre-event output.

– **Disinfect:** ***Ensure nobody can use during disinfection***. Check pH is between 6 and 8, and turbidity <5 NTU (Nephelometric Turbidity Units). Add at least 1 litre of 0.2% chlorine solution for every 100 litres of water volume in the borehole and allow to stand for as long as possible. Flush until residual chlorine is <0.5 mg/l.

– **Sample:** sample for indicator bacteria (evidence of pathogens). If possible, ensure satisfactory samples from two separate sampling exercises are obtained prior to supply to consumers.

Regaining water-treatment works: Use skilled, experienced personnel (who have a working knowledge of the particular water-treatment works, where possible). Reinstatement priorities should be as follows (complete all prior to supply to consumers):

– Ensure source protection as far as possible

– Reinstate physical treatment

– Reinstate disinfection

– Reinstate chemical treatment stages

– Reinstate non-critical treatment (in short term) stages

Follow same model as above: assess/rehabilitate/test/disinfect/sample

164 Where the quality of recreational waters has deteriorated, it is generally assumed that the processes of dispersion, dilution, sedimentation and inactivation (through isolation, predation, natural die-off, etc.) will lead to a certain degree of safety (WHO, 2001). These processes, however, are spatially and temporally dependent on the type and degree of contamination, alongside properties of the water body (type, size, depth, local wind patterns). The safety of recreational waters should be closely monitored and tested until they are accepted as safe for public use.

165 The long-term goal of restoration efforts is to reduce vulnerability and increase community resilience against floods. Priority investment should be made to improve the weakest parts of the system. Heavy capital investment in critical water infrastructure and design lies at one extreme. Conversion of combined sewerage overflows to separate sanitary sewerage and drainage systems or, at least, introduction of storm retention tanks, should be considered wherever viable or in flood-prone areas. Where new land is being developed, separate systems should also be factored into the design. Many countries, especially developing and least developed countries, simply lack the economic resources or financial instruments to make such

investments, despite the considerable benefits of separate systems. If resources are limited, maintenance of systems, at the most significant and vulnerable nodes of the system, should be conducted. Ongoing maintenance of the system is essential to maintain maximum hydraulic capacity during floods by regularly cleaning intakes, distribution pipes, sewer conduits, valves and drains.

166 Water-supply management is concerned with the conversion of all unimproved sources to flood-protected ones, with flood-protection measures. Sanitation system upgrades to more technologically advanced toilets and more frequent emptying of tanks or pits will reduce the risk of overflow, groundwater contamination and communicable diseases. While improved sources themselves imply some resilience to floods, additional measures, such as flood-proofing and early warning systems, will prepare communities for flood events.

167 For example, early warning systems should be used as a trigger for emptying sanitation facilities in advance of the flood. This will have a significant payoff during the actual flood event in terms of minimizing contamination. Investment in additional pumps and generators should also be made. The severity of flood impacts can be minimized if service remains operational and system pressure will be alleviated if back-up equipment is available. Associated with this process should be data collection to inform and update WSPs.

168 When national or local governments lack the capacity to make large capital investments, effective policies and programmes can compensate to protect public health. Flood-related health campaigns, early warning systems, disaster-risk reduction, hygiene promotion, disease and outbreak preparedness and WSPs are non-structural IFM measures that should be pursued. These measures, combined with structural measures when needed, reduce vulnerability and increase community resilience against future flood events.

5.3 Clean-up operations and health protection

169 Many health hazards persist even after floodwaters recede. Harmful pathogens and chemicals are invisible or hard to detect without additional resources (testing) that may be limited during recovery. Flood-affected persons will be motivated to clean up and re-occupy households and buildings as soon as possible. Several safety precautions should be taken to avoid preventable injury and harm (CDC, 2008(c)):

- Minimize exposure to floodwater – wear covering garments and use protective gear (rubber boots, gloves, eyewear);
- Avoid direct contact with surfaces, especially with face, mouth and open wounds;
- Wash hands frequently with soap;
- Treat any wounds immediately – clean them with safe water and soap;
- Beware of electrical hazards (hot wires, power lines) – turn off electrical equipment and supply;
- Inspect property for critical weaknesses (cracks in foundations, deformation, split corners, roof collapse) before entering;
- Be alert to your surroundings.

170 Inundated areas provide a warm and moist environment favourable for the growth and proliferation of mould, which is harmful to human health. The best action against mould is disinfection and thorough drying of surfaces. Any other surfaces in contact with floodwater should also be considered contaminated and will require disinfection. General guidelines for rehabilitation include (CDC, 2008(c)):

- Clean all surfaces (floors, walls, furniture, household furnishings) with warm water and soap;
- Disinfect all clean surfaces (floors, walls, furniture, household furnishings) using a bleach solution (hypochlorite) – 50 ml to 1 litre water for at least 15 minutes;
- Discard all items that cannot be washed and disinfected (mattress, upholstered furniture);
- Wash all clothing, fabrics and textiles with hot water and soap;
- Allow items to dry thoroughly – outside, wherever possible.

171 Rehabilitation of traditional houses and buildings, particularly in developing and least developed countries may not always be possible. Characteristics of the flood (duration, depth, severity), coupled with the inability of materials to withstand floodwater can often lead to devastating results. Indigenous architecture and use of local materials such as mud, organic matter, thatch, stone rubble, bamboo, wood, metal, brick and concrete, especially in poor rural areas, may decay, erode or be washed-away and infrastructure may collapse partially or completely.

172 Wherever possible and salvageable, building materials should be disinfected or simply rinsed with clean water and thoroughly dried before reconstruction begins. If roofs or walls are partially or fully collapsed, the remains should be quickly removed to reduce moisture and improve air circulation for drying. Earthen structures should not be repaired with failed materials that have been sorted or washed of cementing agents and finer elements (Hughes, 1982).

173 Metals (corrugated iron sheets, steel) in extended contact with water or damp areas should be examined for corrosion. If any signs of rust are evident, then the materials should be washed using clean freshwater, thoroughly dried and coated with oil (if possible) to prevent further corrosion (Hughes, 1982). Further construction with materials that are highly susceptible to flooding (mud) should be avoided in flood-prone areas. Portable and easily transferrable materials (bamboo, wood, metal) are preferable.

5.4 Collective learning and institutional development

174 Every flood event presents different risks and opportunities for affected communities and beyond. Learning and building upon these experiences are integral to vulnerability reduction and sustainable development. During and in the aftermath of the flood event, affected actors should document key impacts, problem-solving processes, relief and recovery activities and ongoing challenges. Good records and document management encourage and facilitate critical analysis for learning, evidence of past events and institutional memory. Key outcomes should be integrated into updated flood-mitigation and adaptation measures central to the disaster-management cycle, mass casualty management, WSPs and other important activities that promote community resilience.

175 Rebuilding after a flood involves recovering from the associated economic, social and environmental losses that are intricately linked with health costs and outcomes. Long-term restoration is a participative process and end-users must be integrated into decision-making and rebuilding/strengthening existing systems. Acceptable risk, costs, time and user preference of technology will ultimately define what and how reconstruction will be conducted. Moreover, the recovery process is based on sustainability and must incorporate community participation to yield the greatest benefits to the communities involved. For example, priority may be to restore WSS systems but long-term planning must consider what is sustainable and desired by communities themselves. Community involvement in decision-making and action is a prerequisite for sustainable development. Community self-governance is ideal but rarely achieved, mostly because of conflict in economic and political agendas.

Box 16 — Building urban flood resilience in Mumbai, India *(Gupta, 2007)*

On July 26 2005, more than 60% of Mumbai was flooded by torrential rains that were no contest for the city's antiquated stormwater-drainage system.

The people of Mumbai suffered considerable losses and as they waded though sewerage overflows in the streets, their exposure to water-borne disease was immense. In the aftermath of the disaster, the government of Maharashtra was determined to learn from this event and increase resilience against future flood events.

Since major capital investment to upgrade the outdated drainage system was not a viable option, a fact-finding committee was formulated to recommend key measures to reduce flood risk incrementally. As a result, early warning systems, flood-management plans and emergency control centres were implemented. Enhanced maintenance of storm drains, inlets, waterlogged areas and a ban on plastic bags contributed to reducing the risk of drainage failure at vulnerable network nodes.

The implementation of combined structural and non-structural measures serves as a basis for long-term planning in Mumbai in a multi-hazard approach.

6 SUMMARY

176 This Tool explores the various aspects of health and sanitation related to flood management. Water supply and sanitation systems are often threatened during flood events, posing great risks to public health and therefore increasing the difficulty of post-flood recovery. Those risks go from disruption of basic services, increased communicable disease, injury and trauma, to loss of life. This is particularly true for vulnerable communities, whose resilience capacity is made difficult due to their socioeconomic situation.

177 This publication covers the three phases of flood management: pre-flood planning and preparedness, response and post-flood relief and recovery. Each of these timeframes involves specific actions that can be undertaken in order to minimize impacts on public health.

178 Records and document management are very important all along the flood management process. They allow adopting an integrated risk management approach, where all facts and observations gathered during response and recovery phases help developing long-term and adapted preparedness measures. In order to build equalitarian measures, health and sanitation conditions of all the different groups that compose a society have to be taken into account.

179 Therefore, it is essential to ensure stakeholder and community participation throughout all the planning process. A summary of the assessment and planning steps explored throughout this Tool is provided in **Figure 7**.

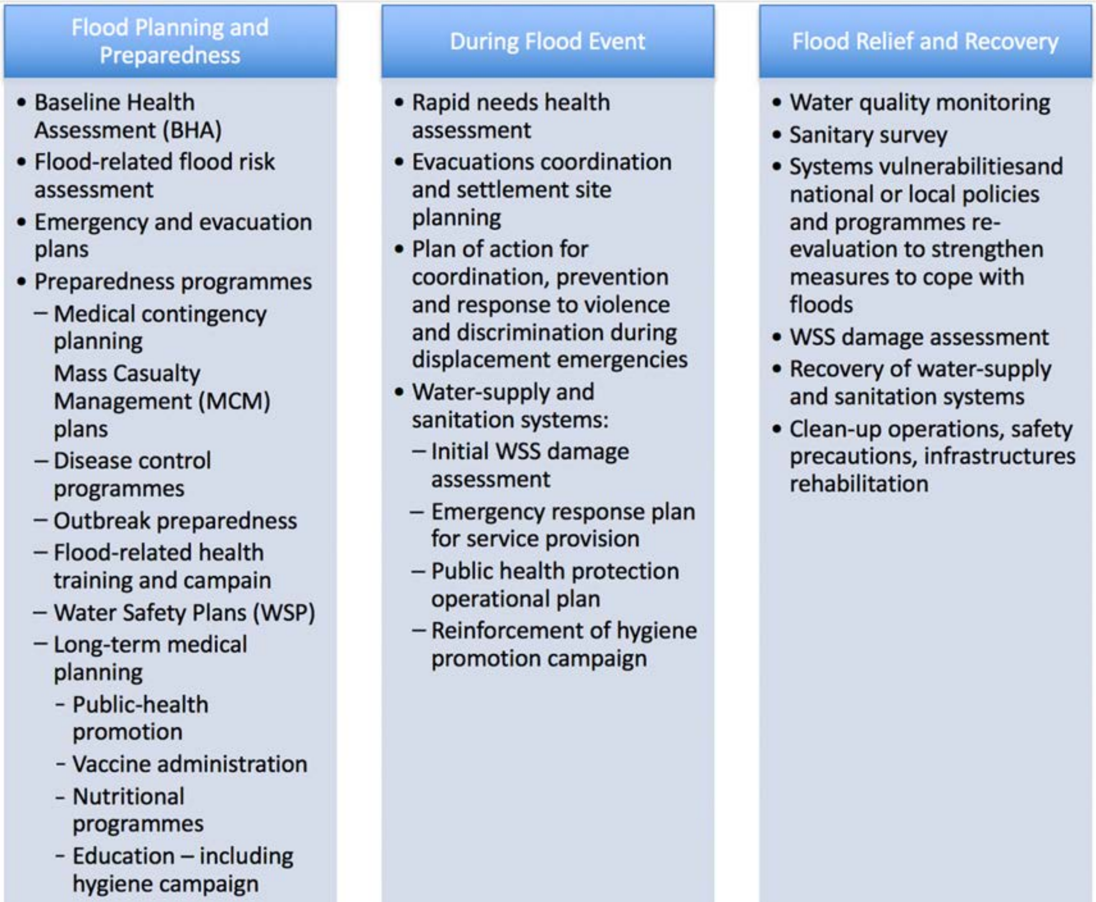


Figure 7 — Assessment and planning steps explored throughout the publication

180 In summary and in closing this Tool, a best management of public health during floods is a commitment to:

– Adoption and implementation of integrated flood management, with extra attention to water-supply and sanitation systems and health facilities;
– Long-term environmental health management (vector control);
– Health systems and surveillance management (including Baseline Health Assessment);
– Multisectoral adaptation and mitigation activities at national and local levels (integrated flood management, integrated water resources management, disaster-risk reduction, water safety plans, health awareness campaigns, hygiene education, integrated coastal zone management/pest management/urban management, climate change etc.);
– Participatory and multi-stakeholder collaboration.

181 This commitment will achieve the following objectives:

– Build community resilience (flood resilience, health resilience, climate resilience) and contribute to sustainable development;
– Reduce vulnerability of public health to flood-related hazards and environmental change (physical, biological, chemical, radiological);
– Improve determinants of the health sector (water, air, food, energy);
– Protect environmental health services and infrastructure.

ANNEX I
RELATIONSHIP BETWEEN FLOOD MITIGATION AND ADAPTION AND FLOOD-RELATED HEALTH HAZARDS

Flood Mitigation & Adaptation Measures		Flood-Related Health Hazard					
			Biological				
		Physical	Water-borne	Water-washed	Vector borne	Chemical	Radiological
Structural	Construction of dikes, levees	Significant	Less significant	Less significant	Less significant	Less significant	Less significant
	Flood barriers and dams	Significant	Less significant	Less significant	Less significant	Less significant	Less significant
Non-structural	Flood proofing	Significant	Significant	Less significant	Less significant	Less significant	Significant
	Flood risk awareness	Significant	Significant	Significant	Significant	Significant	Significant
	Flood-related health campaigns/hygiene promotion	Less significant	Significant	Significant	Significant	Significant	Less significant
	Flood forecasting & EWS	Significant	Less significant	Less significant	Less significant	Significant	Less significant
	Flood hazard mapping	Less significant	Significant	Less significant	Less significant	Significant	Significant
	Land use planning and regulation	Significant	Significant	Less significant	Less significant	Significant	Significant
	Community participation	Significant	Significant	Significant	Significant	Significant	Significant
	Emergency response & assessment	Significant	Significant	Significant	Significant	Significant	Significant
	Disaster risk reduction	Significant	Significant	Significant	Significant	Significant	Significant
	Health Systems Management	Significant	Significant	Significant	Significant	Less significant	Less significant
	Water Safey Plans	Less significant	Significant	Significant	Significant	Significant	Significant

Significant
Less significant

ANNEX II

Common flood-related diseases, features and incubation period				
Disease	Pathogen	Type	Features	Incubation period
Giardiasis	*Giardia duodenalis*	Protozoa	Diarrhoea, abdominal pain, nausea	1–2 weeks
Cryptosporidiosis	*Cryptosporidium parvum*	Protozoa	Diarrhoea, nausea, vomiting, fever	2–10 days
Malaria	*Plasmodium*	Protozoa	Fever, chills, headache, muscular aches and weakness, vomiting, cough, diarrhoea and abdominal pain	7 days
Cholera	*Vibrio cholerae*	Bacteria	Watery diarrhoea, vomiting, leg cramps	2 hours–5 days
Typhoid	*Salmonella typhi*	Bacteria	Fever, malaise and abdominal pain	1–14 days
Shigellosis	*Shigella spp.*	Bacteria	Abdominal cramps, fever, watery or bloody diarrhoea	1–3 days
Campylo-bacteriosis	*Campylobacter spp.*	Bacteria	Diarrhoea, abdominal pain, fever, vomiting, chills	1–2 days
E. coli 0157:H7	*Escherichia coli*	Bacteria	Watery or bloody diarrhoea, abdominal pain, nausea, vomiting, fever, headache, hemolytic uremic syndrome (HUS)	1–8 days
Leptospirosis	*Leptospira*	Bacteria	Fever, headache, vomiting, diarrhoea, redness of eyes, abdominal pain, rash	4–14 days
Legionellosis	*Ligionella pneumophila*	Bacteria	Fever, chills, pneumonia, muscle aches, diarrhoea, vomiting	2–10 days
Hepatitis A	*Hepatitis A*	Virus	Fever, fatigue, stomach pain, nausea, dark urine, jaundice	28 days
Hepatitis E	*Hepatitis E*	Virus	Fever, fatigue, stomach pain, nausea, dark urine, jaundice	40 days
Rotavirus	*Rotavirus*	Virus	Severe watery diarrhoea, fever, vomiting	2 days
Dengue	*Dengue*	Virus	Fever, headache, pain behind the eyes, muscle and joint pains, nausea, vomiting, swollen glands or rash	4–10 days
West Nile Virus / Fever	*West Nile*	Virus	Either no symptoms (80% infected people) or West Nile Fever (20% infected people) – fever, headache, tiredness, and body aches, nausea, vomiting	3–14 days

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(Unless otherwise noted, all websites were last accessed in July 2015)

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