humanitarian innovation fund

WASH in Emergencies
Problem Exploration Report

Surface Water Drainage

Table of Contents

Preface

The Humanitarian Innovation Fund (HIF) is a programme of ELRHA, and we are here to support organisations and individuals to identify, nurture and share innovative and scalable solutions to the challenges facing effective humanitarian assistance.

The HIF has a dedicated fund to support innovation in water, sanitation and hygiene (WASH) in all types of emergencies, from rapid onset to protracted crisis. WASH is a broad theme with serious consequences in many other areas such as health, nutrition, protection and dignity. In the absence of functioning toilets, clean water systems, effective hygiene practices, and safe disposal of waste, pathogens can spread rapidly, most commonly causing diarrheal and respiratory infections which are among the biggest causes of mortality in emergency settings.

Despite this, there is a significant gap between the level of WASH humanitarian assistance needed and the operational reality on the ground. This is why the HIF works closely with multiple stakeholders from across many humanitarian agencies, academia and private sector to understand and overcome practical barriers in the supply and demand of effective solutions.

Over the past three years the HIF has been leading a process to identify the key opportunities for innovation in emergency WASH. Fundamental to this is having a strong understanding of the problems that need to be solved. We note that many innovations focus on improving technology because the problems can often be clearly defined, compared to more complex problems with supply chains, governance or community engagement.

Our problem research began with an extensive Gap Analysis (Bastable and Russell, 2013) consulting over 900 beneficiaries, field practitioners and donors on their most pressing concerns. From these results we prioritised a shortlist of problems including surface water drainage. However drawing lines between where one problem ends and another starts is difficult given the feedback loops within each system. For example reducing waste from plastic bottle usage relies on the availability of other safe water options which in turn is linked to environmental sanitation and hygiene.

This report is one of a series commissioned by ELRHA to explore priority problems in emergency WASH. The researcher selected for each report was asked to explore the nature of the challenges faced, document the dominant current approaches and limitations, and also suggest potential areas for further exploration.

The primary purpose of this research is to support the HIF in identifying leverage points to fund innovation projects in response to the complexity of problems. We seek to collaborate closely with those already active in these areas, avoid duplication of efforts, build on existing experiments and learning, and take informed risks to support new ideas and approaches.

In publishing these reports we hope they will also inform and inspire our peers who share our ambitions for innovation in emergency WASH. In addition to engineers and social scientists who are crucial to this work we hope to engage non-traditional actors from a diverse range of sectors, professions and disciplines to respond to these problems with a different perspective.

The content of this report is drawn from a combination of the researcher's own experiences, qualitative research methodologies including a literature review that spanned grey and published literature and insights from semi-structured interviews with global and regional experts. The report was then edited and designed by Science Practice.

We would like to thank the members of our WASH Technical Working Group for their ongoing guidance: Andy Bastable (Chair), Brian Reed, Dominique Porteaud, Mark Buttle, Sandy Caincross, William Carter, Jenny Lamb, Peter Maes, Joos van den Noortgate, Tom Wildman, Simon Bibby, Brian Clarke, Caetano Dorea, Richard Bauer, Murray Burt, Chris Cormency, and Daniele Lantagne.

Menka Sanghvi
Innovation Management Adviser

Humanitarian Innovation Fund, ELRHA

January 2016

Contributors

The report was written by Dr. Kiran Tota-Maharaj, Department of Engineering Science, Faculty of Engineering and Sciences, University of Greenwich. He led the research, compiled and analysed existing literature and case studies, and conducted interviews with key stakeholders in the field.

The report has benefited greatly from the valuable insights and consideration provided by the following experts: Tom Wildman (United States Agency for International Development), Brian Clarke (Chartered Civil Engineer & Senior Research Fellow, CEHE, University of Surrey), Parneet Paul (Associate Professor of Water Engineering, Kingston University, London, UK), Jenny Lamb (Oxfam GB, Humanitarian Department, Oxford, UK), Brian Reed (Lecturer-Water, Engineering and Development Centre (WEDC), Loughborough University, UK), Regine Skarubowiz (Monitoring and Evaluation Officer,Water and Sanitation for the Urban Poor), Rao Bhamidimarri (Professor of Environmental Engineering and Vice President of Development, London South Bank University, UK).

The report was edited and designed by Science Practice.

Abbreviations

BMPs	Best Management Practices
BPRM	Bureau of Population, Refugees and Migration
CARE	Cooperative for Assistance and Relief Everywhere
ELRHA	Enhancing Learning & Research for Humanitarian Assistance
HIF	Humanitarian Innovation Fund
IDP	Internally Displaced Person
IRC	International Rescue Committee
NGO	Non-Governmental Organisation
SuDS	Sustainable Drainage Systems
SUDS	Sustainable Urban Drainage Systems
UAE	United Arab Emirates
UNHCR	The United Nations High Commissioner for Refugees
UNICEF	The United Nations Children's Fund
USAID	United States Agency for International Development
WASH	Water, Sanitation and Hygiene
WSUD	Water Sensitive Urban Design

Glossary

The terms listed in this glossary are defined according to their use in this report. They may have different meanings in other contexts.

Aquifer — An underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) that contains water or allows water to pass through it.

Foul water / Blackwater — Wastewater containing high levels of organic waste, including faecal matter and urine. It therefore represents a potential reservoir for high levels of pathogens.

Greywater (Sullage) — Wastewater from sinks, showers, baths, and laundry washing; does not include sewage flows or excreta from toilets.

Internally Displaced Person (IDP) — A person who is forced to flee his or her home but who remains within his or her country's border.

Refugee — A person who has been forced to leave their country and cross an internationally recognised boundary in order to escape war, persecution, or natural disaster.

Sewage — Mainly foul water containing faeces, urine or dirty water from homes; it can also include contaminated discharges from industries and other sources (trade effluents).

Soakaway — A pit, typically filled with large stones or 'hardcore', into which surface water or wastewater is piped so that it seeps into the surrounding soil stratum.

Stormwater — Surface water generated by an extreme rainfall event.

Surface water — Rainfall or snow melt fed water run-off, including ponding areas and river catchments; could include water spillage at tap stands and leakage from pipes in potable water supply networks.

Vector — An organism, or agent, that can carry an infectious disease to another organism. The most common vectors include arthropod species, such as mosquitoes, ticks, triatomine bugs, sandflies, and blackflies.

Wastewater — Broad term for contaminated water discharged into the local environment for treatment or safe disposal; could be either greywater or foul water and in cases of uncertainty should be treated as foul water.

Water table — The upper level of an underground groundwater surface in which the soil or rocks are permanently saturated with water.

Waterlogging — The saturation of soil with water.

Executive Summary

Surface water drainage and stormwater management are critical factors in safeguarding the health and surroundings of refugees or internally displaced persons (IDPs) in emergencies. Globally, waterborne diseases and sanitation-related infections are both major contributors to public healthcare burdens and mortality. Effective drainage reduces breeding grounds for vectors (such as mosquitoes) and reduces the creation of muddy stagnant pools that harbour dangerous pathogens which cause a wide range of diseases.

The purpose of drainage on temporary settlements is to remove unnecessary water from one location to another environment. Drainage in emergency and crisis scenarios must handle water of various origins (such as sewage, wastewater or sullage), rainwater (stormwater runoff), flood water, and water leakage from potable supplies (standpipes and storage tanks).

Effective surface water drainage is vital in emergencies in which the risk of flooding is high, as it addresses a fundamental need to avoid the poor environmental health conditions associated with stagnant water ponding, erosion or muddy, swamp-like conditions. Poor drainage can also make it impossible for people to move around camp sites, and it can cause landslides and mudflows. Therefore, drainage systems need to be designed and constructed well, and in combination with other structures, such as access roads and buildings.

A central challenge is that surface water drainage is often difficult to prioritise in the initial planning and development stages of an emergency, and is usually considered after the immediate water, sanitation and hygiene needs have been met. It is often said that the phrase “act first, improve later” represents the most common approach towards developing drainage infrastructures in an emergency situation. This can become even more problematic in the long-term as, in order to be effective, drainage solutions need to be tailored to the needs of specific crisis situations or refugee camps. Strategic planning must occur to understand the contextual factors influencing a region’s surface water and wastewater drainage requirements. In addition to this, open collaboration is needed between camp management agencies, relief agencies and WASH personnel for effective drainage design and construction.

In the long-term, regular maintenance and inspection is key to keeping surface water drainage systems fully functional in temporary emergency settlements. Maintenance should be the collective responsibility of camp management agencies, WASH service providers and the people living in camps.

The findings of this report suggest that a paradigm shift that takes into account the need for long-term, tailored drainage solutions in emergency situations is required. To support this, three areas for further exploration are suggested:

Hydro-Meteorological Hazards and Risks: Understanding hydro-meteorological extremes, and estimating the hydrology and stormwater discharge routes for crisis prone regions can help engineers and sanitation volunteers design, construct and implement better drainage solutions.

Drought Monitoring and Assessment: Understanding the dynamics of droughts and the overall movement of water on a site can support the development of more informed stormwater management plans. Droughts can also impact on solid waste management practices as the need for bottled water can lead to an increase in littering. Plastic bottles can easily get stuck in drainage networks and affect their performance when the next storm event occurs.

Drainage Vulnerability and Surface Water Management: The quantification of drainage vulnerability can support the decision-making processes of humanitarian aid organisations. An Integrated Risk Assessment approach to surface water drainage could take into account the physical infrastructure, environmental vulnerability, and public exposure to health hazards.

Figure 1.
Internally Displaced Persons (IDPs) Camp Water Point, UN Base in Juba, South Sudan. (Source: Oxfam, 2014)

Part 1: The Challenge of Surface Water Drainage in Emergencies

1.1 Understanding the Need

Surface water drainage is a key factor in ensuring that acceptable standards of water supply, sanitation, and hygiene promotion (WASH) are met in emergencies. The planning and design of drainage systems, both in camps and non-camp emergency situations where informal settlements are developed, is often a matter of major importance in protecting the health of refugees or internally displaced persons (IDPs).

Sources of surface water include rainfall, flood water, water spillage from tap stands, leakage from piping systems, and wastewater from sinks, showers or laundry washing.

System concepts, techniques, and design considerations for surface water, groundwater and foul water networks are numerous and include Sustainable Drainage Systems (SuDS) also referred to as Sustainable Urban Drainage Systems (SUDS), Stormwater Management, Water Sensitive Urban Design (WSUD), Low Impact Drainage, and Best Management Practices (BMPs). However, surface water drainage systems in camps and informal non-camp emergency situations generally do not adhere to typical engineering planning guidelines, construction standards and building regulations applied in industrialised countries. The drainage infrastructure across the world is rarely provided with adequate facilities, materials, and water supply networks needed for the provision of appropriate foul water, surface water, and/or combined drainage systems.

There is a proven historical link between water engineering improvements, such as water treatment and supply systems or sewerage and drainage systems, and an overall increase in the level of public health. Because in many emergencies the tendency is to implement ad-hoc or short-term water management approaches, this often leads to elevated risks of morbidity and mortality. Surface water (or stormwater) runoff is an important factor when considering the prevailing conditions that might contribute to degrading the environment in camps and exacerbating public health risks.

1.2 Humanitarian Aid Actors

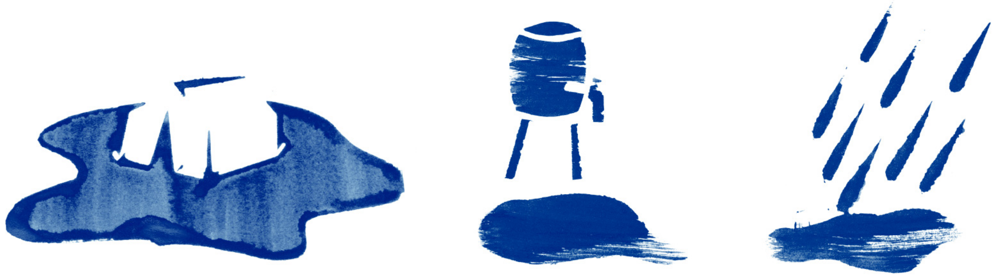
The rapid and unplanned concentration of refugee or IDP populations in humanitarian crisis zones creates many health hazards and, in some cases, can support the spread of diseases and even epidemics. Displaced populations in camps can often suffer from waterborne diseases (Bigot et al.,1997). The United Nations High Commissioner for Refugees (UNHCR) is mandated by the international community to assist and protect the world's refugees. UNHCR estimated that there were over 50 million forcibly displaced refugees worldwide in 2012, with a large population still at risk today (Betts et al., 2012; UNHCR, 2015). There is an increasing need to respond to the changing nature of conflicts. Because of this, the UNHCR's responses must continuously evolve and adapt to new emergency situations and crises.

The UNHCR rallies donor support for its humanitarian activities in emergencies and crisis regions from governments and various organisations. The Agency, together with aligned non-governmental organisations (NGOs) such as OXFAM, International Rescue Committee (IRC), CARE, or World Vision, currently seeks to adapt humanitarian responses to the changing nature of forced population displacements.

Working with a broad range of specialised agencies is critical for the UNHCR, especially when developing strategies in crucial WASH areas such as water supply and surface water drainage. The experiences of the UNHCR, the Bureau of Population, Refugees, and Migration (BPRM), the United States Agency for International Development (USAID) and OXFAM with regards to drainage schemes in camps across different parts of the world have pointed to an area of need. It is apparent that if drainage infrastructure associated with the camp access ways, water pumping or tap collection points, bathing or laundering areas is not properly designed or constructed, the risk of pathogen transmission and vector breeding significantly increases.

1.3 Causes and Risks

Surface water can come from a number of different sources, both natural and man-made. Natural sources include rainfall which can cause large pools of water to form, particularly if there is a low, or no, infiltration capacity in the prevailing ground conditions. Man-made sources include water spillage from tap stands, leakage from the potable water supply pipe systems, and greywater/sullage (wastewater from sinks, showers, baths, laundry washing, but not sewage flows or excreta from toilets). These surface water pools can become breeding grounds for mosquitoes and parasitic worms, and can increase the risks of diarrhoea, worm infection, and other health problems. Large pools of surface water and the lack of effective drainage systems can also lead to the contamination of water sources and supply systems.



Surface water can also create logistical and accessibility challenges by creating muddy swamp-like conditions in areas used by pedestrians and wheeled vehicles to a point that roads and paths are impassable. In addition to being unsightly and off-putting, such conditions represent a poor living environment for the millions of refugees, displaced people and slum residents across the world (Kolsky, 1998). At times, drainage systems such as ditches or soak-pits have very little infiltration capacity in the soil which, in turn, creates further ponding and surface water problems. Additionally, traditional drainage systems such as soakaways can also increase the risk of contaminating groundwater which could serve as a potential source of drinking water. Therefore, selected concepts from Sustainable Urban Drainage Systems (SUDS), Sustainable Drainage Systems (SuDS), Stormwater Management, Water Sensitive Urban Design (WSUD), Low Impact Drainage, or Best Management Practices (BMPs) can play a significant role in designing and implementing effective and sustainable water drainage systems in areas designated for camps, including temporary relief settlements. However, the main challenge for most relief agencies is developing drainage systems that first satisfy the need for rapid deployment and can then offer the potential for integrated development. Additional technical training and support for both relief agency staff, as well as local refugees and IDP groups, will likely be required to address this evolving need.

1.4 Contextual Challenges

80% of refugees and displaced people live in tropical or semi-tropical countries where vector--borne diseases, such as malaria and dengue, are common.

Today more than 26 million refugees in countries throughout the world are dependent on international relief assistance (UNHCR, 2015). More than 80% of refugees and displaced people are living in tropical or semi-tropical countries where vector-borne diseases such as malaria, dengue, or kala azar are common and have a high fatality rate if untreated (UNHCR, 2015). Decisions on where to place a refugee settlement are often made for political as well as practical reasons. Launched in 1997 to improve the quality of assistance provided to people affected by disasters, the Sphere Project developed a set of minimum standards and best practices for core areas of emergency response, including water supply, sanitation, and hygiene promotion (WASH). One of the minimum standards for WASH is effective drainage. There is a direct link between the presence of surface water and the level of public health risk. The purpose of drainage on temporary settlements is to remove unnecessary water from one location and deliver it to another environment. Drainage systems will be required to handle flows of different types, including foul water, greywater and surface water, together with flood water from nearby areas and water leaking from potable supply systems (stand pipes, storage tanks). Poor drainage can make it difficult for people to move around the camp sites and can even cause landslides and mudflows. Furthermore, major problems linked to surface water runoff can arise in towns and cities where damaged infrastructure or varying levels of sub-catchment impermeability can reduce the effectiveness of drainage systems.

In order to be effective, drainage systems need to be designed in a way that takes into account existing developments in the area, as well as important local hydrological and environmental issues. It is the type and level of emergency that determines the nature of the water management needs and requirements. Refugee and IDP camps can be built in remote, rural, drought-stricken areas but also in tropical, highly developed town and city areas which might have high levels of precipitation. In both situations, as well as any others in between, providing a robust and suitable surface water drainage system is of prime importance. Drainage systems should be initially conceived, constructed and, if necessary, later adapted to link effectively with other existing structures and facilities (such as access roads and buildings). Regular maintenance and inspection is an ongoing requirement to ensure that any drainage system remains fully functional. The responsibilities of all groups and individuals conducting routine maintenance and structural repairs must be addressed early in the planning phase.

Some of the most common causes of drainage problems in temporary settlements and emergency camps are: inadequate sewage and wastewater disposal, site drainage of surface water and stormwater runoff, and inundation from surface water and stormwater runoff generated in external areas. The latter could present extremely high levels of risk to refugees or IDPs if camps are located in major natural drainage channels, such as the bed or flood plain of a seasonal river. To address this challenge, in the Darfur crisis, water for a refugee camp was extracted from the sandy bed of a seasonal river. Rainfall in another region recharged both the river channel via seasonal flood flows and, for a much longer period, the aquifer formed by the sand and gravel river bed provided a source of water for potable supplies.

Effective surface water drainage is vital in emergencies where the risk of flooding is high and there is a an associated risk of poor environmental health conditions developing from ponds of stagnant water, erosion and muddy swamp-like conditions (Brikké, 2000).

However, surface water drainage is often difficult to prioritise in the initial planning and development stages of refugee camps, and tends to be considered after immediate water, sanitation and hygiene needs have been met (Lamb, 2015). While refugee camp sites with natural slopes and drainage may not require additional infrastructural works, challenges can still arise if structures are built or encroach on drainage system lines, especially in one-time extreme surface water or stormwater flows (Reed, 2015). Nevertheless, in localised areas, basic drainage infrastructure such as the provision of drains to prevent water from flowing into latrines or shelters is essential (Bhamidimarri, 2015).

With regards to the location of a camp site, the challenge is that often humanitarian agencies have little decision-making power over the actual situation of a camp. Another consideration is that different agencies will focus on different aspects of drainage. While WASH providers will look at access to water sources and supportive public infrastructure, shelter providers will tend to look at slope and soil conditions and natural drainage. This report does not provide a comprehensive overview of all of these different perspectives, but we acknowledge that all of these views need to be taken into consideration when developing a surface water drainage strategy for a camp site.

1.5 Health Risks

Globally, waterborne diseases and sanitation-related infections are one of the major contributors to public healthcare burdens and mortality (Prüss and Havelaar 2001). Many different viral, bacterial and parasitic diseases have been associated with waterborne transmission in and around refugee camps (Hunter,1997; 2003). Removing surface water, grey water and foul water in drainage systems is an important environmental health intervention for reducing diseases in refugee camps. Poor surface water drainage and leakage from stand pipes or water taps provide breeding sites for disease vectors. Runoff from sites can also contain pathogens that can pollute ground water sources increasing the risk of diseases such as lymphatic filariasis (Hunter, 1997; 2003). Runoff from latrines and bathing facilities or wastewater produced after cooking and dishwashing activities can carry various harmful microorganisms (Prüss and Havelaar, 2001). Similarly, if greywater is not drained properly, it is likely to lead to infections, illnesses and even epidemics.

Inadequate drainage networks in endemic regions have been statistically associated with cholera incidences.

For example, cholera continues to be transmitted in environments characterised by inadequate water supply and poor sanitation (Heymann, 2008). In one refugee camp in Bangladesh where sanitation facilities had been provided, the cholera rate was 1.6 per 1,000 persons, whereas in two camps without such facilities the rates were 4.0 and 4.3 per 1,000 persons (Khan and Shahidullah, 1982).

Cholera dynamics in endemic regions display regular seasonal cycles and pronounced inter-annual variability; these are related to climate patterns such as temperature and precipitation (Sasaki et al., 2009). Increased precipitation in these areas was associated with the occurrence of cholera outbreaks and inadequate drainage networks were statistically associated with cholera incidences (Sasaki et al., 2009).

A study by Guthmann et al. (2006) found that a large outbreak of Hepatitis E that occurred among displaced populations in 2004, in Darfur, Sudan, was of epidemic proportions and confirmed the need to ensure adequate water treatment and distribution systems

Figure 2.
Water ponding as a result of poor surface water drainage, Bentiu Camp, South Sudan, June 2014. (Source: MSF, 2014)

as a priority. The study also highlighted the fact that adopting water infrastructure strategies in 2004 was the key for preventing future outbreaks of Hepatitis E in Sudan.

Similarly, a recent study by Wildman (2015) found that typhoid fever, caused by the virulent bacteria *Salmonella typhi* (S.typhi) has been associated with major epidemics at refugee camps as a result of contaminated water and poor sanitation. In areas where schistosomiasis is a recognised health risk and where surface water could be used for irrigation, extra care should be taken when designing, constructing and maintaining drainage systems to minimise infection risks (Kolsky, 1998). This is particularly relevant where earth drains are used and/or water supply and sanitation provisions are inadequate. Properly designed drainage systems that are constructed in a manner that recognises capacity and structural requirements are essential to guarantee suitable levels of performance. Furthermore, planned and competent maintenance is required for removing debris, weeds and waste in camp settings. All of these factors are important measures for reducing environmental risk levels (Kolsky, 1998).

A significant challenge occurs when refugees who have not formerly been exposed to particular diseases are forced to flee into areas where the associated pathogen is endemic. This is often the case for refugees from mountainous regions who are forced to flee to lowland areas where diseases such as malaria are prevalent. These refugees will have lower levels of immunity to such infections.

Vector-borne diseases often affect refugee populations as a result of crowded and unhygienic conditions.

Vector-borne diseases often affect refugee populations as a result of crowded and unhygienic conditions (Paul, 2015). Malaria is one of the most problematic vector-borne diseases worldwide in terms of morbidity and mortality rates (Thomson, 1995). Malaria is recognised by major relief organisations as one of the top five causes of child mortality in the acute phase of an emergency. There are several cases when poor drainage systems or inadequate and polluted water supplies were neglected because, at the time, they were not considered to be an emergency or a priority (Bhamidimarri, 2015; Paul, 2015; Lamb, 2015). This neglect of environmental factors where cholera and malaria epidemics occur can lead to significant increases in vector populations and ultimately transform into epidemics (Guha-Sapir and Salih, 1995).

Effective surface water drainage systems can play a key role in minimising the occurrence of environmental conditions that lead to increased vector populations by reducing potential breeding grounds. The type of water collection system used and the conditions in which water is kept can also contribute to reducing the risk of vector-borne diseases. As refugees often store water in pots and jars for later use, providing them with containers which can be adequately sealed when not in use would minimise the potential number of container-based insect vectors. In turn, these steps can help alleviate some of the public health concerns and challenges faced by refugees and IDPs in camps (Cuny, 1977).

CASE STUDY – Water pooling around standpipes

Access to potable water in refugee or IDP camps is often intermediated through public standpipes, taps and pipes. These offer affected communities a level of water service that responds to their socio-economic needs. Leaking or faulty standpipes, taps or pipes can cause pools of standing water to collect around communal facilities. Furthermore, water passing through water supply piping networks can quickly become contaminated if the pipes are leaky or if there are breaks in the system that can allow sewage to seep into the potable water network. Poor maintenance, as well as old and porous water pipes can also absorb the pollutants from leaking sewer lines, thus contaminating the potable water supply.

Figure 3.
Child collecting water from a standpipe in Ruwaished camp, Jordan. (Source: A. van Genderen Stort, UNHCR, 2014)

Spillage at standpipes and taps is inevitable. There is an assumption that there is a 10% loss of water from leaks and spillages when water is collected from standpipes. Surveys have shown that camp sites tend to have a flat topography which does not support the movement of water. From a civil engineering perspective, the best position for standpipes would be at the low points in the system to ensure the best pressure and rapid filling of the containers. However, from a user perspective it is better to position standpipes at high points in the system to allow people to walk uphill with empty containers and downhill with filled ones. The role of supporting NGOs involved in the design and implementation of water systems is to resolve such issues by providing training for standpipe operators and back-up support for a period of six months following installation. The training should include information about the management, maintenance and hygiene of the water system.

Taps are crucial components of the standpipe and water supply on camp sites. They must be exceptionally robust to withstand high wear and tear due to frequent daily usages, occasional abuse and vandalism (Haarhoff and Rietveld, 2009). It is essential to have taps of the highest quality to prevent leaks and spills. Nevertheless, it is equally important to have a systematic procedure for tap maintenance and replacement. This is necessary because its lifetime will be considerably lower than the lifetime of most of the other infrastructural elements for water supply systems.

The platforms around the standpipes should be made of smooth pervious materials such as porous concrete, and should be sloped to one side to allow water to slide off (Haarhoff and Rietveld, 2009). The drainage water on the standpipe platform has to be collected and directed away without compromising the safety of users. If spillages are simply left to drain off the standpipe platforms they can erode the surrounding natural ground and produce a hazard risk for those collecting water (Haarhoff and Rietveld, 2009). Once off the platform, the water should be channelled away from the standpipe and employed for useful secondary purposes such as the watering of hedgerows, trees or vegetable gardens.

Part 2: Context Specific Surface Water Drainage Responses

The front-line field workers in emergency situations are usually volunteers working for various international non-governmental organisations and humanitarian agencies (Bhamidimarri, 2015). These people require knowledge and practical experience in a broad range of subjects including water and sanitation, public health and epidemic management (Paul, 2015). The time taken to reach minimum standards for effective drainage is affected by resources, access, security and the living standards of the area prior to a disaster (Sphere, 2011).

A detailed review of the factors involved in the decision making processes used when setting up drainage provision in emergency camp sites would be very valuable in identifying existing gaps and vulnerabilities. Understanding these gaps as well as the vulnerabilities of drainage provisions made by various relief agencies could support the development of a structured approach that could contribute to the improvement of flooding resilience for future emergencies. For the purpose of this report, two key factors and their potential impact on chosen surface water drainage responses and strategies are considered. These are the level of emergency (acute, transitional, or stabilised) and the camp location (refugee camp, urban context, rural context).

2.1 Emergency Level Specific Responses

Emergencies are very diverse and dynamic events, ranging in spatial and temporal characteristics. Because of this, emergency responses often need to be tailored to the specific attributes of each crisis. From a temporal perspective, humanitarian crises can have different levels of acuity, ranging from an *acute crisis stage* within the first weeks, a *transition phase* in the first few months, and a *community development phase* for a few months up to a year after the emergency. Controlling the transition from an acute humanitarian emergency relief phase to a community development phase is a critical matter in ensuring the effectiveness of progress towards recovery (Clarke, 2015a). Reducing the duration of the transition phase by ensuring that aid agencies achieve technical, social and operational objectives are important stages which are directly related to surface water drainage.

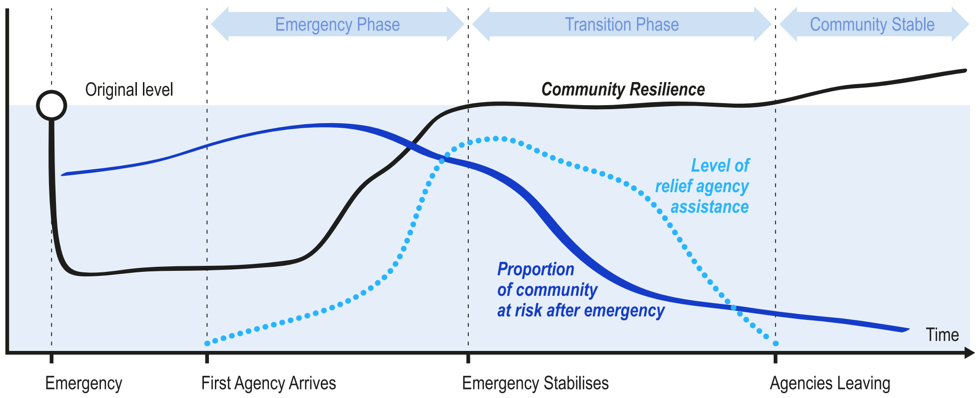


Figure 4.
The evolution of community resilience, proportion of community at risk, and relief agency assistance throughout the lifecycle of an emergency.
(Source: Adapted from Clarke, 2015b)

When deciding on appropriate surface water drainage responses in the case of an emergency, there are a number of factors and processes that can impact on the transition from an emergency phase to a community development one.

Some of these factors and processes include (Clarke, 2015b):

- Population affected, numbers, conditions and locations, regional surface water and foul water drainage factors to support strategic planning;
- Local conditions and community characteristics, standard and expert assessments;
- Determining the reliability and quality of existing infrastructure systems;
- Understanding process requirements and limitations at field operational levels and research advised;
- (e.g. potential evidence for precipitation increases or decreases linked to global warming);
- Integrating water, food and shelter needs, requiring structured and multi-factor inputs from relief agency experts;
- Available relief agencies and local technical capacities in key factors and/or collaborators for drainage design and construction;
- Development of monitoring expertise and procedures for identifying immediate and foreseeable risks;
- Implementing health systems and procedures for identifying important community and local health issues, feedback loops into water management;
- Assessing individual relief agency water resource management limitations;
- Minimising infection risks by introducing emergency measures to protect the population from pathogen transfer;
- Supporting the progressive development of a reliable hygiene control environment;
- Developing separate and reliable surface water drainage systems (if practicable);
- Providing reliable and appropriate foul water/sewage collection and treatment systems (e.g. including pit latrines) which also have provision for ensuring reliable surface water drainage;
- When designing and developing a grey water drainage system (if required), minimise pathogen related risks by ensuring that grey water systems are not readily available for misuse or discharge untreated contents into the local surface environment.

A consistent understanding of conventional land drainage and sewerage systems, as well as knowledge of design procedures, construction techniques and implementation factors are needed in order to develop effective drainage responses. In an emergency scenario a detailed range of both high and low technology options must be considered. The wide range of contextual factors that need to be taken into account means that initial decisions are often made against a background of uncertainty. Although there may be many case specific constraints, it may be possible to settle key technical performance features associated with surface water drainage in the short term (Clarke, 2015b). Another factor to keep in mind is the fact that, in most cases, community excreta management overlaps with drainage. Therefore, in some semi-permanent and permanent camp sites, minimising existing system failures and flood risks might involve combined sewerage systems (Clarke, 2015a).

The total reconstruction of either blocked or severely damaged sewerage systems is almost invariably a lengthy process. Notwithstanding the technical challenge of actually tracing and properly understanding existing systems, in larger urban areas a task of such magnitude is probably well beyond the direct staff resources of relief agencies. However, short term benefits can be achieved by a clear understanding of the relationship between water usage and wastewater generation. In the short term, this could significantly reduce health risks in the local population by limiting their exposure to potential sources of infection but also give rise to a requirement for greywater drainage.

2.2 Location Specific Responses

A key factor affecting the type of surface drainage response in a crisis situation is the location of the emergency. Environmental characteristics such as climate, geography, level of urbanisation and population concentration have a significant impact on the urgency and overall strategy with which drainage challengesare addressed in an emergency. This section introduces some concrete case studies of crisis situations and their approach to addressing the challenges of surface water drainage.

2.2.1 Bentiu Refugee Camp, South Sudan

The refugee camp Bentiu in South Sudan has 50,000 inhabitants and is located in a low-lying swamp area of 70 hectares. South Sudan's civil war broke out in December 2013, creating a huge number of refugees, both within South Sudan and neighbouring countries (Grontmij, 2015). It is a large project, in a difficult location, in the middle of a war zone. The total cost of the crisis and displacement project amounts to about US $20 million. In the 2014 rainy season the entire camp flooded, including the toilets, schools and hospital. One of the surface water drainage systems designed by the Dutch consultancy firm Grontmij includes a levee to prevent surface water flooding around the camp.

Figure 5.
In August 2014, the low-lying refugee camp Bentiu in South Sudan was completely flooded. Dutch consultancy firm Grontmij are building a levee fully encircling the camp to prevent surface water flooding during the rainy season. (Source: Grontmij, 2015)

In the case of this refugee camp, as well as in the case of most camps situated in low-lying areas, drainage systems which include canals and pumping stations are required for the flow of surface water away from the camp site. A combination of levees and drainage schemes (pumps, canals, surface and subsurface drains) are required to prevent refugees having to walk through ankle-high mud during the rainy season in June. Low-lying refugee and IDP camps are always at risk from surface water flooding. For low-lying areas, the combination of levees and engineered systems (pumping, canals and drainage pipes) is required for improved living conditions (Grontmij, 2015). Nonetheless, such systems can require considerable capital implementation costs and their operation could rely on heavy pumping and therefore, continuous energy, with associated on-going operational revenue costs (Reed, 2015).

The initial response of relief agencies is strongly influenced by the systems they have in storage, staff skill sets, logistical constraints, financial resources and the equipment that can be acquired in the short-term. Cost at this stage is often viewed in a more holistic manner and negotiations with potential funding partners will commence. However, as the emergency develops into a camp situation (transition phase) a more detailed management and engineering approach must be obtained to provide the basis for evaluation and assessing multiple options and issues.

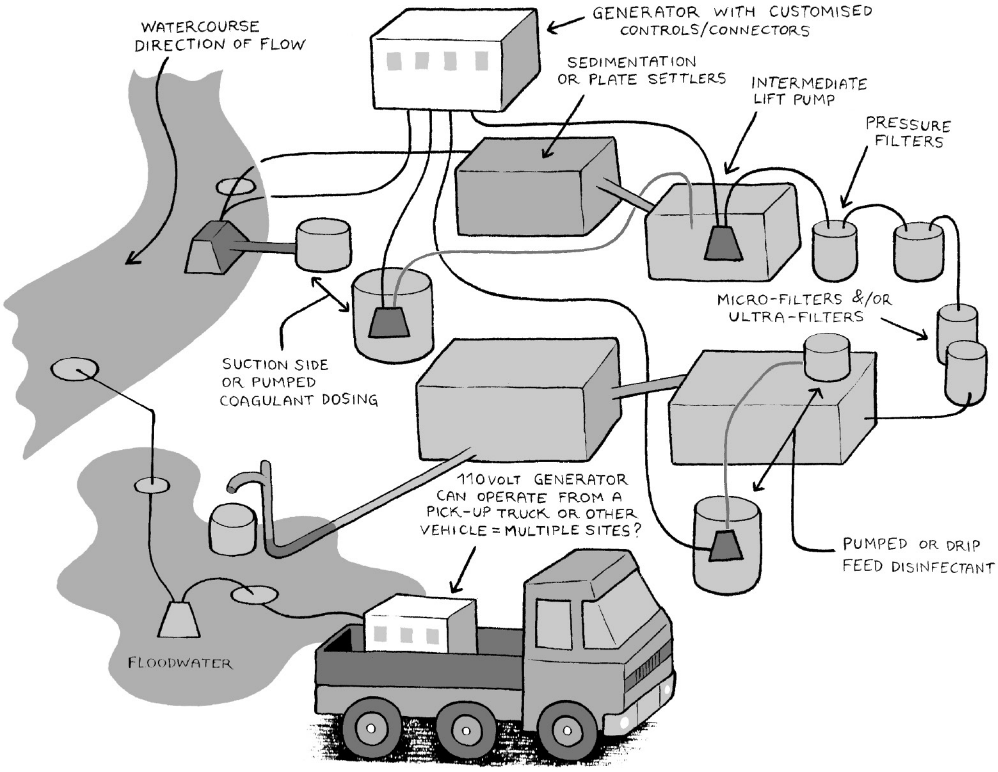
It is appreciated that managerial, cultural, social and other factors also need to be assessed in parallel with technical water and sanitation issues; however, capacity development in multiple areas could be enhanced by such a collaborative approach.

A thorough and informed assessment about where the camp should be sited is key to minimising flooding risks.

A thorough and informed assessment about where the camp should be sited is key to minimising flooding risks. Such an assessment should take into account the local topography and likely hydrological conditions. Flood control and management should be a significant aim in the process of designing a camp. While the design should rely on best practices and local knowledge, if this is missing, making worst case scenario assumptions might present the best viable option. Given the developing pattern of camps becoming progressively larger and longer-term solutions, this could represent an opportunity to start collecting more detailed essential data on location. Site specific information is particularly important for engineers and other professionals addressing drainage system designs and the ongoing issues of flooding risk.

Surface water and foul drainage problems have affected a significant number of refugee and IDP camps in recent decades. However, learning from the challenges and the process of designing camp drainage systems has been slow. A reason for this is that reporting from the field is not common. Often, in an emergency situation the resources are focused mainly on offering support, rather than documenting processes. For example, because of a lack of practice on 'reporting on a day-to-day basis' there is not a clear understanding of whether developing kit based pumping systems might be beneficial to aid agencies. The urgent pumping of surface water and contaminated effluents by relief agencies during an emergency is not uncommon, but further documentation is needed on the process and its overall impact (see Figure 6 for a concept drainage pumping system).

Figure 6.
Concept for developing an integrated system of submersible pump options to support rapid on-site deployment of relief agency water treatment, water supply, surface water or wastewater pumping requirements. (Source: Adapted from Brian Clarke, 2012)



2.2.2 Zaatari Refugee Camp, Jordan

In January 2013, severe weather conditions across northern Jordan, including heavy rain, snow and sub-zero temperatures, worsened the situation for over 55,000 Syrian refugees living at the Zaatari camp site (UNICEF, 2013). Widespread flooding occurred, swamping tents and overwhelming the drainage system across the camp. The heavy rain created an extremely muddy surface which made it difficult for water removal tankers and trucks to access the camp and drain the water.

Figure 7.
Tents and facilities in Zaatari camp flooded by the heavy rains which hit northern Jordan in early January 2013. (Source: UN News Centre Archives, 2013)

Drainage and infrastructure works are currently in progress to establish wastewater and surface water/stormwater drainage systems for the displaced Syrian refugees at the Zaatari refugee camp (Khaleej Times, 2015). A United Arab Emirates (UAE) funded project is currently underway in Jordan to improve living conditions for Syrian refugees. The UAE has pledged Dh 18 million in aid for the Zaatari camp in 2014, of which the sum of Dh 7 million is allocated to health initiatives and the rest for sanitation projects. The drainage system is expected to divert excess surface water to serve agricultural needs. The first phase of the infrastructural project includes sewage collection from each refugee household in the camp, with each household connecting to a pipe that transports sewage to a main tank in the zone. The second phase of construction includes a network of pipes that will transport surface water drainage and greywater to a wastewater treatment plant (Khaleej Times, 2015).

2.2.3 Haiti and Port-au-Prince Post-Earthquake Crisis

Haiti's magnitude 7.0 earthquake in January 2010, left 220,000 people dead, 300,000 injured and rubble nearly everywhere across the Caribbean island nation. Poor drainage systems lead to flooding around urbanised areas of the capital Port-au-Prince which resulted in 120 cases of cholera being recorded during the early stages of the natural disaster (Al Jazeera, 2010). The catastrophe resulted in an unprecedented level of humanitarian aid totalling approximately US $13 billion in donations and pledges. Nevertheless, six years after the earthquake, Haitians are still struggling to rebuild their lives. Cholera has now affected more than 720,000 Haitians and killed almost 9,000 between 2010 and 2015 (Bharti et al., 2015; Hooper, 2015). These data dramatically illustrate the impact poor drainage, water management and sanitation can have on a small island developing state such as Haiti in the aftermath of a natural disaster.

Figure 8.
Poor drainage systems which led to flooding in areas outside Haiti's capital Port-au-Prince resulted in 120 cases of cholera. (Source: Al Jazeera, 2010)

2.2.4 Mega-Floods in Pakistan

During the 2011 monsoon season, Pakistan experienced a series of catastrophic floods throughout the region. The 2011 Sindh floods began in the middle of the August monsoon season with excessive rainfall. The floods caused catastrophic damage with an estimated 434 civilians killed, and 5.3 million people and 1,524,773 homes affected (Shah, 2012). Around 1.7 million acres of arable land were inundated by floodwaters. The economic damage caused by this disaster was estimated at US $10.1 billion or 5.8 percent of Pakistan's GDP (Shah, 2012).

Figure 9.
Catastrophic Mega-Floods in the Sindh Province, Pakistan during the 2011 monsoon season. (Source: Caritas, 2011)

Humanitarian aid agencies report that millions are still in dire need of assistance and there have been renewed warnings to people in the worst-hit province of Sindh (Polastro et al., 2011; Shah, 2012). Such flooding disasters have exposed the country's inability to cope with calamites of this scale and the urgent need for an integrated approach for dealing with disaster management, drainage and flooding related matters. The inability to deal with this scale of emergency also raises the matter of future vulnerabilities. Given the post-disaster crisis and the urgent need for relief, rehabilitation and reconstruction of drainage infrastructure, the task may seem difficult to achieve within a short time frame (Polastro et al., 2011). Several humanitarian organisations active during this crisis reported insufficient financial resources and funding to meet basic needs such as shelter, food and clean water for the communities of the Sindh region (Polastro et al., 2011).

Part 3: Current Approaches and Limitations

Existing research states that there are two primary standards for surface water drainage in an emergency (Cuny, 1977; Wildman, 2015; Reed, 2015):

1. People should have an environment that is acceptably free from the risk of water erosion and from standing water including stormwater, flood water, domestic wastewater and wastewater from medical facilities;
2. Refugees and IDPs should have the means-installations (e.g. drainage channels/soakaways) and techniques to dispose of surface water and greywater conveniently and effectively to protect their shelters, families and communal facilities from flooding and erosion.

Access and distance to water collection points are also important as they affect the amount of time and energy expenditure spent on this task. Long distances transporting water imply that a substantial amount of a refugee's scarce calories are spent on this task alone (Shrestha and Cronin, 2006; Cronin et al., 2008). Depending on the available financial and human resources, the establishment and maintenance of a camp drainage system usually falls under the responsibility of the camp management agency, the WASH service provider and/or the local sanitation authorities (Wildman, 2015). The stakeholders involved need to agree upon their roles and responsibilities, and clearly communicate them to the camp population. Ideally, camp sites are planned prior to the arrival of refugees or IDPs, on sandy soil with a slightly sloping gradient. However, in most cases this is not possible as available land may not be best suited for surface water drainage.

The topography and type of soil or ground determines the best option for drainage systems. For example, infiltration is usually the easiest way to drain excess water and is often utilised. However, this might not always be the best option; for example, soak pits in camps built on loamy or clay soils where infiltration is limited may in fact be wholly ineffective and problematic in their own right. Surface runoff on typical camp sites consists mainly of rainwater precipitation, leaks from water supply pipelines, spillage during water collection and transportation. Designing and constructing drainage systems requires expert advice from engineers to make sure that water flows away quickly and smoothly and is disposed of in a surface watercourse or soakaway in a safe manner. Drainage installed by one community should not create problems for other communities downstream, nor should it affect ecologically important sites (Nsengimana, 2015).

3.1 Conventional Drainage Schemes

The Sphere report on Humanitarian Charter and Minimum Standards in Humanitarian Response in relation to water supply, sanitation and hygiene promotion (WASH) includes the following key standards for drainage (Sphere, 2011):

- Water point drainage should be well planned, built and maintained (including drainage from washing and bathing areas, as well as water collection points and hand washing facilities);
- There should be no pollution of surface water and/or groundwater sources from drainage water;

- Shelters, paths, water and sanitation facilities should not be flooded or eroded by water;
- There should be no erosion caused by drainage water.

Drainage plans in emergency sites must be integrated with other infrastructural developments such as road construction to avoid unnecessary surface water problems.

Davis and Lambert (2002) stated that drainage plans in emergency sites must be integrated with other infrastructural developments such as road construction to avoid unnecessary surface water problems. Sewerage systems should avoid depressions or dry water courses which could be filled with rainfall runoff. Drainage systems must take into account rainfall patterns, as well as existing latrines, with shallow cut-off drains to divert rainfall runoff. Spillage or drainage from defecation systems must not run towards any surface water source or shallow ground water source (Davis and Lambert, 2002).

Drainage systems on sites will begin from the receiving water body or outfall. Drains will need to be designed backwards from this point and, where possible, follow the natural gradient of the ground surface.

Factors affecting surface water flows on camp sites depend mainly on soil conditions, the slope of the terrain (topography) and on land usage. For example, water seeps more readily into sandy soil than into clay or rocky ground and flows more rapidly down steep slopes, giving less time to infiltrate. In addition, vegetation traps much of the water and also loosens the soil, making infiltration easier. Drainage must allow water to pass effectively across the camp site while allowing safe vehicular and pedestrian access. Secondary drainage should feed into larger interceptor drains that connect into a receiving water body or outfall. Surface water should ideally flow fast enough that sediments and solids it is carrying are not deposited within the camp site. Drains with sloping sides and narrow bases help in maintaining a steady flow. Ground which slopes greater than 5% is considered a steep slope.

Protection against erosion and excess infiltration can be done by lining or providing protection at particular vulnerable points along the drainage network. Drainage will require turn-out-drains and design features to channel the flow of water to the desired locations. Effective drainage construction, operation and maintenance activities are important and rely on the involvement of local communities and aid agencies.

3.1.1 Surface Water and Stormwater Drains

The design of stormwater and surface water drains is usually carried out taking into account climatic and hydrological data. However, this data may be scarce, or may not cover the community where work is to be carried out. This can be problematic in the field. If available the local community can provide outline assistance by describing when and where major flooding problems have occurred in the past and possibly, information on some issues associated with the flooding event(s). If there is no reliable and appropriate rainfall data then one cannot design surface water drainage networks with a high degree of certainty.

In many cases the adoption of stormwater designs is based on estimates regarding the return period, rainfall profile, and intensity of rainfall per hour. This is done using a large safety factor, and pipe work and ditch networks for which the details are somewhat provisional (e.g. pipe versus channel sections, materials, lengths, gradients, soil conditions, channel roughness).

The size of the surface water drains is usually calculated based on the volume of water they are expected to transport in extreme storm events.

Stormwater and surface water drains should be designed to collect water from all parts of a camp site and lead it to a main drain or multiple sub-catchment drains, which then discharge into a local stream or larger body of water. The major features of a drainage network should be determined by topographical constraints unless provision is to be made for pumping. The sizes of drains and channels are usually calculated based on the estimated quantity flow of water they are expected to transport as a result of an extreme storm event within their catchment area.

Most extreme floods occur relatively infrequently and are unpredictable. Therefore, using a safety margin, maximum flows of stormwater are calculated based on flood events expected to occur once every 10 years. If stormwater drains are designed to carry only the volume of water produced from an annual flood, they will not be able to handle the flow of water from heavier flooding events, which may occur as often as every 3 to 5 years. Designing for drainage exceedance must also take into account storm events with a likelihood of happening once in 50 or 100 years and even beyond. When thinking about longer storm return periods, simply designing larger channels may not be sufficient. Alternative methods such as partitioning larger camps into sub-catchments should also be considered. Stormwater drains perform best when constructed using concrete or alternative lining. Drainage channels not protected with linings can suffer erosion when water flows at high velocities or if the sides of the drains are too steep. Earth constructed surface water drains often become clogged and overgrown causing severe problems with stormwater flows during minor flooding. Incorrectly designed stormwater drainage systems can lead to the formation of stagnant pools. These then become breeding sites for disease vectors such as mosquitoes, raising the risk of dengue fever, malaria and the risk of schistosomiasis (Prüss and Havelaar, 2001).

3.1.2 Greywater Disposal Methods

A person generates around 15 to 20 litres of greywater per day when collecting water from a standpipe.

It is estimated that a person generates around 15 to 20 litres of greywater per day when collecting water from a standpipe (Cairncross and Ouano, 1991). Greywater or sullage is often disposed of using on-site methods or through the drainage systems available in camps. Soakaway pits can be constructed for greywater disposal based on the water table. If soakaways are used, the pit should be located away from the residential area of the camp and away from water sources. It is not recommended that sullage be disposed of in pit latrines, as this may interfere with the breakdown of excreta in the pit and may overload latrine soakaways where pour-flush latrines are used. Regardless of the proposed drainage solution, key to their effective use is making sure that they are close to the source of greywater.

3.1.3 Combined Drains

Combined drains are designed to carry both surface water and greywater (sullage). However, combined drains need to be well designed and maintained so that greywater does not pool in drains and form insect breeding sites. This challenge can be overcome by using a system with a small insert drain that carries sullage into a larger drain for carrying stormwater.

Where there is previous precipitation and/or no stormwater flow in the surface water drain, greywater is sometimes introduced into a much larger pipe. Greywater will then flow with a minimal velocity, causing occasional ponding. In some combined sewers, wastewater flows account for less than 5% of the combined foul water and surface water flows; during storm events 95% of the flow is mainly surface water runoff.

3.1.4 Buried Drains and Combined Sewers

Drains may also be buried and incorporated into sewerage systems. Because these types of systems will require detailed planning and design they may not be applicable in an emergency situation. However, they can be applied to disaster relief sites or camps where the residency period is longer and retrofitting drainage systems possible.

Buried drains have inlet chambers at regular intervals that allow the entry of stormwater. The drainage system then leads directly either to a watercourse or to a wastewater treatment facility. The stormwater should always flow either into a stabilisation pond, or into a storage pool constructed to take stormwater flows above a certain volume. Despite the additional planning and design time required, buried drains and combined sewers can be considered a viable surface water drainage solution in temporary settlements.

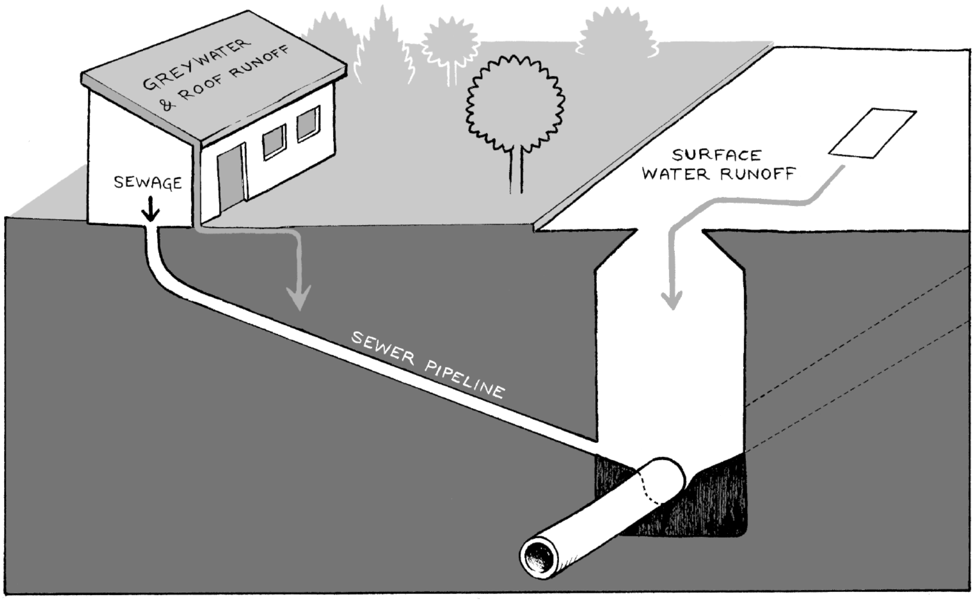


Figure 10.
A conventional combined sewer system and buried drains to convey stormwater, sewage and greywater (sullage) to a centralised wastewater treatment facility. (Source: Adapted from Tilley et al., 2014)

3.2 Sustainable Drainage Systems

Sustainable Drainage Systems (SuDS) are systems that are constructed or engineered using man-made materials and/or natural systems that tend to preserve existing open space, protect natural systems (groundwater, surface water) for improved drainage and filtration, and make use of existing urban planning and maintenance to manage urban water flows. They are also referred to as Sustainable Urban Drainage Systems (SUDS), Stormwater Management, Water Sensitive Urban Design (WSUD), Low Impact Drainage and Best Management Practices (BMPs). Some of the most suitable BMPs for sustainable surface water drainage include filter media roofs, soakaways, water butts, rainwater harvesting systems, filter strips, infiltration trenches, swales with an impermeable layer for groundwater protection, bio-retention systems, pervious concrete, geocellular systems, sand and gravel filters, and detention basins. However, these are not suitable for contaminated surface water which consists of excreta, high silt levels and poor solid waste management (Reed,2013). These solutions can either be retrofitted or embedded into camp site designs to improve surface water drainage. SuDS, SUDS, WSUD or BMPs can also include the use of modern engineered materials specifically designed for stormwater drainage, such as high-performance polypropylene pipes. These pipes can be utilised in a comprehensive range of water management and superior drainage solutions based on their hydraulic capacity, internal burst pressure and the nature of internal flow conditions (laminar-transitional-turbulent flows). Such pipe systems can be embedded into gravity-flow surface water drainage applications on site. The selection of high-performance polypropylene pipes can be appropriate where durable pipe joints and section stiffness is required to deal with larger fluctuations in water flow. These pipes combine advanced polypropylene resin technology with a dual-wall profile design to ensure long-term performance and durability and thus reduce the effects of earth dug ditches or surface drains.

3.2.1 Rainwater Harvesting

Most stormwater and surface water runoff generated in and around refugee camps is the result of rainfall precipitation. Rainwater harvesting is an approach used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques (Clarke, 2015). Harvested water can be an important water source in many refugee camp areas which have a significant level of annual rainfall and suitable patterns of precipitation, together with a lack of conventional and centralised water supply systems. This technique can also be a viable option in areas where groundwater is lacking and the quality of surface water is poor. When harvested from clean catchments, rainwater is relatively clean. Its quality is usually acceptable for many purposes, with little or even no treatment, although disinfection is recommended. The physical and chemical properties of rainwater are usually superior to sources of groundwater that may have been subjected to contamination based on the geological site conditions and microbiological pollutants.

Rainwater harvesting can be used to relieve the pressure on existing site water sources by providing additional water. It can also help distribute the volume of water around the camp and provide a water supply buffer for use in times of emergency. Given suitable rainfall conditions, the technique can be used to address emergencies within camp sites, including the breakdown of potable water supply systems. Furthermore, with sufficient storage provision, rainfall harvesting can reduce storm drainage loads and alleviate flooding risks around camps. Rainwater harvesting technologies can be flexible and built to address a range of requirements.

Figure 11.
Temporary improvised rainwater harvesting solution in Myanmar. Such solutions can provide an alternative source of water in areas prone to drought. (Source: A. Steele, 2008)

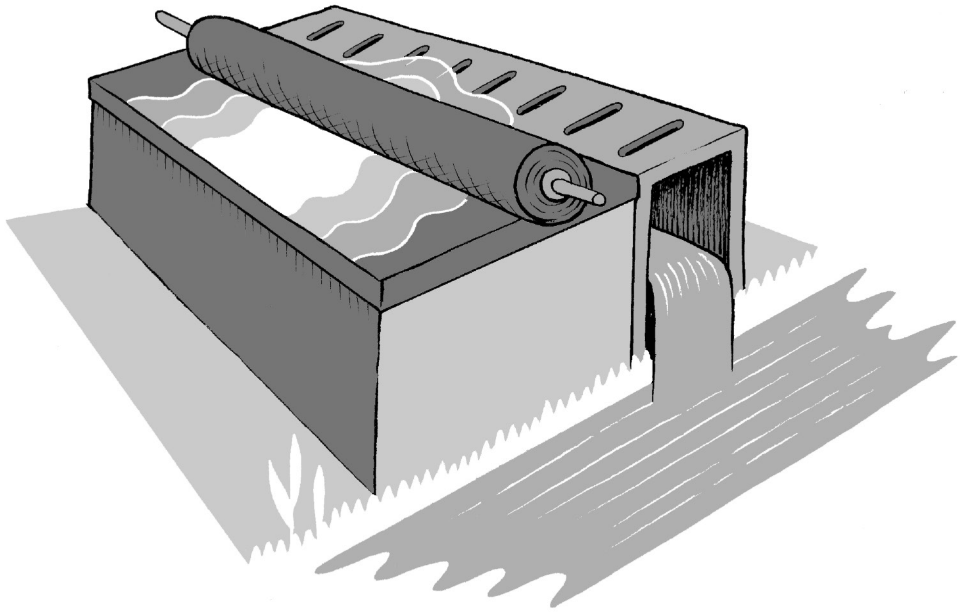


Figure 12.
Applications of synthetic fibre materials or geotextiles as a simple yet effective solution to keeping pollutants out of trench drains.(Source: Adapted from Tilley et al., 2014)

3.2.2 Low-Technology Equipment and Systems

Low-technology equipment such as dewatering bags, sand and gravel bags, silt dike barrier systems, and stormwater containment sumps are important for supporting onsite surface water management in emergencies. For example, materials using polyethylene components can be excellent in absorbing grease and contaminants present in surface water runoff. In more permanent camp settings, drain guard systems to stop sediments and other debris from entering into the inlets of drainage canals can be provided.

Non-toxic vector control systems can be applied in areas prone to water ponding. For example, using biodegradable organic enzymatic or bio-catalytic insecticides can prevent or inhibit the potential breeding of vectors. However, the limitations of individual emergency water treatment systems for removing herbicides or pesticides should be fully appreciated before they are used in any individual camp application or in the immediate water environment.

Submersible pumps can be used to redirect surface water. The main advantage of submersible pumps is that they do not have suction side pipework but are modular; this means that surface water throughput and even solids handling capacities can be optimised by specialised impeller design (Clarke, 2015). Ground conditions in relief agency camps are often plain earth surfaces that can easily become swamps in a short amount of time. Plastic surface cover sheets, geotextiles or proprietary systems can be used to reinforce the soil surface in areas used for paths or access ways to tents and buildings. These can be very important in providing safe conditions and reducing health risks.

3.3 Ongoing Maintenance of Drainage Systems

Civil or water engineers employed to design drainage, water treatment and water supply systems in emergency and refugee or IDP settlements should take into account the drainage of swamp areas, land levelling, the removal or planting of vegetation in or near swampy areas and the construction of levees. These stormwater control methods can be very effective and provide long-term surface water drainage solutions. In these situations, much of the small-scale and physical work will often be carried out by refugees/IDPs to ensure proper operation and maintenance (Erickson et al., 2013).

In order to keep performing as designed, stormwater treatment facilities and drainage systems will require periodic maintenance.

Stormwater treatment and drainage systems must receive planned, intentional and regular maintenance to provide the predetermined design rates of discharge, levels of surface water runoff volume reduction, contaminant load reduction or other primary objectives over an extended period of time. In order to keep performing as designed, stormwater treatment facilities and drainage systems will require periodic maintenance (Erickson et al., 2013). For example, as a detention pond fills with sediment over time, it will approach its storage capacity and previously settled solids may be re-suspended and washed out of the pond. Infiltration trenches will not operate as designed if not properly constructed but also if not suitably maintained. These systems can be at risk of partial or total clogging, exhibiting slow infiltration rates or becoming blocked (Erickson et al., 2013).

The design of a maintenance system for drainage depends on the context. Cleaning and maintenance of drainage infrastructure is necessary for functionality (Cairncross and Ouano, 1991). Support from the refugee camp population and camp management is essential. Visual inspection involves inspecting stormwater management systems and drainage infrastructure for evidence of malfunction. However, visual inspection cannot guarantee that the drainage system is operating properly (Rossmiller, 2013). Further inspection and maintenance can be supported by Capacity Testing. Capacity testing involves either the measurement of sediment surface elevations within SuDS or BMPs or taking measurements to determine the saturated hydraulic conductivity of soils in the area (Wilson et al., 2004).

In an emergency camp setting, the occasional clearing of the drainage system can be undertaken on a cash-for-work basis (Paul, 2015). People will need to have available or be supplied with appropriate tools and equipment necessary for effective maintenance of the drainage system. In particular it is important to ensure that deposited materials are removed from the drain and disposed of in a safe manner so that overspilling and ponding does not occur during the next storm event. In addition to this, it is important to ensure that waste material removed from the drainage system is disposed of in a manner that does not allow it to be washed back into the system.

Community participation in maintaining drains is essential for alleviating some of the main challenges facing camps and temporary settlements; this could include employing sanitarians and giving them responsibility for drain inspection and cleaning (Davis and Lambert, 2002). Extensive discussions and education can persuade people to change their habits around water management and drainage (Bhamidimarri, 2015). Maintaining the drains can soon become part of a daily routine for responsible community members. Those responsible will need basic construction tools such as hoes, shovels, buckets, wheelbarrows, gloves, waterproof boots and overalls. Minor repairs may also be needed at the end of each rainy season to ensure that stone pitching and constructed drifts and culverts retain their integrity.

Camp management agencies and WASH service providers need to support and promote good practices to help maintain surface water drainage systems. Weekly work plans for drainage inspections must be established and gaps identified and reported to the relevant agencies and WASH providers. Specific training can also be provided for those interested in supporting maintenance operations.

WASH service providers and camp management agencies need to ensure the availability of sufficient and technically adequate spare materials (e.g. water taps, pipes, washers, bonding agents), as well as ensuring that water pumps and taps work effectively. Overall, there is an increasing pressure on relief agencies to change their existing approaches towards addressing WASH standards in an emergency. Relief agencies are expected to change their culture and focus on the way water is stored, used, transported and disposed of in an emergency (Griffiths et al.,2005). In turn, the aim of this change would be to help NGOs recognise shortcomings and support the development of more effective water management approaches.

Part 4: Areas for Further Exploration

Most studies on WASH and drainage focus primarily on the final source of water but often fail to acknowledge the routes which lead to contamination (Reed, 2015). The Sphere handbook identifies four main questions on drainage in temporary accommodations and refugee or IDP camps (Sphere, 2011):

- Is there a drainage problem (e.g. flooding of dwellings or toilets, vector breeding sites, polluted water contaminating living areas of water supplies)?
- Is the soil prone to waterlogging?
- Do people have the means to protect their dwellings and toilet from local flooding?
- Are water points and bathing areas well drained?

However, the main challenge is identifying from these perspectives how public health is at risk when drainage infrastructure does not meet the criteria and standards identified by Sphere (2011). Listing broad areas for consideration does not guarantee an effective solution. This report suggests three approaches that could encourage the development of more context-specific processes to improve drainage in emergency situations.

4.1 The Need for Tailored Drainage Approaches

Research should be conducted on a case-by-case basis in existing camps to establish to the best practicable level of certainty whether appropriate drainage facilities have been provided, and whether water distribution points and dwelling areas are free from ponding water.

The next step should be to categorise the priorities for surface water drainage according to rainfall levels - high rainfall, medium rainfall and drought affected areas. While in high rainfall areas the priority will be to get floodwater out of the catchment, in drought areas the priority will be to store as much harvested rainfall as possible (Clarke, 2015). Adapting surface water drainage strategies in this way can lead to more effective solutions, better designed to address the problems specific to the area.

There are knowledge gaps in understanding how affected populations can deal with drainage issues, what the context-appropriate techniques for drainage are, and how maintenance can successfully be carried out. Research is also lacking in understanding the correlation between different drainage practices and possible pathways of vectors or waterborne pathogenic organisms from hand washing facilities and other water points. Specifically, this report suggests three areas in which research advancements would provide valuable knowledge for the development of effective drainage practices, these are: research into hydro-meteorological hazards and risk, drought monitoring and assessment, and drainage vulnerability and surface water management.

4.1.1 Hydro-Meteorological Hazards and Risk

Hydro-meteorological extremes account for an overwhelming majority of natural hazards in the world today affecting millions of people. These extremes result in mega-flood events such as flash flooding, urban floods and other storm related floods. In more populated areas of emergency, floods can have devastating impacts. Therefore monitoring and predicting floods is of great importance.

At a broader level, measuring and mapping floods in areas associated with displaced persons or refugees can provide valuable information for the location and design of temporary accommodation. Understanding hydro-meteorological extremes in crisis prone regions is critical in determining the size of pipes, culverts and channels for the required drainage infrastructure. Understanding and estimating the hydrology of a site, as well as stormwater discharge routes can aid engineers or sanitation volunteers to design, construct and implement better drainage systems.

Information about local meteorological risks, such as floods or drought, is needed to design and implement effective surface water drainage solutions.

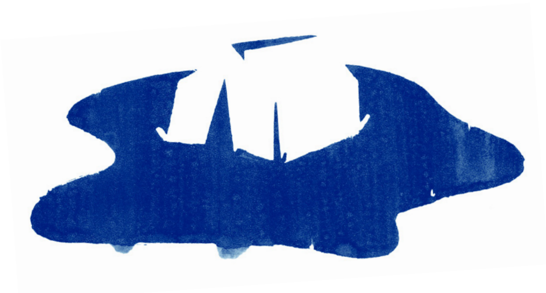
Detailed contextual information about floods, their scale, and frequency, can also support the humanitarian sector in prioritising surface water drainage efforts. For example, given the growing evidence of climate warming producing more floods, humanitarian agencies could reevaluate the way they invest resources and concentrate efforts on storm water drainage solutions.

4.1.2 Drought Monitoring and Assessment

Drought monitoring and assessment is an essential component in understanding the movement of water and is directly linked to overall stormwater management plans. Droughts are a continuous function of rainfall precipitation and affect physical and geographical variables. Droughts also dictate the flow of water to and from camp sites either by truck storage in tanks or in bottles and plastic containers. Depending on the existing drainage infrastructure during drought periods, solid waste can easily enter the drainage networks, compromising their performance when the next storm event occurs.

In drought conditions greywater reuse can provide an essential resource for non-potable use, after planned capture and treatment. However, further research is required to cover the existing gaps in knowledge and provide a better understanding of the characteristics of droughts and temporary emergency relief accommodation needs.

Droughts can pose a challenge to drainage systems in highly urbanised areas as well. An example of this is the 1976 summer drought that affected the southeast of the Greater London area. The drought slowed down flows in some combined sewers and led to periodic blockages, and the development of difficult anaerobic conditions in some older combined sewer networks. The latter problem was principally due to exceptionally slow flow velocities caused by a combination of little or no groundwater infiltration into the sewers, the total lack of influent from surface water drainage connections and a severe reduction of water content/solids ratios within the foul water discharged from domestic conditions (Clarke, 2015b).



4.1.3 Drainage Vulnerability and Surface Water Management

The quantification of drainage vulnerability can help in the decision making processes of humanitarian aid organisations. Contributing factors from short and heavy rainfall events, lack of infiltration capacity, compounded by poor drainage design, poor construction and lack of space are key contributors to drainage vulnerability. Drainage vulnerability is also linked to the volume of water (due to precipitation, groundwater table, potable water consumption, greywater, nearby hydro-systems and wastewater) on the temporary site. Responsibility for drainage infrastructure and associated management needs to be split between logisticians at the camp management level, together with WASH staff and aid agencies at the local levels.

Water drainage parameters for surface water management need to be recorded to offer relevant information on specific factors that will determine where temporary accommodation can be provided. These parameters include physiochemical, biological, geological and topographical measurements of the area which can provide vital information to properly prepare both aid agencies and refugees for the hazards they may face from poor drainage and sanitation.

Conducting an Integrated Risk Assessment for surface water drainage in the case of an emergency is recommended. This assessment should make use of historical hydrographs, flood risk maps and flood vulnerability maps, and should calculate potable water consumption and wastewater generation on site. This process will imply a multidisciplinary approach requiring contributions from hydrology, environmental science, economics and the social sciences. The stormwater management and drainage risk assessment should take into account the physical infrastructure, environmental vulnerability and exposure to public health hazards.

4.2 Concluding Remarks

Poor surface water drainage has a significant impact on the overall wellbeing and health of IDPs and refugees. Even though complex or advanced technologies are available, they are not always suitable for use in an individual emergency or within particular IDP groups or refugee camps, each of which can present unique challenges. As a result of complex and timely emergency factors, the phrase “act first, improve later” plays an important role in how drainage infrastructure measures have been adopted in the past. In the case of emergencies, a comprehensive assessment of drainage needs is required. This assessment needs to take into account hydrological factors, meteorological hazards and risks, drought issues and aspects of surface water drainage unique to the particular case.

When drainage systems or surface water management are to be implemented in refugee camps or temporary settlements, there are a number of steps which must be taken in order to assure their effective functioning. The long-term planning of drainage systems should be taken into account from the very early stages of an emergency. This is becoming an important consideration as the nature of conflicts and crises is increasingly changing. For example, there are several cases where IDP and refugee camps which were at first temporary, became semi-permanent and in some cases permanent.

In either a short-term or long-term emergency scenario, an appropriate and carefully designed surface water drainage system (including stormwater management) is one of the most critical factors towards safeguarding the health and quality of surroundings of IDP and refugee populations.

References

Bastable, A. and Russell, L., 2013.
Gap Analysis in Emergency Water, Sanitation and Hygiene Promotion.
Humanitarian Innovation Fund, London, UK.
[Online] Available at: http://www.elrha.org/wp-content/uploads/2015/01/hif_wash_gap_analysis_1.pdf
[Accessed 25th January 2016]

Betts, A., Loescher, G., and Milner, J. (2012).
The United Nations High Commissioner for Refugees (UNHCR): the politics and practice of refugee protection, 2nd Edition, Routledge.

Bhamidimarri, R. (2015).
Interviewed by by Kiran Tota-Maharaj, Innovating Emergency Water,
Sanitation and Hygiene for Surface Water Drainage, University of Greenwich, 25 September.

Bharti, N., Lu, X., Bengtsson, L., Wetter, E., & Tatem, A. J. (2015).
Remotely measuring populations during a crisis by overlaying two data sources.
International health, 7(2), 90-98.

Bigot, A., Blok, L., Boelaert, M., Chartier, Y., Corijn, P., Davis, A., and Griekspoor, A. (1997).
Refugee health: an approach to emergency situations.

Brikké, F. (2000).
'Operation and maintenance of rural water supply and sanitation systems'.
World Health Organisation (WHO), Geneva, Switzerland.
Available online at: http://www.who.int/water_sanitation_health/hygiene/om/omruralsystems/en/

Cairncross, S., and Ouano, E. A. R. (1991).
Surface water drainage for low-income communities.
In *Surface water drainage for low-income communities.* World Health Organization.

Clarke, B. (2015a).
Interviewed by Kiran Tota-Maharaj, Innovating Emergency Water, Sanitation
and Hygiene for Surface Water Drainage, University of Greenwich, 16 September.

Clarke, B. (2015b).
Surface Water Control in Humanitarian Relief. Personal Communications, September 30, 2015.

Cronin, A., Shrestha, D., Cornier, N., Abdalla, F., Ezard, N., & Aramburu, C. (2008).
A review of water and sanitation provision in refugee camps in association
with selected health and nutrition indicators-the need for integrated service provision.
Journal of water and health, 6(1), 1-13.

Cuny, F.C. (1977).
Refugee camps and Camp Planning: The State of the Art, Disasters, 1(2), 125-143.

Davis, J., and Lambert, R. (2002).
Engineering in Emergencies - A Practical Guide for Relief Workers.
2nd edition Intermediate Technology Publications Ltd. London, UK.

Erickson, A. J., Weiss, P. T., & Gulliver, J. S. (2013).
Optimizing stormwater treatment practices: a handbook of assessment and maintenance.
Springer Science & Business Media.

Griffiths, D. J., Sigona, N., and Zetter, R. (2005).
Refugee community organisations and dispersal: networks, resources and social capital.
Policy Press.

Grontmij (2015).
Grontmij takes care of drainage refugee camp Bentiu, South Sudan.
Available online at: http://www.dutchwatersector.com/news-events/news/13792-grontmij-takes-care-of-drainage-refugee-camp-bentiu-south-sudan.html

Guha-Sapir, D. and Salih, M. (1995).
3.1. Environment and Sudden Population Displacement:
Policy Issues for Humanitarian Action and Development programmes.
CRED/ECHO/UCL, The environmental impact of sudden population displacements.

Guthmann, JP, Klovstad H, Boccia D, Hamid N, Pinoges L, Nizou JY, Tatay M, Diaz F, Moren A, Grais RF, Ciglenecki I, Nicand E, and Guerin PJ (2006).
A Large Outbreak of Hepatitis E among a Displaced Population in Darfur Sudan.
Clinical Infectious Diseases, 42(12), 1685-1691.

Heymann, D.L (ed.) (2008).
Cholera and other vibrioses. In: Control of communicable diseases manual.
19th ed. Washington, DC, USA: American Public Health Association: p. 120.

Hooper, M. (2015).
Will the City Rise Again? The Contested Geography of Housing Reconstruction in Post-Disaster Haiti.
Housing Studies, (ahead-of-print), 1-20.

Hunter, P.R. (2003).
Climate change and waterborne and vector-borne disease,
Journal of Applied Microbiology, 94, 37-46.

Hunter, P.R. (1997).
Waterborne Disease: Epidemiology and Ecology. Chichester: Wiley.

Haarhoff, J. and Rietveld, L. (2009).
Public standpipe design and maintenance for rural South Africa.
Journal of the South African Institution of Civil Engineering, 51(1), Paper 687, pp 6-14

Khaleej Times (2015).
United Arab Emirates (UAE) aided project begins in Zaatari refugee camp.
Available online at: http://khaleejtimes.com/nation/general/uae-aided-project-begins-in-zaatari-refugee-camp

Kolsky, P. (1998).
Storm Drainage: An engineering guide to the low-cost evaluation of system performance.
London, Intermediate Technology Publications.

Lamb, J. (2015).
Interviewed by Kiran Tota-Maharaj, Innovating Emergency Water, Sanitation
and Hygiene for Surface Water Drainage, University of Greenwich, 17 September.

Nsengimana, T. (2015).
Poor drainage systems in Gihembe Refugee Camp 'costing us lives'.
Available online at: http://www.newtimes.co.rw/section/article/2015-05-19/188939/

Oxfam (2014).
Emergency response.
Available online at: http://www.oxfam.org.uk/what-we-do/emergency-response/

Paul, P. (2015).
Interviewed by Kiran Tota-Maharaj, Innovating Emergency Water, Sanitation
and Hygiene for Surface Water Drainage, University of Greenwich, 17 September.

Polastro, R., Nagrah, A., Steen, N., & Zafar, F. (2011).
Inter-agency real time evaluation of the humanitarian response to Pakistan's 2010 flood crisis.
Madrid: DARA.

Prüss, A. and Havelaar, A. (2001).
The global burden of disease study and applications in water, sanitation and hygiene.
In *Water Quality: Guidelines, Standards and Health*
ed. Fewtrell, L. and Bartram, J. pp. 43–59. London: IWA Publishing.

Reed, B (2013).
Storm-water management in low-income countries.
Proceedings of the Institution of Civil Engineers. *Municipal Engineer* 166(2): 111–120.

Reed, B. (2015).
Surface water in temporary humanitarian settlements.
Personal Communications, September 18, 2015.

Rossmiller, R.L. (2013).
Stormwater Design for Sustainable Development. McGraw Hill Professional.

Salama, P., Spiegel, P., Talley, L., & Waldman, R. (2004).
Lessons learned from complex emergencies over past decade.
The Lancet, 364(9447), 1801-1813.

Sasaki, S., Suzuki, H., Fujino, Y., Kimura, Y., and Cheelo, M. (2009).
Impact of drainage networks on cholera outbreaks in Lusaka, Zambia.
American Journal of Public Health, 99(11), 1982–1987. doi: 10.2105/AJPH.2008.151076.

Shah, S. A. (2012).
Gender and building homes in disaster in Sindh, Pakistan.
Gender and Development, 20(2), 249-264.

Sphere (2011).
The Sphere Project, Humanitarian Charter and Minimum Standards in Disaster Response.
Sphere Project, Practical Action Publishing, United Kingdom.

Thomson, M. C. (1995).
Disease prevention through vector control: Guidelines for relief organisations (Vol. 10). Oxfam.

Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph., Zurbrügg, C. (2014).
Compendium of Sanitation Systems and Technologies — (2nd Revised Edition).
Swiss Federal Institute of Aquatic Science and Technology (Eawag), Duebendorf, Switzerland.
ISBN 978-3-906484-57-0.

Uddin Khan, M. and Shahidullah, Md. (1982)
Role of water and sanitation in the incidence of cholera in refugee camps.
Trans. Royal Society Trop. Med. Hyg. 76(3), 373–377.

UNHCR (2015).
Internally Displaced People — On the Run in their Own Land.
Available online at: http://www.unhcr.org/pages/49c3646c146.html

UNICEF (2013).
Syria: amid severe weather, UN agency flags worsening situation for children in Jordanian refugee camps.
Available online at: http://www.un.org/apps/news/story.asp?NewsID=43900#.VggM99JVikp

Wilder-Smith, A. (2005).
Tsunami in South Asia: what is the risk of post-disaster infectious disease outbreaks?
Annals-Academy of Medicine Singapore, 34(10), 625.

Wildman, T. (2015).
Interviewed by Kiran Tota-Maharaj, Innovating Emergency Water, Sanitation
and Hygiene for Surface Water Drainage, University of Greenwich, 15 September.

Wilson, S., Bray, R., & Cooper, P. (2004).
Sustainable Drainage Systems–Hydraulic, Structural and Water Quality Advice (C609).
Construction Industry Research and Information, London.

About the HIF

The Humanitarian Innovation Fund (HIF) is a non-profit grant making facility supporting organisations and individuals to identify, nurture and share innovative and scalable solutions to the challenges facing effective humanitarian assistance.

The HIF is a programme of elrha

The HIF's WASH initiative is funded by the UK Government.

UKaid from the British people

Address: Humanitarian Innovation Fund
ELRHA
C/o Save the Children
1 St John's Lane
London
EC1M 4AR
United Kingdom

Email: info@humanitarianinnovation.org

Twitter: @The_HIF

Website: humanitarianinnovation.org

HIF humanitarian innovation fund

Suggested citation:

Tota-Maharaj, K. (2016). 'Surface Water Drainage'.
WASH in Emergencies | HIF Problem Exploration Report. Cardiff: ELRHA

This report was edited and designed by Science Practice

January 2016