URBAN CRISES

Urban Crises Learning Partnership (UCLP)

Water Market Actors in Dhaka: Strengthening Earthquake Resilience and Preparedness

Summary Report

Graeme English, Luiza Cintra Campos and Jonathan Parkinson

About the authors

Graeme English*, University College London; Luiza Cintra Campos, University College London; Jonathan Parkinson, Oxfam

*Contact: graemee9@gmail.com

Urban Crises Learning Fund

This paper is part of a series of research pieces produced under the Urban Crises Learning Fund managed by the Institute for Environment and Development. Funded by the Department for International Development (DFID), the fund aims to build an in-depth understanding of how the humanitarian sector can most effectively operate in urban contexts. This publication was funded with the generous contributions of UK aid from the UK government (DFID). This is an independent report and does not necessarily reflect the views of IIED or DFID. Any errors are on the part of the authors.

IIED's Human Settlements Group

The Human Settlements Group at the International Institute for Environment and Development (IIED) works to reduce poverty and improve health and housing conditions in the urban centres of Africa, Asia and Latin America. It seeks to combine this with promoting good governance and more ecologically sustainable patterns of urban development and rural-urban linkages.

Acknowledgements

The authors would like to acknowledge the following staff members of Oxfam Bangladesh: Soma Fatima, Simon Rahman, Saida Begum, and Roushan Ali.

Further information: Larissa Pelham, larissa.pelham@oxfam.org

Citation

English, G, Campos, LC and Parkinson, J (2017) *Water Market Actors in Dhaka: Strengthening Earthquake Resilience and Preparedness*. Summary Report. Urban Crises Learning Partnership (UCLP).

The Urban Crises Learning Partnership (UCLP) was a two-year (2015-17) learning initiative aimed at improving humanitarian preparedness and response in urban areas. It is a partnership between Habitat for Humanity GB, Oxfam GB, the Overseas Development Institute (ODI), and University College London (UCL). The project has carried out primary research in Haiti and Bangladesh through the National Offices of Habitat for Humanity in both countries, and Oxfam in Bangladesh.

The UCLP has two primary objectives: to improve the way stakeholders in urban crises engage with each other to form new partnerships and make better decisions; and to improve disaster preparedness and response in urban areas by developing, testing, and disseminating new approaches to the formation of these relationships and systems.

The project has addressed these objectives by exploring four related themes: the role of actors who are not part of the formal national or international humanitarian system; accountability to affected populations (AAP); urban systems; and coordinating urban disaster preparedness.

This paper by Graeme English, Luiza Campos, and Jonathan Parkinson makes a valuable contribution to the last of these themes – coordinating urban disaster preparedness. By focusing on a specific and important sector – water – in the Bangladeshi capital, the paper draws attention to a range of preparedness measures that should take place prior to a major event such as an earthquake. The paper reviews current understanding of urban disaster risk reduction for domestic water resources and distribution. It indicates that stakeholders need to better understand water market systems in order to improve their responses and preparedness for an earthquake. It analyses the current situation related to resilience in the domestic water supply chain in Dhaka, and applies market-system mapping to highlight how stakeholders can work better with communities and market actors, as well as to highlight weak links in distribution chains.

The paper serves as a useful companion piece to two other papers in this series – the Dhaka City Earthquake Simulation Report; and Partnership, Coordination, and Accountability in Urban Disaster Management: A Review of Policies in Bangladesh.

Alan Brouder, UCLP Coordinator
Habitat for Humanity GB
November 2017

Contents

Abbreviations and Acronyms

ADPC	Asian Disaster Preparedness Centre
BUERP	Bangladesh Urban Earthquake Resilience Project
CBO	Community-Based Organisation
CDMP	Comprehensive Disaster Management Programme
DDM	Department of Disaster Management
DNCC	Dhaka North City Corporation
DPHE	Department of Public Health Engineering
DRR	Disaster Risk Reduction
DWASA	Dhaka Water Supply and Sewerage Authority
EMI	Earthquakes and Megacities Initiative
EMMA	Emergency Market Mapping and Analysis
GIS	Geographic Information System
IDP	Internally Displaced Person(s)
IFRC	International Federation of the Red Cross and Red Crescent
INGOs	International Non-Governmental Organisations
NGO	Non-Governmental Organisation
PCMA	Pre-Crisis Market Assessment
SOD	Standing Orders on Disaster
UNDP	United Nations Development Programme
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organisation

Summary

Natural hazards such as earthquakes in urban areas present a wide range of challenges to governments, humanitarian organisations, and utility suppliers. Due to the complex, interconnected nature of a city and its residents' reliance on local market systems for the majority of their basic needs, preparing for and managing the impact of an earthquake has become increasingly difficult.

Domestic water systems supply a particularly vital commodity in the city, but are also highly vulnerable to disruption due to earthquakes. Interruptions to water supply chains, and reduced access to resources due to an earthquake where many are displaced, can lead to outbreak of disease. Water system infrastructure often takes many months to reinstate, which means that many people could be without a reliable, clean water source – compounding shelter and livelihood issues.

Dhaka is one of the world's most densely populated megacities and has been subject to rapid, often unplanned urbanisation over the past 50 years. This has contributed to high levels of socioeconomic vulnerability in many communities, directly affecting their resilience to disaster. A large earthquake, of a magnitude similar to the 1885 Bengal Earthquake, is expected to affect Dhaka in the near future. A variety of government institutes and non-governmental organisations (NGOs) in Bangladesh are recognising the need to improve disaster risk reduction, and in recent years the urban disaster mitigation and management measures taking place have increased.

This report reviews current understanding of urban disaster risk reduction for domestic water resources and distribution. It indicates that stakeholders need to better understand the water market systems in order to improve their responses and preparedness for an earthquake. It analyses the current situation related to resilience in the domestic water supply chain in Dhaka city, and applies market-system mapping to highlight how stakeholders can work better with communities and market actors, as well as to highlight weak links in distribution chains.

A review of experiences from earthquakes affecting cities around the world was undertaken in order to transfer learning to stakeholders in Dhaka. Field work was carried out, including interviews with key informants: professionals working within the water distribution system in the city, and involved in the creation of disaster risk reduction and contingency planning for the domestic water sector. Bringing this information together, the report recommends that stakeholders should be proactive in supporting government agencies in contingency planning actions, whilst putting further effort into understanding how water market systems operate both in normal times and in the wake of an earthquake.

Introduction

Bangladesh is recognised as a very high-risk location for natural disasters, ranking 5th in the 2016 World Risk Index Report (UNU-EHS, 2016) due to a combination of both high exposure and vulnerability. At the same time, the country receives a particularly poor rating for its emergency coping capacity, which includes lack of efficacy in governance and disaster preparedness. While flooding poses a regularly occurring threat countrywide, and cyclones often ravage the coastal belt of the country, there is also a threat of a catastrophic earthquake affecting the nation (Alam, 2016).

The country's capital, Dhaka, is recognised to be at high risk from a large earthquake (Miller, 2016; Steckler *et al.*, 2016). The geographical and geological factors that create this hazard to the city include its proximity to the intersection of three tectonic plates, its location on low-lying land crossed by several rivers and on a shallow water-table, and its location on top of soft, sedimentary terrain (EMI and World Bank, 2014b).

The city also bears the burden of rapid population growth which has resulted in some extremely high-density areas, and an average density of about 45,000 people per square kilometre (Cox, 2012). It is also one of the fastest growing cities, with a population growing in size since the 1950s. This has resulted in areas of unplanned urbanisation, which, combined with widespread sub-standard building construction, increases vulnerability (Charlesworth, 2012). In addition to these factors, there are high levels of socio-economic vulnerability in the city, with many slum areas having poor access to vital infrastructure and services (Islam *et al.*, 2006; BBS, 2015).

Due to the hazards and vulnerabilities present in Dhaka, the need for better disaster risk reduction strategies has been widely recognised. Several government bodies have been formed which have put in place initiatives such as the Comprehensive Disaster Management Program (CDMP Bangladesh, 2009). A growing number of local NGOs, as well as international non-governmental organisations (INGOs) and consortia have focused on preparation, mitigation, and response to future emergencies (Stott and Nadiruzzaman, 2014).

Infrastructure and services for the provision of water, sanitation, and hygiene (WASH) have been demonstrated to be at high risk of disruption in earthquake zones (Davis, 2008). In Dhaka, the risk factors are amplified by the many other vulnerabilities of a city where access to clean water and adequate sanitation is already insufficient (Khan, 2012).

During an emergency such as an earthquake, the likelihood of a water-borne disease outbreak increases, especially where population density is high and water and sanitation services are inadequate (WHO, 2004). Disease outbreaks following earthquakes can occur when people drink infected water as a result of damage to water infrastructure, sewers, and treatment plants, or as a result of interrupted service provision (Lemonick, 2011).

There is a need to better understand how domestic water providers and other market actors, governmental bodies, and humanitarian NGOs can work better with communities in cities to reduce risk to water systems , and restore water and sanitation services following an earthquake (Ali and Kadir, 2015). While many organisations operating in Dhaka look to reduce the risks to communities, there is a lack of adequate coordination between them, which results in inadequate long-term strategies (Alam *et al.*, 2015). There is also a recognised need for better understanding of how disasters in the urban context relate to inadequate living conditions for the poor, and to the complicated nature of governance in cities (CFURS, 2017).

Research Objective

The objective of the study was to document the earthquake preparedness of domestic water market system actors in Dhaka, in order to improve response mechanisms and disaster risk reduction (DRR) programmes carried out by humanitarian actors in the city. It is expected that this knowledge will help them to better support local markets in the domestic water sector prior to, and in the event of, an earthquake.

Specifically, it is expected that the results of this study will contribute the above by:

1. Understanding the impact of a large urban earthquake on domestic water resources, through a review of earthquake case studies from around the world and of the situation in Dhaka.
2. Demonstrating how tools for understanding market systems can be used to reduce risks to domestic water supplies in an earthquake.
3. Identifying groups that may have significant influence on the implementation of risk reduction strategies for the domestic water sector, as well as those who are vulnerable and overlooked.
4. Deriving recommendations for stakeholders working within disaster risk reduction and contingency planning for earthquakes, resulting in improved resilience and faster restoration of systems.

The study will therefore provide insight on the following questions:

- What are the probable impacts of an urban domestic water supply disruption to Dhaka following an earthquake, based on past case studies and experience?
- What are the available tools and frameworks available for investigating the risk and vulnerabilities around domestic water provision in Dhaka in the event of an earthquake?
- How can information be gathered in Dhaka to support decisions by stakeholders and community members to reduce the risks associated with damaged water infrastructure?

Methodology

Review of the Current Situation and Emergency Plans in Dhaka

A review of the current situation in Dhaka was carried out, examining the vulnerability and exposure to an earthquake as well as some of the preparations, contingency plans, and risk-reduction programmes carried out in the city.

Review of International Experiences and Recommendations

Earthquakes have struck cities around the world in both developed and developing countries in recent years. Following such catastrophes, in many cases lessons have been documented by responding organisations to promote ways of acting more efficiently, preparing, and rebuilding with more resilience. The most relevant case studies were reviewed to document issues with the domestic water supply in disaster-affected urban areas, as well as successful measures of preparedness and response. The case studies informed interviews with individuals and organisations during the field study. These case studies and interviews were analysed to understand which of the recommendations identified through the literature and field research would be most applicable to Dhaka.

Case-Study Selection Criteria

Case-study investigations showed that there is a continued need to invest time into DRR programming, particularly within urban settings. To better understand the effect of an earthquake on the domestic water infrastructure of a city, three case studies were analysed. Case Study 1 (**Box 1**) looks at the 2011 earthquake affecting the city of Christchurch in New Zealand, Case Study 2 (**Box 2**) draws out relevant knowledge for the 2010 Haiti earthquake, and Case Study 3 (**Box 3**) reviews lessons learned from the Kathmandu valley earthquake in 2015.

Field Study

A field study was carried out involving a range of actors working with domestic water provision in the city. Semi-structured interviews were conducted to: a) validate understanding of the market systems in place and support the production of water market maps; and, b) gather qualitative information from a variety of actors about their area(s) of expertise.

During these interviews, a potential future earthquake scenario affecting Dhaka was described to the interviewees – focussing their attention on the potential impacts to their assets, equipment, and services. Current contingency plans in the event of an earthquake were discussed, to understand the level of the organisations' engagement with the plans, and their understanding of city-wide emergency planning was recorded. The interviews were also intended to strengthen stakeholder preparedness, and the overall contingency planning process, in order to produce a more collective, co-ordinated response in the city.

Since responding to a large emergency such as an earthquake requires a concerted effort by a range of actors and stakeholders, the interviews are also designed to better understand interactions between stakeholders. Questionnaires were produced **(Appendix 1)** and used in a semi-structured way to capture information from these key informants on the subject areas in which they are most involved.

Interviewees

These represented a variety of stakeholders involved in the supply and distribution of domestic water, or the supporting supply chains, as well as suppliers of water processing components or equipment. A selection was made from the following:

1. Operational staff at municipal water supplier DWASA (Dhaka Water Supply & Sewerage Authority)

The aim was to better understand awareness and preparations for an earthquake at an operational level. It was necessary to speak to representatives of DWASA treatment, distribution, and storage plants, in addition to operational staff, in order to assess the following:

- Knowledge and experience of risk assessment practices within the organisation related to earthquakes.
- Awareness of DWASA's earthquake contingency planning, as well as how this had been communicated to staff.
- Scope for improvement of DWASA's existing contingency planning processes.

The information gathered was compared with lessons learned in other urban earthquake contexts. Two representatives from the operational arm of DWASA were interviewed, including the Chief Engineer as well as one water plant manager, two employees, and one contractor. Due to the collaboration between DWASA and government bodies involved in DRR, representatives from the Department of Disaster Management and Dhaka North City Corporation were also interviewed.

2. Private organisations supplying water filtration and purification supplies

Market traders may be able to supply at least some of the materials required for point-of-use or household water treatment during an earthquake situation. This supports the capacity of local businesses to increase long-term resilience and economic recovery time. The objective here was to:

- Gather information about preparedness measures for emergency situations, and about the capacity to become part of the response to a disaster.
- Understand how relevant supply chains may be affected, and how these could be supported in emergencies.

Interviews with representatives from one supplier of water purification equipment and one supplier of other equipment were carried out.

3. Bottled water suppliers or water filtration companies

This refers to the small-scale suppliers of bottled water or 'jar' water to communities, as well as the larger organisations that supply bottled water or filtration equipment to apartment buildings and offices. Such suppliers may be able to provide water in the initial recovery phase, prior to repairs of the municipal systems. They may not be aware of their potential role in disaster recovery.

The questions aimed to:

- Gather information on how organisations and traders perceived disasters and potential earthquakes.
- Understand the current formal or informal emergency plans for these actors.

Three private vendors and water suppliers were interviewed, with assistance from the local NGO DSK and the ward councillor in the Mirpur area.

4. Water truck service providers

While water trucking takes place in drought season, this is also a crucial service following a large earthquake where water infrastructure is damaged. For this reason it was useful to speak to DWASA-run trucking providers, as well as private businesses (if applicable).

Two interviews were conducted which aimed to garner their experience of issues with water supply during ‘normal’ times, which may influence how effective a water trucking service might be when supplying disaster-affected populations and displaced people.

5. Local NGO representatives working in the area of disaster risk reduction for water supplies

The aim was to gain more detailed understanding of the work being done to improve public knowledge of the disaster-related risk to water supplies in Dhaka, as well as their knowledge of city-wide contingency plans for the water supply.

The following related categories of informants may also shed light on the subject area:

- Leaders of community-based organisations working with DRR
- Contactors or companies for water-equipment maintenance
- Operators of water ATMs or shared/community wells
- Engineers or contractors for water equipment

Earthquakes and Water Supplies

Effects of Earthquakes on Potable Water Systems and Services

The ability to efficiently recover from an earthquake – or in other words, the 'seismic resiliency' of an urban region – is directly related to the resiliency of the available water systems. The seismic resilience of a water system has been defined as "the ability of a water system to recover from an earthquake while mitigating and containing earthquake effects with minimal social disruption" (Davis, 2008).

Following an earthquake, water-related issues can be one of the dominant issues that determine the ability of urban areas to recover. The major water-related areas of concern, compiled by Davis, touch on a wide range of different areas in the recovery of a society (2008):

- Damage to water-storage infrastructure
- Piping for water transmission
- Coordinating regional emergency responses
- Firefighting with limited water supplies
- Restoring water supply for critical buildings (e.g. hospitals and schools)
- Long restoration times of water services (up to 6 months)
- Limited access to restoration materials and supply chains
- Business disruption due to lack of water

Piped water systems

Although water and sanitation systems are vulnerable to damage following an earthquake in both cities and rural areas, the problem is particularly acute in urban areas due to the huge quantity of piping required and the interaction of the water system with large buildings (Zohra, Mahmouda and Luc, 2012). If water systems are damaged, this introduces the possibility of contaminants (including chemicals, industrial or agricultural waste, and disease pathogens) reaching the consumers due to improper treatment or entry during distribution (WHO, 2004).

Water systems have been grouped with combustible fuels, telecommunications systems, transport, electrical power, and wastewater infrastructure under the 'lifelines' which modern communities rely on, particularly in the city. Following an earthquake, immediate damage to lifelines can threaten lives and, in the long-term recovery phase, the economic and social stability of the region (O'Rourke, 1998).

Buried pipelines are recognised to be at risk from earthquakes, and the types of failure that may occur are outlined in **Table 1**).

Davis (2008) suggests that a systems approach to seismic resilience of water systems is more effective because piped water systems are complicated, expensive, integrated deeply into many levels of society, and damage to them has far reaching effects. While the focus during much of the 20th century has been on strengthening specific components of a water system (pipes or pump stations, for example), looking at the system as a whole is now recommended in order to understand the interaction of components and stakeholders (Davis, 2008).

Case Study Box 1 shows some of the impacts to water and sanitation infrastructure following the 2011 earthquake in Christchurch, New Zealand – a city with a well-developed water network that uses boreholes as a primary water source.

The 'Shakeout Scenario', published in 2008, (Jones *et al.*, 2008) examined the implications of a major earthquake on the San Andreas fault line in various urban counties of California. Prior to the study, the state had made large investments in lifeline infrastructure including water pipelines – typically to replace older cast-iron piping with earthquake-resistant steel and polyethylene piping. These investments are recognised to have greatly reduced the amount of damage. In the Scenario, however, the impact on water supplies was recognised to be the lifeline which would take the longest to restore, with some of the worst hit locations

Table 1. Types of disaster-related hazards for water pipelines*

Hazards to buried pipelines	Details	Typical examples and impacts
Surface rupture	This is where a fault extends to the earth's surface, so that two sides of the fault will be offset against each other or misaligned at the ground's surface.	A horizontal displacement, strike, or slip can cause both structures and water lines to laterally shear
Earthquake-induced landslides	Can expose buried piping or crush pipes.	Susceptibility to a landslide depends on the type of earth, but is typically less likely in low-lying areas. Pipelines can be uncovered, crushed, or penetrated due to soil, rock, and debris flows.
Liquefaction and associated lateral spreading or settlement of soil	Water-saturated sand (such as that present under Dhaka) may act like quicksand under earthquake conditions, causing buckling and bending of earth.	Piping in areas where liquefaction and violent ground shaking occur are most likely to break or leak.

*Sources: Jones *et al.*, 2008; ABAG Earthquake & Hazards Program, 2010

found unlikely to restore water connections for six months (Jones *et al.*, 2008). It can be inferred that earthquakes in urban locations which haven't invested in modern, earthquake-resistant pipelines and fittings will take even longer to recover from an earthquake.

Other recommendations from the Shakeout Scenario which could be applied in contexts such as Dhaka are:

- To map the potential for liquefaction[1] and ensure that water suppliers install additional valves for redundancy.
- To consider stockpiling a range of piping clamps, and pipes if possible – although this was considered to be prohibitively expensive.
- To purchase emergency supplies of portable water-treatment systems with backup power supplies.

Other Water Supplies

Piped, centralised systems are the predominant water source for many cities – but in many developing nations, there are several other important sources used by those without access or with intermittent access to this utility (Ali and Kadir, 2015). Small-scale, scattered water supplies exist in both rural and urban areas, where they can be prominent mostly due to the technology available in the area and the local political economy. Supplies such as wells can be vulnerable to disruption from emergencies, which can lead to contamination or damage. Supply chains for small-scale vendors can often be disrupted, resulting in sources of livelihood being interrupted and ultimately a slower recovery (Wisner and Adams, 2003).

Water vendors using a range of delivery methods – from trucks to trolleys – are common across the world where water scarcity or infrastructure does not permit access to centralised water supplies. There are health concerns that relate to the inadequate volumes of water available to people, as well as the increased chances for contamination before and during distribution (WHO, 2004).

As an earthquake is very likely to cause damage and disruption to roads, it will be likely that water vendors and water tankers will be unable to service communities in need of water without roads being cleared or repaired in advance. In addition, there may be interruption of communication systems, adding complication to coordination measures.

Since there may be disruption to both surface water and ground water sources – with surface water being diverted or its quality deteriorating, and groundwater levels reducing – there will be an impact on the quantity of water gathered by both municipal suppliers and small private entities operating in the city.

[1] Liquefaction, in the context of an earthquake, is defined as a process where earth or soil becomes solidified by shaking, which forces groundwater to the surface and destabilises buildings and utilities (Stott and Nadiruzzaman, 2014).

Case Study Box 1: The 2011 Earthquake in Christchurch, New Zealand

Water and sanitation infrastructure was badly affected in the 2011 disaster in Christchurch. Many suburbs lost their water supply, and eastern areas were flooded due to broken piping (both water and sewage) as well as soil liquefaction. There were 50 locations with pumped wells and 1500 kilometres of underground water piping across the city. The earthquake caused damage to 150 kilometres of water pipes which were later replaced, while four storage reservoirs and more than 80 wells were damaged. Since the sewage pipes in Christchurch are relatively close to the surface, and wells are between 16 and 177 metres deep, there was relatively low risk of contamination for well water sources; however, as a precaution, deeper wells were used to draw water following the damage. Drinking water was contaminated in areas where water and sewage pipes were damaged, and residents were required to carry out household water treatment (HHWT) in the form of boiling their drinking water, while 25 chlorination plants were installed at pump stations. Water restrictions were implemented by the local government to reduce consumption.

After the earthquake, 16 per cent of the city's sewer system, which stretches to 1838 kilometres, was damaged; 13 out of 97 sewage pumping stations required complete replacement. The wastewater treatment plant was also damaged and operated at 30 per cent of its usual capacity due to ingress of silt to the sewers. To reduce clogging, trucks were dispatched to remove silt from pipelines. Forty million litres of untreated sewage leaked from pipelines into surface waters, increasing to over seven billion litres after six months (Brears, 2012).

Analysis of the water pipelines found that areas of soil liquefaction had a much larger incidence of damage than other areas: 80 per cent of the damaged pipelines were found in liquefied zones. It also found that PVC and HDPE (plastic) pipes suffered significantly less damage than galvanised iron and steel pipes (Cubrinovski, Hughes and O'Rourke, 2014).

The New Zealand earthquake in Christchurch also showed that there are large gains to be made if governments and utilities better understand and communicate with communities. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) teamed up with representatives from the city council, other government bodies, and engineering organisations to rebuild the city's infrastructure (mainly transport and water systems). The Canterbury Earthquake Recovery Authority (CERA) was set up to lead the collaboration of many organisations from public and private sectors, NGOs, as well as community groups. CERA developed a Recovery Strategy for long-term rehabilitation and increased resilience, while documenting the recovery. A community resilience programme was created and led by CERA to develop neighbourhood plans and provide support to vulnerable people (CERA, 2012).

Key recommendations

- Improve communication between government agencies and local communities of affected people, within DRR efforts before and during recovery.
- Ensure communities are aware of contaminated water, and prepare emergency water treatment facilities or HHWT recommendations.
- Replace pipelines with HDPE or PVC pipes to significantly reduce instances of damage in soil liquefaction zones.

Disease Outbreaks Following Disaster

Provision of poor-quality water following an earthquake can be associated with the outbreak of waterborne diseases such as those presented in **Table 2**. The primary reasons for infectious diseases spreading following disasters have been suggested to be rooted in the displacement of populations (Watson *et al.*, 2007; Kouadio *et al.*, 2014). Noji (2000) noted that natural disasters which do not lead to the displacement of people rarely result in epidemics. Developing countries are more vulnerable to an outbreak of disease following a natural disaster, as in the case of Haiti (**Case Study Box 2**). This is because displacement is considerably more likely, there is often a lack of infrastructure and resources, and disaster risk strategies and preparation are often lacking (Watson *et al.*, 2007).

Table 2 waterborne disease transmission post- Disaster

Disease type	Disease	Transmission routes	Affected populations
Water-borne Disease	Diarrhoea, including acute watery diarrhoea	Faecal-oral route via contaminated drinking water and poor sanitation. Unsafe food and contaminated cooking equipment.	Flooding victims and displaced populations with poor sanitation, malnutrition.
	Cholera		As above, and those exposed to dead bodies and living in crowded conditions.
	Dysentery		Displaced populations and those living in crowded conditions.
	Hepatitis A and Hepatitis E	Faecal-oral route, via contaminated drinking water and poor sanitation.	Typically populations with inadequate water, sanitation, and hygiene practices.
	Leptospirosis	Oral route, via water contamination with zoonotic bacteria (typically from rats).	Proximity to stagnant water; using infected water for cleaning and drinking.

Lemonick (2011) states that natural disasters do not directly create epidemics, and argues that the risks are often overstated – particularly that of dead bodies contributing to epidemics. However, he suggests that disease risk is dependent on the status of the population before the disaster, and on the manner of its displacement. A large population that already has a poor health status and living conditions, and which is experiencing overcrowding as well as inadequate water, sanitation, and health services, is more likely to suffer from an outbreak (Lemonick, 2011).

Case Study Box 2 – The 2010 Haiti Earthquake

Many lessons can be learned from the earthquake in Port-au-Prince, Haiti – including the heightened impact of natural disaster on cities with an already poorly functioning water system. It is a case that highlights the dangers of a disease outbreaks associated with long-term camps for internally displaced persons (IDP), and the need for WASH capacity -building programmes as part of DRR efforts.

Prior to the 2010 earthquake, around 69 per cent of the population in Port-au-Prince had access to an improved water source[2], and only 17 per cent had the use of improved sanitation. In the 20 years prior to the disaster, both of these figures had been decreasing (WHO/UNICEF, 2012). The earthquake resulted in over one million IDPs in settlements around Port-au-Prince, which in conjunction with the lack of WASH facilities, contributed to a huge cholera outbreak (Tappero and Tauxe, 2011). The main water distribution system in Port-au-Prince and the surrounding areas received water from springs in adjacent mountains, and was chlorinated close to the source(s) before being distributed to approximately one million people. The system was unreliable and required HHWT before it would be potable. Despite the size of the system, there were few water main breaks; and where they occurred, these were repaired within weeks of the earthquake. Still, water sources were damaged and contaminated. No wastewater treatment facilities existed in the country, with wastewater typically directed into poorly made drainage channels (DesRoches *et al.*, 2011). Since no earthquake contingency planning existed before the disaster, stakeholders lacked synchronisation; and although one year into the recovery period there were signs of improvement and capacity-building efforts, progress remained slow. Most assessments have found that poor governance and coordination between stakeholders contributed to the slow recovery in Port-au-Prince (DesRoches *et al.*, 2011).

In an OECD evaluation, Patrick (2011) suggests that DRR programs should be integrated into recovery efforts to "capitalise on available funding and political interest"(Patrick, 2011). Meanwhile, an Oxfam project reported that Cash For Work programming to support DRR served an important need in helping to mitigate future vulnerability, but required more thought in its implementation (Young *et al.*, 2011). Establishment of water kiosks proved successful following initial recovery efforts, but it was shown that the creation of functional water committees was very important for their successful implementation (Foster, 2011). A promising pilot programme led by US Agency for International Development (USAID) was KATYE ('neighbourhood' in Creole). This involved community urban planning with a focus on water and sanitation, and DRR elements which included improvement to drainage. The programme also noted that further coordination between relief organisations is required both for the initial response as well as later development programmes, with this being more feasible if working on a neighbourhood basis (Brown, 2012).

The Disasters Emergency Committee (DEC) review of responses after the earthquake suggested that agencies should "always seek to work with and through municipalities and pre-existing service providers whenever possible to strengthen local structures" (Clermont *et al.*, 2011). This should remind stakeholders that during the recovery phase, a concerted effort should be made to support the work of *local* stakeholders. The review also suggests that humanitarian organisations must interact with markets and the local private sector – particularly to employ water providers and source local goods (Clermont *et al.*, 2011)

Key learnings:

- Surface and groundwater sources, in addition to distribution infrastructure, are likely to be damaged and/or contaminated.
- Unreliable WASH provision before an earthquake leads to additional complications in provision to IDP camps.
- Community urban planning exercises, including WASH elements, provide for additional understanding of vulnerability and improve resilience.
- Poor governance and coordination between stakeholders significantly increases recovery times.

[2] An 'improved water source' is defined by the WHO as one of the following: piped water into dwelling or plot, a public tap or standpipe, a protected tubewell or borehole, a protected dug well, a protected spring, or a rainwater collection system (WHO/UNICEF, 2006).

Scenarios and Preparation

Earthquake Risk and Scenarios in Dhaka

Over the past 200 years, the city has experienced more than 15 earthquakes of modified Mercalli intensity VI and above. At this intensity, earthquakes are classed as 'strong' and are expected to be structurally damaging to basic buildings. Of these events, the most recent was in 2001 – however this was relatively small in magnitude, measuring 5.1 on the moment magnitude scale (EMI and World Bank, 2014b).

The highly destructive Great Indian Earthquake of 1897 had a magnitude of over 8.1 on the moment magnitude scale at its epicentre in Shillong, India, which is 250 kilometres from Dhaka. Despite the distance, the magnitude of the earthquake translated to a Mercallli intensity of VIII in Dhaka, causing the destruction of masonry buildings across the region. The Bengal Earthquake of 1885 – also known as the Manikganj Earthquake due to the location of its epicentre, about 60 kilometres from Dhaka city – was felt as an intensity VIII event. The magnitude was estimated to be 7.0 on the moment magnitude scale, and due to the proximity to the city it caused widespread destruction of buildings and the loss of many lives. It has been estimated that this event has a return period of about 130–135 years, meaning that a serious earthquake could occur in the region between 2015 and 2020 (Khan, 2005, 2016; Al Zaman and Jahan Monira, 2017).

Although there have been no large events in recent years, the clustering of small-magnitude earthquakes in the same region that was hit by the 1885 earthquake has indicated that this fault is still active, and the most likely region for a forthcoming earthquake (Khan, 2016).

The potential impact a recurrence of the Bengal Earthquake would have is very large, due to the vastly increased population and number of poorly constructed, non-engineered tall buildings in Dhaka and the surrounding area (Akhter, 2009). A 2014 World Vision study suggested that less than 10 per cent of buildings in the city were constructed following building codes (Shaw, 2014). In addition, simulations have estimated that 88,000 buildings would be damaged in an earthquake (EMI and World Bank, 2014a). Other estimates suggest that 75,000 buildings could be damaged beyond repair (Government of the People's Republic of Bangladesh, 2008). These projections are crucial when discussing water provision to the affected population, since a huge number of vulnerable people are likely to move to camps for internally displaced persons (IDPs), requiring water to be safely sourced, transported, and distributed.

To provide context for this study, it is useful to have a reference scenario for a potential earthquake in Dhaka. The most detailed and widely used simulation carried out so far was in 2014 by the World Bank and EMI: the Earthquake and Megacities Initiative, which based simulations on a 7.5 magnitude event affecting the Modhupur (or Madhupur) fault to the north of Dhaka's centre. There are several other faults which could affect the city, including the Dauki fault and three parts of the plate boundary which borders Myanmar. However, the Madhupur fault scenario was found to be the most likely seismic source (EMI and World Bank, 2014a). A similar 7.5 magnitude Madhupur-fault earthquake scenario was also used by a contingency planning report produced for DWASA (Government of the People's Republic of Bangladesh, 2008).

Much of the city is built upon saturated soil with a high likelihood of liquefaction, which provides an additional risk to structures and lifelines (EMI and World Bank, 2014a). Many buildings are constructed on top of soft and unconsolidated sedimentary soil because Dhaka is built on land surrounded by several rivers, and with many sub-surface channels. Much of the metropolitan area is underlain by sediment of between 10 and 30 metres thick; this has been shown in the past to amplify ground motion considerably (Khan, 2016), in addition to the damage caused by liquefaction around pipes and foundations. Khan likens the land beneath Dhaka to that of Mexico City, referencing the devastating 1985 earthquake where soil amplification caused ground motion to a similar degree as that in the epicentre region, which was 350km away. Meanwhile, Mexico's September 2017 earthquake – which was of a significantly smaller magnitude (7.1 compared to 8.0) with an epicentre 160km away in Puebla – was also subject to similar amplification effects and possible liquefaction (Wei-Haas, 2017). The suggestion is that Dhaka would experience strong multiplying effects due to its geological conditions (Khan, 2016).

A study carried out in 2016 found that the threat could be larger than previously understood. Although fault lines underneath Bangladesh have been recognised for decades, recent research found that there is dangerous level of hidden subduction occurring between plates, which is concealed by large quantities of sedimentary earth from the Ganges and Brahmaputra river deltas. This creates the potential for a hidden 'megathrust' fault to create an earthquake of magnitude between 8.2 and 9.0 underneath Dhaka, or in the other highly populated regions of Bangladesh and its borders with Myanmar and India (Steckler *et al.*, 2016).

Water Supply Status in Dhaka

The municipal water supply for the city is managed by the public utility DWASA. Seventy-eight per cent of water is extracted from approximately 700 groundwater sources in and around the city, while treated surface water from the Shitalakkshya and Buriganga rivers makes up the remaining 22 per cent (DWASA, 2015).

Water quality testing for all rivers around the city showed that there are particularly high levels of pollution during the dry season (Sohel *et al.*, 2003), which is also when many residents experience a poor piped water service and are forced to switch to other sources (Aziz, 2012). Recent tests on six rivers surrounding the city (the Buriganga, the Turag, the Balu, the Shitalakkhya, the Dhaleshwari, and the Bangshi) found most water to be unsuitable for human consumption, and in some cases "hardly treatable" (The Daily Star, 2016) due to the presence of pesticides and heavy metals (Hossain *et al.*, 2016; The Daily Star, 2016).

Due to the high groundwater abstraction rates, not only from DWASA but private (often illegal) boreholes, measurements show that the water table is declining. One study found a decline of two metres per year since 1986 (Akther, Ahmed and Rasheed, 2009). Measurements made in 2005 found that in central areas of the city the rate of depletion was at 2.5 metres per year, and was increasing exponentially (Hoque, Hoque and Ahmed, 2007). Data gathered by DWASA in 2011 shows a general trend toward a very deep water table, up to 1000 feet.

Quality analysis of water taken from several locations in the DWASA network showed that 100 per cent of the samples had a presumptive coliform count above World Health Organisation (WHO) guidelines. Bottled water, bought in 20 litre 'jars' was also tested during the same study, sub-categorised into 'filtered' and 'mineral' waters: filtered water failed to meet WHO guidelines in 87.5 per cent of cases, and mineral water in 50 per cent of the cases (Islam *et al.*, 2011).

Sources of water for the population of Dhaka have been identified and have been grouped into public, private, and shared sources, as shown in **Figure 1**. Those highlighted with an asterisk are the sources most used during the drought season from April to June.

Figure 1. Sources of water supply in Dhaka. (Source: Aziz, 2012)

Public	Private	Shared
• City corporation water tankers • Piped (DWASA) water supply • Standpipe/post or Public Taps*	• Purchased (bottle/jar water)* • Bore well (motor operated) within home • Bore/tube well/hand pump within home	• Pond, open water sources • Shared bore/tube well (hand pump) • Shared borewell (motor pump) • Shared tube-well with an attached water line • Other shared well • Other local neighbour's water supply*

*water sources most used during summer droughts.

The main actors involved in water supply in the city are the following (Rahman, 2017; Aziz, 2012; Alam *et al*. 2015):

- DWASA piped water – mainly for shared tube-wells and household piped supplies
- Bottle/jar suppliers – small-scale market vendors
- Tank/truck distribution – including those operated by DWASA during times of drought (see **Figure 2** and **Figure 3**)
- Suppliers of water lines (illegally) attached to DWASA tube wells – used by 31 per cent of slum residents
- Suppliers of other non-potable water, including private vendors
- NGOs and CBOs supplying potable water in slum areas
- Suppliers of disinfection and treatment products

Figure 2. 20-litre water jars supplied by a 'van' or delivery rickshaw.

Credit: Graeme English

Figure 3. A DWASA truck delivering jars of treated, purified drinking water to businesses.

Credit: Graeme English

Earthquake Damage to Water Supplies in Dhaka

Some estimations of the scale of damage to water supply equipment that would follow an earthquake in the city have been carried out, and include pipelines, wells, tanks, and pumping facilities. The risk to pipelines was categorised taking into account the expected vulnerability of certain materials. A field survey placed the majority of pipes in the 'ductile' materials category, although this consisted of a range of materials including galvanised iron, which has been found to be vulnerable to earthquake damage in the Christchurch case study (**Box 1**).

Estimates suggest that over half of the pipelines in Dhaka (800 kilometres) were at 'very high' risk of liquefaction damage. In total, the field survey placed nearly 400 facilities (including over half of all wells and pumping plants) at either 'high' or 'very high' risk of liquefaction, while giving overhead tanks a low probability of functionality (Government of the People's Republic of Bangladesh, 2008).

In its analysis, the Dhaka Profile and Earthquake Risk Atlas provides insight into the risks to lifeline utilities in the city. The Atlas was created by the Bangladesh Urban Earthquake Resilience Project (BUERP), which was organised by EMI and the World Bank in recognition of the limited understanding of earthquake risks for the city. Using the same scenario, the study found that 228 kilometres (out of a total estimated 1138 kilometres) of water pipeline repairs would be required across the city (EMI and World Bank, 2014b).

The liquefaction analysis was based on borehole data that cover the susceptibility of structures up to 3 metres below ground level – where the city's water and sewerage are located – as well as on further information about impacts to roads and other services (EMI and World Bank, 2014b). The study recognised that knowledge in this area needs improvement, given the significant impact that liquefaction can have. It also mapped the locations of critical facilities, which included 28 water tanks amongst hospitals and fire stations, many of which were in high-risk areas.

Using Market Mapping for Water Supplies in Dhaka

Mapping the city's water supply market can be carried out for a wide range of items – the key goods and services needed to maintain health and livelihoods. The approach is particularly important in cities, which are highly dependent on market forces, and market maps are used so that humanitarian and development agencies can better understand the market forces affecting vital commodities. Mapping of the water market has previously been carried out in several locations to better understand how actions can be taken before or after a crisis. Ethiopia (Mutsaka, 2012) and Gaza (Bauer, 2013) are two examples. This has often taken place as part of an Emergency Market Mapping and Analysis (EMMA) exercise with the aim of improving programming in a way that works in synchronisation with market forces. EMMA can work at the intersection of humanitarian and development programmes, and can lead to recommendations for emergency preparedness and response, as well as more traditionally development-focussed DRR and resilience programmes.

The pre-Crisis Market Assessment (PCMA) process follows a similar process to EMMA, and requires an initial clear plan for carrying out a full assessment. However, it is a highly in-depth analysis, requiring a wide range of resources. **Table 3** lays out the key objectives of a Pre-Crisis Market Assessment (PCMA) as stated in their guidance document (International Rescue Committee, 2016) and outlines their relevance to this study.

Market maps have been created based on the available information on potable water sources used in Dhaka, as well as information on the market environment and the important infrastructure, inputs and services that have been identified through research on the city and case studies on other locations. **Figure 4** displays a 'baseline' scenario: how water access functions in normal circumstances. **Figure 5** displays a 'post-earthquake' scenario, which suggests impacts on the market by a potential earthquake.

The maps have been refined using field research in Dhaka in order to better capture the interactions between the market system, and to capture the important actors and potential weak links in the various market chains. The 'post-earthquake' scenario (**Figure 5**) has been produced based on information in the Dhaka Risk Atlas (EMI and World Bank, 2014b) as well as information from the earthquake case studies in this report.

For both maps, water sources in the market chain are shown on the left-hand side; these are both publically owned (red) and private sources (green). On the right side of the market chain are the recipients of water. In order to simplify the map, this has been kept to a single group of domestic recipients – although it is recognised that it represents a variety of distinct groups. Critical components in the system are labelled with an exclamation mark. Partial and heavy disruption are shown by a part and full cross, respectively. Arrow thickness represents the most important connections.

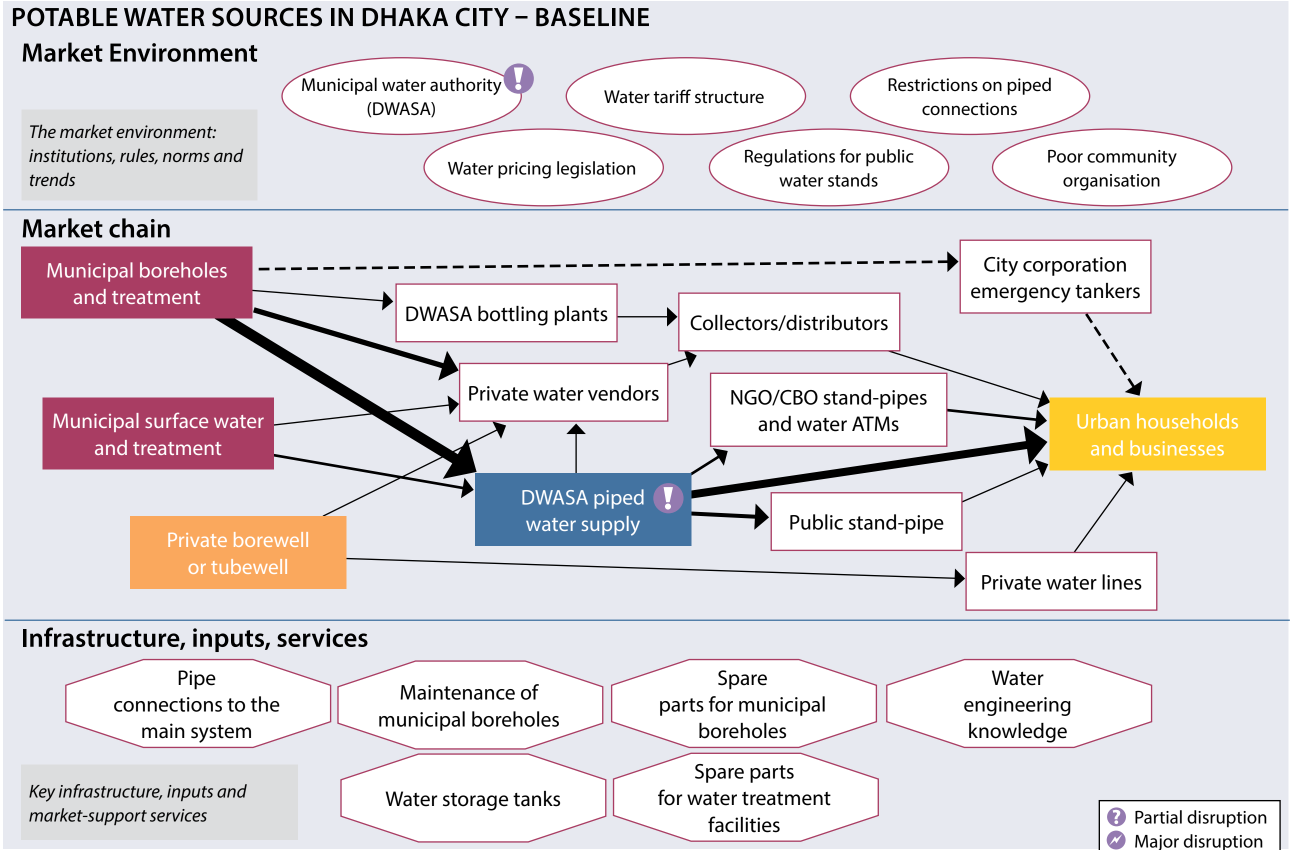
The maps show that the DWASA piped water supply system is a critical element in this system, because it interacts with many stakeholders. City corporation tankers, while used to respond to shortages or problems in the system under normal circumstances, are expected to be very important after an earthquake scenario.

The PCMA approach can be used in Dhaka to inform planning of programmes to build resilience, or of DRR programmes amongst communities and for supply organisations.

Table 3. PCMA process and application

Key Steps in the PCMA Process	Summary of Application for this Study
Determine objectives	• Improve preparedness and resilience for water supply/access in various communities during and after an earthquake. • Understand the degree to which drinking water market actors can supply population in/after an earthquake. • Develop capacity in market understanding for humanitarian actors involved in earthquake response.
Define related analytical questions	• How can markets be supported during an earthquake? • How does the water market function, what infrastructure and services are available, and what policies and institutions are influencing this market?
Define crisis scenario	• Water supply market systems are affected by an earthquake in Dhaka (see section 3.3)
Determine a 'reference year'	• Instead of selecting a reference year, reference case studies are analysed in this report. The case studies of Haiti and Nepal demonstrate impacts of a similar urban earthquake.
Scope of assessment and critical market systems	• Dhaka city • Drinking water systems will need to look at specific supplies, such as water purification supplies, water carriers, key repair equipment and supplies, etc.

Figure 4. A market map for Dhaka's water sources in normal (BASELINE) conditions



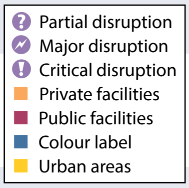
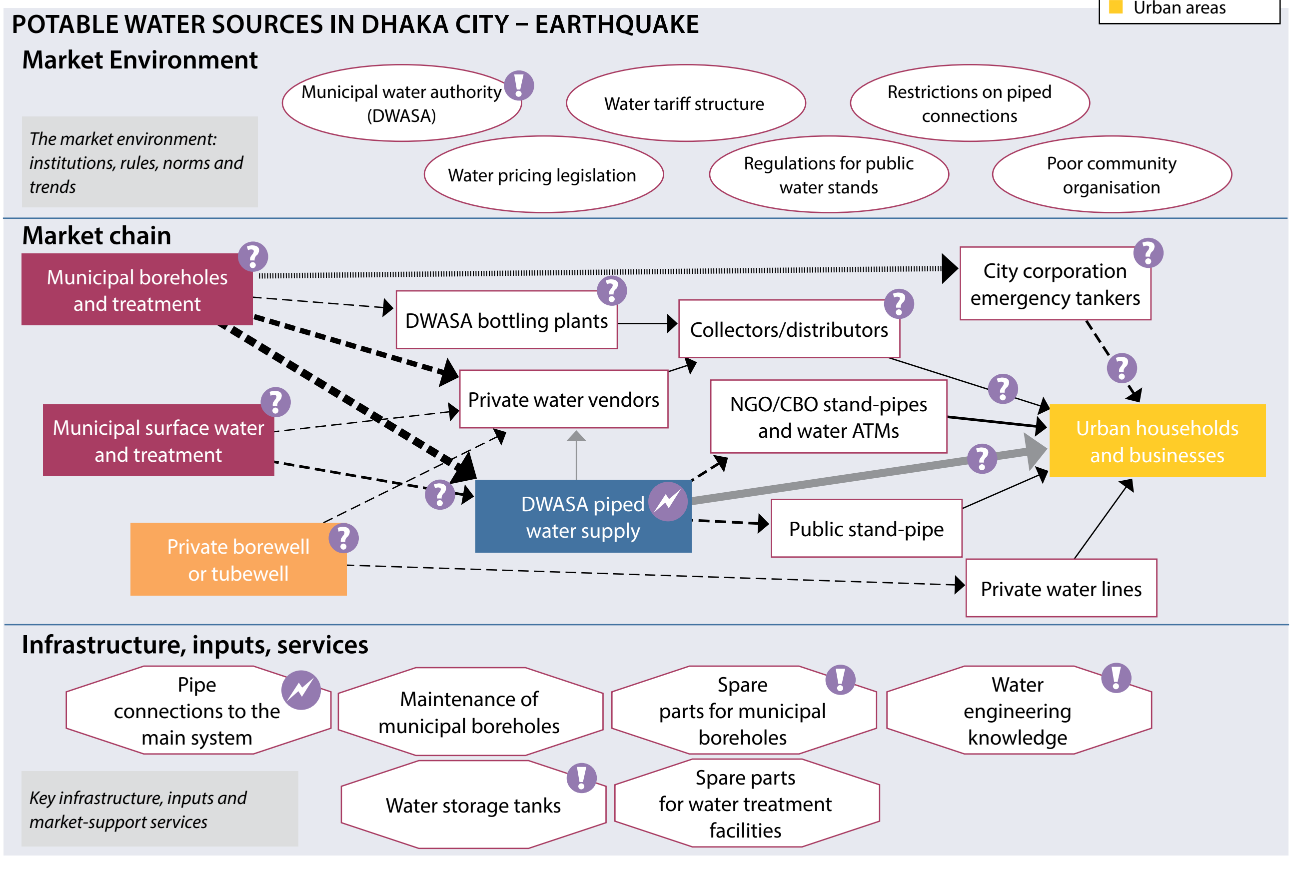


Figure 5. A market map for Dhaka's water sources following an earthquake



Dhaka's City-Level Earthquake Preparations

Earthquake Awareness

Despite being in the world's top twenty highest-risk cities for earthquake hazard and vulnerability (Akhter, 2009; Charlesworth, 2012), Dhaka has a low level of preparedness. A 2009 survey of 444 Dhaka city residents concluded that an "overwhelming majority" of respondents were not aware of their personal risk and have little in the way of preparations for earthquake (Paul and Hossain Bhuiyan, 2009). Another, more recent study found that even where there is awareness of the risk to the city, most people lack any training on disaster preparedness, and have no insurance or savings for such a hazard. Nearly 90 per cent of the respondents (a selection residents from 21 sub-districts of the city) had taken no precautions for a major earthquake (Khatun and Islam, 2015). Awareness of the poor quality of some large structures in the city has been heightened with the collapse of buildings in both 2005 (ADPC, 2005) and the Rana Plaza garment factory disaster in 2013. There have been several programmes to raise community awareness of earthquake hazards and earthquake preparedness in the city (ADPC, 2005; Labib et al., 2017) and these actions have been recognised by the national government, which has implemented additional capacity-building plans. Through a training programme that includes earthquake disasters, the government is now attempting to recruit community volunteers to be first responders and form search and rescue teams (Cash et al., 2013). Case Study 3, which looks at the 2015 earthquake that affected the Kathmandu

Case Study Box 3 – The 2015 earthquake in Nepal

Despite Nepal's preparation programmes before the 2015 earthquake, there was a lack of focus on the urban area which was ultimately affected. All case studies reviewed suggest that WASH equipment was required in large quantities due to widespread damage, and this need could have perhaps be reduced or streamlined with effective DRR programs, or by working with communities in more effective ways. WASH stocks were amongst the most required material and equipment for all agencies. Meanwhile, responding organisations were challenged by a lack of local expert staff, particularly for procuring equipment and logistics (Austin et al., 2016). This shows a need for better understanding of local markets as part of disaster risk reduction programming in cities.

A DEC review recognised a lack of engagement by its humanitarian agencies with disaster-affected urban areas. Few INGOs were working in urban areas, but buildings were often damaged internally, so low-income renters were identified to have the most pressing unmet needs – for both shelter and water. Since the earthquake re-routed water sources, sustainable water provision was seen as a major issue in some areas and water was trucked in to fill the gap (Sanderson et al., 2015). It should have been expected, therefore, that low-income populations renting their houses within urban areas subject to earthquake damage would be vulnerable and in need of assistance to restore water supplies. The DEC recognised the Nepal Risk Reduction Consortium (NRRC) for a level of success linked to its '9 Minimum Characteristics of a Disaster Resilient Community', which contained a framework for increasing resilience. These guidelines include a section on 'Connecting WASH and DRR', which recognises that organisations need to approach WASH development in a way which includes risk-reduction initiatives (NRRC Nepal Risk Reduction Consortium, 2013).

A 2008 programme was designed to strategically locate five earthquake-resistant deep tube wells that could be used in an emergency, with back-up power supplies in the Kathmandu valley. This was carried out in recognition that damage to municipal water resources would take over a month to repair (Jimee et al., 2008). Additional emergency wells were installed two months before the earthquake by the US Army Corps of Engineers, later providing water for 5000 displaced people (Budnik, 2015). Another initiative, which was found to be particularly effective for Oxfam, was the placing of emergency supply containers in particularly high-risk zones. These could be filled with equipment needed during the response. Typical items used by Oxfam for the relief programme were plastic buckets, chlorine tablets, tap stands, chemical testing equipment, and rolls of plastic sheeting.

Key recommendations:

- Ensure DRR programming takes place in urban areas, reducing the likelihood of overlooking vulnerable low-income renters during crises.
- Ensure DRR and resilience projects have a WASH element.
- Ensure that earthquake-resistant contingency tube wells with sufficient capacity are installed, and emergency equipment is stored in high-risk areas.

valley in Nepal, demonstrates the importance of urban programming for earthquake awareness: urban renters there were recognised to have been overlooked in contingency planning and response.

National Disaster Plans

Bangladesh's Standing Orders on Disaster (SOD) was created in 1997 to ensure preparedness and effective management for a range of disaster risks, and to increase cooperation between different government departments in these tasks. These Orders have been periodically updated, and the committee responsible for review currently meets twice a year to bring together government secretaries, ministers, and engineers, along with representatives of many humanitarian agencies. During SOD meetings, earthquake preparedness and awareness programmes are reviewed, as well as the stocks of search and rescue equipment (MoFDM, 2010).

The Comprehensive Disaster Management Programme (CDMP) was set up a few years later, in 2005, as a joint initiative between the Ministry of Disaster Management and Relief (MoDMR) and the UN Development Programme (UNDP). Its main objective was to strengthen Bangladesh's capacity to manage disaster risk and to put DRR programmes in place (UNDP, 2016). It plays an important role in Dhaka, by supporting both the city's North and South corporations (DSCC and DNCC) in developing urban disaster volunteer programmes, training, and contingency plans.

Contingency Planning

Disaster response typically involves the identification and strengthening of resources and capacity, and is typically a generalised scenario, whereas contingency planning addresses a specific type of hazard such as an earthquake. Contingency planning tends to establish operational procedures based on expected resource needs and capacity. In 2012, the International Federation of the Red Cross and Red Crescent (IFRC) produced a contingency planning manual, based on international experience, which sets out best practice for the preparation and response to disasters at local, national, and international levels. It sets out sectoral responsibilities that complement the Sphere Humanitarian Charter and Minimum Standards in Humanitarian Response (The Sphere Project, 2011); and for WASH, it makes recommendations for restoring the water supply, sources, distribution, and additional treatment. It promotes standard operating procedures for each sector, setting out what should be done and with what methods, the responsible parties for implementation, and the resources available (IFRC, 2012).

In 2009, the CDMP produced an earthquake contingency plan for Dhaka, with the aim of optimising the efforts of first responders and restoring damaged utilities. It defined first-level responders as those "required in the early stages of a disaster for the preservation of life, environment, and property"; they consist of the armed forces and civil defence organisations as well as government organisations directly working in disaster management. Second- and third-level responders were also defined in the plan, with second-level responders primarily consisting of utility and lifeline providers – with much focus on centralised water provision. Third-level responders are also defined to include NGOs, CBOs, a few government departments, and media organisations.

DWASA and the WASH Cluster

Based on UN recommendations for coordinating a large-scale emergency response with a range of stakeholders, several functional groups or clusters were created. The WASH cluster was created to focus on essential utilities including the water supply, and to predict the amount of damage to water pipelines and critical water supply infrastructure. The WASH cluster's lead actors are the city's North and South Corporations, while UNICEF was proposed as the 'global cluster partner' to coordinate international responses.

In conjunction with a variety of other organisations, including the Department of Public Heath Engineering (DPHE), DWASA was designated as the key agency for preparedness and response in three time-based phases: pre-disaster, emergency response, and early recovery. These actions included the facilitation of alternative water supply systems, creating minimum drinking water standards, and promoting water conservation and purification methods. DWASA was also given responsibility for the early recovery phase, in the weeks and months after an earthquake. This would include surveillance of disease outbreaks, damage assessment, and restoration planning. The actions are summarised in **Figure 6** (CDMP Bangladesh, 2009).

Figure 6. CDMP's Proposed actions for DWASA in earthquake preparation, response and recovery

Pre disaster phase	Emergency response phase	Early recovery phase
Vulnerability assessment for water infrastructure	Activation of emergency plans	Performance evaluation of response
Contingency plans including creation of emergency deep wells	Communicate emergency water needs	Facilitate emergency water supplies
Emergency guidelines for water standards, epidemic surveillance and sanitation	Rapid water systems damage assessment	Continued epidemic surveillance
Facilitation of emergency systems of water supplies	Maintain water supply in welfare camps	Damage assessment converted into plans for restoration
Promote water conservation	Water quality checks for all sources in use	Continued water quality checks

Displacement Camps

Within the contingency plan for the city, the planning for population displacement is carried out – along with a needs assessment for displaced people – primarily based on the Sphere standards. This includes the identification of locations for camps in the very limited open space of the city, as well as proposed emergency water storage locations. Despite the planning and calculations given, there is a recognition that even with a suitable number of skilled workers, the water infrastructure in place in 2009 would take several months and a high cost to repair following an earthquake (CDMP Bangladesh, 2009). This would potentially leave a large cross-section of the population without a reliable, safe domestic water source for an extended period of time, significantly raising the risks of epidemics.

Ward-Level Spatial Contingency Plans

In addition to city-wide contingency planning, and following best practices established in the Hyogo Framework for Action (UNISDR, 2005), Dhaka city has begun to produce 'ward-level spatial contingency plans'. In 2014, a scenario-based contingency plan was published for ward 11 in the Mirpur area of the DNCC. The plan considers an earthquake scenario and defines key actors for immediate response, as well as resource requirements (Dhaka North City Corporation, 2014). Although the plan is relatively comprehensive and follows the UN cluster system in its format, it covers only the initial 72 hours following an event, and does not consider longer-term recovery. The plan is also advisory, and stipulates that the preparatory actions can only be carried out given appropriate resources and a large number of trained volunteers. It estimates the water requirements of a predicted number of displaced people; however, the source and delivery methods are not considered, while the estimations appear to be based on the potential capacity of proposed evacuation camps instead of the estimated number of people displaced.

DWASA Preparations

The IFRC's Contingency Planning Guide states that plans for water provision should specify both the quantity and quality of water, in addition to the supply and distribution systems used. A protocol for water treatment and alternative water sources should also be defined, as well as additional equipment for water tankers and for related purposes, if required (IFRC, 2012). These details are not fully defined in Dhaka's contingency plans, with some items lacking preparation and planning – notably the sources of water and treatment protocols.

In 2009, the Department of Disaster Management released an earthquake contingency plan for DWASA under guidance from the Asian Disaster preparedness Centre (ADPC) and the National Society for Earthquake Technology-Nepal (NSET) (Government of the People's Republic of Bangladesh, 2008). Its primary intended audience was DWASA staff. The document presents plans for the provision of immediate emergency water supplies, and for restoration of infrastructure and waste water facilities immediately following impact. The preparedness portion of the document mostly focuses on assessing vulnerability of the complete water supply system including pipelines, tanks, pumping machinery, wells, and lift stations. The city's single wastewater treatment plant is also assessed for its vulnerability, and is expected to be heavily damaged. In recognition that an estimated 870,000 people could be displaced and over 250,000 in need for housing in designated emergency shelters, the report suggests that a daily 13,000 metres- cubed of water would be needed for distribution in the camps. While there is no suggestion of how this water will be collected and distributed, pre-positioning of water resources is suggested for an initial three days' supply near the largest camps. There is no suggestion of how this will be implemented, however.

Estimations are provided for the number of repairs required to DWASA equipment, along with some projections of the labour required to carry these out. However, the equipment and materials required, along with an implementation plan for supplying them, are omitted; and it is suggested that these would be detailed in later revisions. The report details the repairs in order of priority, which starts with repair of wells/ boreholes and then of pumping equipment, with pipelines further down the list.

There has been an effort to begin preparedness work for the CDMP programme. However, there is little evidence that implementation plans have been created to carry out the estimated work. . Furthermore, while international agencies and global humanitarian partners (UNICEF, the World Bank, and the Asian Development Bank) are mentioned in the CDMP contingency plans, detail on the level and scope of collaboration is not suggested. While the proposed repair work concentrates on rehabilitation of DWASA equipment, it should be recognised that only around 70 per cent of residents receive their drinking water from a piped connection, and there are many supply chains providing water to residents, many of which involve private organisations (Uddin and Baten, 2011; Aziz, 2012).

Overall, although contingency and risk-reduction plans are being created, it is not clear whether these have been applied successfully, or if stakeholders are fully aware of them. In some cases, resources may not be available for the relevant stakeholders to fully realise the suggested plans. A discussion around the general awareness and practicality of these plans, through selected interviews, is presented in section 4.1.

Stakeholder Perceptions and Preparedness

Interviews were carried out with representatives from a selection of stakeholder groups as defined in section 1.2.3 (see **Appendix 1** for details). The results of key interviews have been organised into themes in the sections that follow.

Institutional Planning and Involvement

As detailed in section 3.5, several institutions have been involved in disaster planning initiatives. A key representative of DNCC and project director of the Urban Resilience Project[3] was interviewed to provide additional understanding of the interactions the City Corporation has with affected communities, NGOs, and other important market actors in working to prepare for urban disasters. This section is based on information gathered from various interviewees as listed in Appendix 1.

The DNCC has responsibility for coordinating clusters, including the WASH cluster, which gives DWASA many responsibilities. Although the organisation oversees work to improve resilience and earthquake contingency planning in the water supply sector, it does not control the actions taken by DWASA. However, one of DNCC's responsibilities related to water provision is the stockpiling and collection of filters and other WASH stocks in several warehouses. It was suggested that the DNCC's most important function is the operation of the emergency control room that coordinates the many clusters outlined in the city's contingency plan.

It was noted by the DNCC representative that DWASA's organisational structure does not currently allow for innovation and improvement to the water system for DRR, and that the required actions are unlikely to be taken due to an intense focus on operational matters. This was confirmed in discussion with the DWASA's chief engineer, who emphasised that the organisation is under-resourced and currently operates with a system of 'daily emergencies': responding to water shortages through its system control centre. Although there is a dedicated department for responding to daily system-wide issues, no department takes responsibility for defining contingency plans as detailed in section 3.5. Progress to improve management of the city-wide water infrastructure has been made however, with a GIS[4]-based monitoring system recently brought into operation. It was suggested that this system would be operational following an earthquake, providing live mapping to diagnose damage, although this has not been verified.

It is clear that improvements to WASH provision in slum areas have been made in recent years, with many people given improved access to shared, metered water dispensers and card-operated water ATMs. However, this provision needs constant monitoring and improvements due to the high number of migrants arriving in the city.

Risk Reduction and Resilience Programmes

Based on the interviews with DWASA representatives, some small-scale operations have been carried out to replace old parts of the water piping system with HDPE piping. This was done to reduce leakages, but it should be noted that it also improves earthquake resistance as shown in **Box 1**.

The DNCC has recently released two documents on the findings associated with the Urban Resilience Project, which indicates that positive steps towards better understanding and interaction with communities on risk-reduction issues have been carried out. One is a 'town watching' manual, which defines methods for assessing risk in communities. It is intended to assist both government organisations and NGOs to carry out monitoring programmes and identify key stakeholders, setting out best practice for any organisation working in this area so that learning can be applied across different organisations. The second is a ward-level risk index, which rates each ward for its vulnerability in a range of factors including physical, social, and economic. This is intended to direct future DRR work and highlight opportunities to improve resilience by building awareness and capacity for actions. It could

[3] The Urban Resilience Project, funded by the World Bank, oversees preparedness programmes and the response to disasters in the city, while working to implement resilient buildings and retrofitting.
[4] Geographic Information System

also form the basis for the type of community urban planning exercises that were successful in Haiti, such as the KATYE project and the formation of water committees as mentioned in **Box 2**.

Both the DNCC and the Department of Disaster Management (DDM) have recognised that further work could be carried out to form effective partnerships between private businesses in order to push forward DRR programmes. One example of such a partnership was explored by the DNCC in 2016, while investigating debris management: a resource database was compiled featuring the range of assets held by private companies which could be taken advantage of during a disaster. There was also recognition that NGOs, with their high levels of community partnership and knowledge, would be well positioned to help form better partnerships with private businesses and small vendors in the event of a disaster – or preferably before, during DRR actions.

The organisations represented were aware of limitations in the risk reduction and resilience programmes for the city. However, a common theme was that projects are often funded for a short period by external organisations and INGOs, and this means that improvements can be superficial or quickly become outdated. A significant lack of funding for resilience-building projects, which could improve outcomes following an earthquake, was recognised by both the DNCC by the national Department of Disaster Management. Advocacy and raising awareness amongst the general public were seen as crucial tasks for the Urban Resilience Project and City Corporations, with regular newspaper articles, published by the national newspapers the Daily Star and the Bangladesh Pratidin, about the lack of resilience, potential hazards, and significant vulnerabilities in the city.

Disaster Response and Recovery Planning

The Department of Disaster Management (DDM) produced the city's 2008–2009 earthquake contingency plans, which detail disaster response and recovery, but limited resources have meant that these have not been updated or refined as expected. There are currently no plans to update them, despite recognition that they are lacking in detail. Informants from DWASA stated that water is given third priority, following gas and electricity services.

The contingency plans presented in the previous chapters were written by consultants, and it was stated that it is unlikely such documents have been read by management, let alone operational staff. The representative of DNCC was aware that there may be informal contingencies in place (for example, shutting off electrical connections during earthquake or flooding), but none of these have been formalised or written down as standard operating procedures or even emergency plans.

Operational staff at one of Mirpur-13's three wells and bottling plants confirmed that written plans for emergencies do not currently exist, and the assumption has been that an earthquake would only affect the building or electricity supply. There was no recognition that the tube-well source could also be affected. Informal contingency planning at the facility level involved activation of emergency power supplies, but official plans for a major incident had not been made available to staff. No awareness of contamination risks due to earthquake-related damage of wells (see **Box 3**) was shown by operators or management.

DWASA management stated that contingency planning for the provision of water in an earthquake has commenced as of 2017. However, there was no expected date of completion for this work with progress estimated at 20–30 per cent by the superintending engineer. Meanwhile, short-term recovery planning actions, such as equipment repair and resource planning, had not been started. DDM suggested that plans for longer-term recovery from a potential earthquake were not within the scope of work for the near future.

Private Sector and Community-Based Organisations

Information from a selection of organisations was gathered through interviews to provide understanding of other water-market actors' ability to react to a city-wide disaster. All of the institutional stakeholders interviewed recognised that independent organisations are well-placed to act in response to the hazards identified to the city, considering the slow moving, bureaucratic nature of government organisations.

Local Water Purification Supplier

Aquasure is a private business based in Dhaka which. It was launched by a French social enterprise of the same name to supply water purification equipment and supplies that can be used in emergency situations. Aquasure currently works to supply seven humanitarian and development organisations in Dhaka, including BRAC and Oxfam, who carry their own stocks of Aquasure product for responding to emergencies across Bangladesh. Currently two product lines are available through the company: a water small purification device designed to work with wastewater, supplying clean water to small communities particularly in times of drought; and a tablet-based water treatment product to be used by households in emergencies. The company has stocks of equipment and tablets, but would not be in a position to supply these quickly and in large-enough quantities under an earthquake scenario because restocking of supplies could take 7–10 days.

Currently, the business does not supply its products in the open market. But it is considering working with private vendors to scope the potential for supplying the tablet product across the city, which would allow households to purchase the tablets either in case of an emergency or for general use due to the poor quality of the water available.

Aquasure also works in partnership with humanitarian agencies to assist in capacity-building programmes, and would be willing to put further effort into this work. A partnership with the Bangladesh government DPHE has seen the company supplying 80 treatment units and supplies of tablets, which are used for emergency response in four flood-prone urban districts.

Private Water Vendors

Although DWASA is the dominant water supplier in the city, and recognised by most informants as the most important stakeholder in city-wide water provision, private water suppliers in the Mirpur area of the city were also interviewed. In Mirpur, the water is collected from private, hand-pumped tube wells, most of which have been built illegally without the permission of DWASA; it is then transported, usually by rickshaw, and sold to businesses and households. This water is not treated, and can be sold at a variable price depending on the availability of clean water at the time. Where there is a problem with one well, the suppliers are able to find alternative sources and, where necessary, source water from outside of the city. When responding to questions on resilience, water suppliers demonstrated good knowledge and flexibility regarding emergency situations, including an ability to change plans when problems arise to ensure delivery to regular customers.

Community-Based Organisations

Leaders of a CBO working in water provision for underserved communities were interviewed to understand how water is supplied to some of the most vulnerable people in the Mirpur area of the city. The organisation was able to make a written agreement with DWASA, so that it can collect water directly from pumping stations at commercial prices, to deliver and sell it at a low cost to slum dwellers, homeless people, and poor street merchants. Tanks with a capacity of 400 litres are filled and delivered by vendors supported by the CBO – providing them with a livelihood, while improving water access for a large number of people in the area. The CBO recognises the benefits of working with a range of stakeholders, and often works alongside the local NGO Dushtha Shasthya Kendra in order to maintain relationships with DWASA and other government-run organisations. Interview participants were unaware of the potential impacts of an earthquake on water resources, and suggested that there is a general lack of awareness of contingency planning for earthquakes in the community.

Discussion

Much of the population of Dhaka, as well as actors working in the water sector, will be affected by interruptions to their water supply if an earthquake of the expected magnitude takes place. Supply chains will be affected, and the displacement of many people to emergency encampments will mean that there will be an urgent need for water to be supplied to a very large population.

DWASA is the most important actor in Dhaka's water sector. It has complete control of the water sources throughout the city in order to control a rapidly declining water table (DWASA, 2011) and in an attempt to ensure service provision to vulnerable populations. While DWASA is already adept at dealing with day-to-day crises and issues with water access – particularly during the summer months of April to June – its contingency planning for a large earthquake is incomplete. Since contingency plans created by the DDM were only advisory, detailed action-planning and development of standard operating procedures has not been prioritised. This is particularly due to the challenging nature of managing water resources in a city which is growing rapidly, with a population projected to exceed 27 million by 2030 (UN DESA, 2014). However, this does not stem from a lack of awareness of the hazard amongst the stakeholders interviewed, but rather from a lack of widespread understanding of the impacts of an earthquake on urban water resources.

It is possible that some of the other actors within the sector could aid earthquake-affected people by providing their services and equipment – provided they can be supported (and organised) by responding organisations including the government, NGOs, and humanitarian agencies. For small scale water suppliers, for example, their flexible approach could provide an alternative to emergency water supplied by DWASA. In order to achieve this, there must be further effort within communities to build on work already carried out by the DNCC.

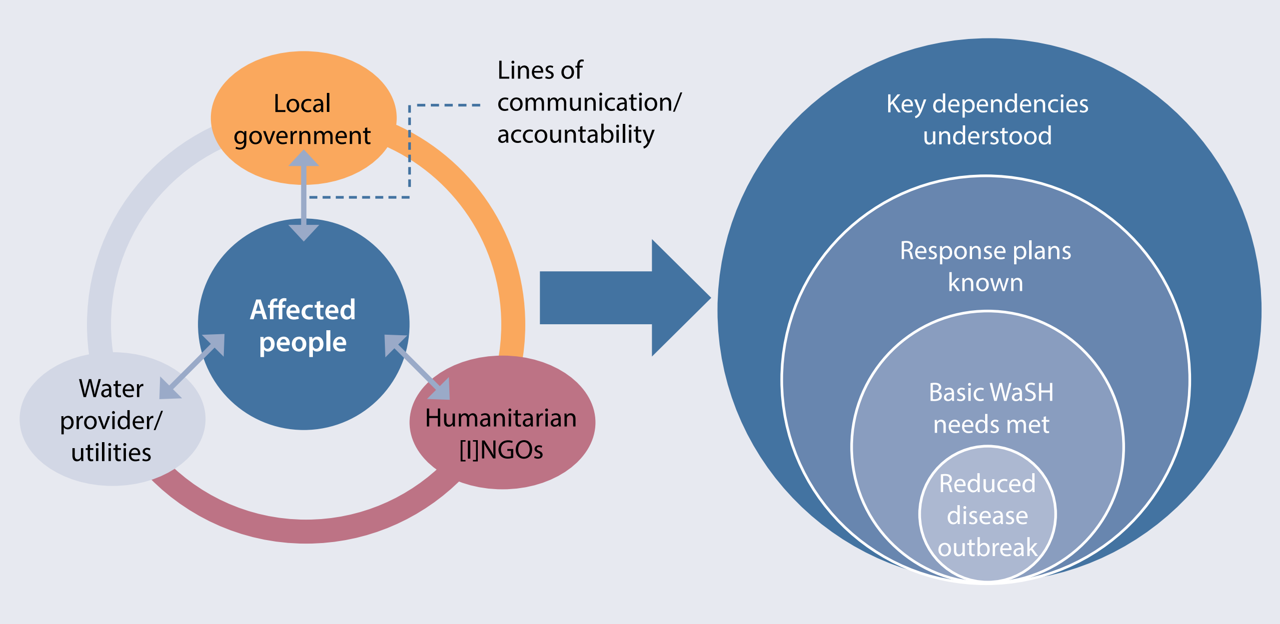
In addition to this, there is scope for the private sector to be more involved in collaboration and partnerships with public organisations, for DRR or improvement to contingency planning as suggested in the Sendai Framework of 2015. UNISDR currently operates the Arise programme, which encourages private sector actors to take the initiative in DRR in order to work effectively with public organisations and deliver funded risk management programmes – although currently there are no member organisations in Bangladesh (UNISDR, 2017).

There is high potential of disease spread after an earthquake in Dhaka, particularly in low-income communities already subject to water-related diseases (Uddin and Baten, 2011). This is due to the high numbers of displaced people expected in such a scenario, (CDMP Bangladesh, 2009) and the necessary repairs to water infrastructure which are expected to be time-consuming (Government of the People's Republic of Bangladesh, 2008). The risk of outbreaks is more likely for those who already experience poor living conditions and problems with their water supply, as in many areas of Dhaka. However, the water supply is not the only factor in a potential outbreak: overcrowding is also a factor, as it is likely that much of the urban population will be evacuated to camps.

To reduce risks associated with the impact of an earthquake and subsequent evacuation to camps, a concerted effort is needed to complete contingency and recovery plans. The proposed actions should be carried out, including the pre-positioning of emergency equipment and water supplies, community organisation and capacity building, and the training of volunteers in earthquake-specific response. Although the most recent plans related to an earthquake contingency direct many actions at DWASA, these requirements have not been met because the organisation has been unable to fund the development and research required. It is recommended that options for further collaboration with (I)NGOs and private companies are tested.

A simplified version of a domestic water market map has been created (**Figure 4** and **Figure 5**), which can be built upon with the results of further field research on the current situation in the city. Better understanding of the complicated nature of the water market in Dhaka should enable stakeholders to improve their actions to provide water more effectively during normal times – but also during and after an earthquake as DRR initiatives improve based on observations of the business-as-usual situation. Better understanding of the whole water market will also enable various actors (government groups and NGOs) to make better use of the organisations

Figure 7. improved communication leading to improvement in resilience and response



and community groups already acting in the WASH sector, making more informed decisions about how to manage a disaster.

By improving understanding of the stakeholders involved in water provision, along with methods of water distribution, organisations should be able to find better ways of working with CBOs, as well as with private water and equipment suppliers, to fine-tune contingency plans.

Figure 7 shows how the stakeholders active in a disaster or DRR situation interact with affected people. If their approach can be coordinated, and accountability improved, the outputs on the right-hand side can be achieved – ultimately leading to a reduced risk of disease outbreaks.

In conjunction with a better understanding of how stakeholders are prepared to respond to a disaster and to engage with the public (based on information gathered in the field-work), this approach could lead to improvements in accountability for earthquake-affected populations as well as in service delivery for organisations like DWASA. This approach can also improve understanding of contingency plans that have been undertaken by community or NGO actors, which could lead to recommendations for service providers and humanitarian organisations working in Dhaka city. Ultimately, with better understanding, water suppliers, NGOs, and government actors will be assisted in reaching the minimum standards for domestic water outlined by the Sphere project, and in quantities suitable for people affected by a disaster.

Conclusion

This study aimed to better understand water provision and disaster risk in Dhaka city, to help stakeholders in the water supply market reduce risks for potentially earthquake affected people. Although the Sphere standards offer some guidelines for humanitarian actors, they do not include methods designed for urban areas since the complex urban markets for water are not considered. Although some contingency planning has been carried out for a predicted earthquake in Dhaka, a lot of work needs to be done to reduce risks, define emergency procedures, and ultimately increase the speed of recovery for affected people.

For this further work to be successful, it should be implemented by a variety of stakeholders such as the government, NGOs, and water suppliers. The aim should be to provide a more resilient water supply, which will ultimately reduce the risk of disease outbreaks and the other negative impacts that an earthquake can have on water infrastructure and vulnerable populations. Collaboration between communities with government agencies will be vital for the formation of effective contingency plans, and this report suggests some ways that private businesses and individuals could improve resilience. Support is required for government agencies, including DWASA, to ensure that contingency planning reaches all parts of the key organisations and that DRR becomes mainstreamed in everyday operations. Ultimately, improved communication between communities and stakeholders, as well as a proactive effort to plan for the worst-case scenario for water provision, will result in a reduced impact and all-round faster recovery for Dhaka city.

References

ABAG Earthquake & Hazards Program (2010) *Water System and Disasters – Background Information Compiled for the 2009–2010 Update of the ABAG-Led Multi-Jurisdictional Local Hazard Mitigation Plan for the San Francisco Bay Area*.

ADPC (2005) 'Community-based Earthquake Risk Management in Dhaka City', *Safer Cities*, 15(May), pp. 1–8.

Akhter, S. H. (2009) *Earthquakes of dhaka*.

Akther, H., Ahmed, M. S. and Rasheed, K. B. S. (2009) 'Spatial and Temporal Analysis of Groundwater Level Fluctuation in Dhaka City, Bangladesh', *Bangladesh. Asian Journal of Earth Sciences*, 2, pp. 49–57. Available at: www.academicjournals.com.

Alam, E. (2016) 'Earthquake and Tsunami Knowledge, Risk Perception and Preparedness in the SE Bangladesh', *Journal of Geography & Natural Disasters*, 6(1), pp. 1–7. doi: 10.4172/2167-0587.1000154.

Alam, S. S., Alam, A. J. and Rahman, S. (2015) *Urban climate resilience, water and sanitation Improving multi-stakeholder collaboration*. Dhaka.

Ali, S. I. and Kadir, K. (2015) *Water Treatment: WASH in Emergencies Problem Exploration Report*. Available at: http://www.elrha.org/wp-content/uploads/2016/01/Water-Treatment-WASH-Problem-Exploration-Report.pdf.

Austin, L., Grosso, S. and Neil, G. O. (2016) 'NEPAL EARTHQUAKE 2015 REVIEW OF SURGE PRACTICES'.

Aziz, S. S. (2012) 'State of Service Delivery in Dhaka City : An Overview of Drinking Water Supply', (July).

Bauer, R. (2013) *Water Markets in Gaza: An Emergency Market Mapping & Analysis (EMMA) Survey on Private and Public Water Supply Markets in Gaza*. Available at: https://www.uea.ac.uk/documents/40159/0/EMMA+Water+Market+Report_Gaza_Nov+2012.pdf/5f41a506-03f8-4595-9bb7-e3c1ac9cc7f4.

BBS (2015) *Census of slum areas and floating population (2014)*, *Bangladesh Bureau of Statistics (BBS)*. Dhaka. Available at: www.bbs.gov.bd.

Brears, R. (2012) 'The effects of the earthquake on urban freshwater resources in Christchurch', *American International Journal of Contemporary Research*, 2(10), pp. 145–149.

Brown, C. (2012) *The 21st Century Urban Disaster*.

Budnik, J. (2015) *Humanitarian assistance projects provide disaster relief in Nepal*, *DSCA*. Available at: http://www.dsca.mil/news-media/news-archive/humanitarian-assistance-projects-provide-disaster-relief-nepal (Accessed: 20 September 2017).

BUERP (2014) *Legal and Institutional Arrangements (LIA) Framework Guidebook*.

Cash, R. A., Halder, S. R., Husain, M., Islam, M. S., Mallick, F. H., May, M. A., Rahman, M. and Rahman, M. A. (2013) 'Reducing the health effect of natural hazards in Bangladesh', *The Lancet*. Elsevier Ltd, 382(9910), pp. 2094–2103. doi: 10.1016/S0140-6736(13)61948-0.

CDMP Bangladesh (2009) *EARTHQUAKE CONTINGENCY PLAN FOR DHAKA CITY*. Available at: https://www.scribd.com/document/261613579/Earthquake-Contingency-Plan-for-Dhaka-City-Corporation.

CERA (2012) *Recovery Strategy for Greater Christchurch*. Canterbury Earthquak Recovery Authority.

CFURS (2017) *Partnership, coordination, and accountability in urban disaster preparedness and response: a synthesis review of public policies, strategies, and disaster management plans in Bangladesh*. Dhaka, Bangladesh.

Charlesworth, E. (2012) *Factors Pertaining to Building Resilience in Urban Slum Settlements of Dhaka , Bangladesh*. Melbourne.

Clermont, C., Sanderson, D., Sharma, A. and Spraos, H. (2011) 'Urban disasters: Lessons from Haiti', *Disasters Emergency Committee*, (March). Available at: http://www.decappeal.com/sites/default/files/files/Evaluations/Haiti/DEC-Haiti-urban-study.pdf.

Cox, W. (2012) *EVOLVING URBAN FORM: DHAKA*, *New Geography*. Available at: http://www.newgeography.com/content/003004-evolving-urban-form-dhaka (Accessed: 4 June 2017).

Cubrinovski, M., Hughes, M. and O'Rourke, T. D. (2014) 'Impacts of liquefaction on the potable water system of Christchurch in the 2010–2011 Canterbury (NZ) Earthquakes', *Journal of Water Supply: Research and Technology – AQUA*, 63(2), pp. 95–105. doi: 10.2166/aqua.2013.004.

Davis, C. A. (2008) 'Seismic Practices To Improve Water System Resilience', in *14th World Conference on Earthquake Engineering (14WCEE) Paper (No. S21-015)*. Los Angeles. Available at: http://www.iitk.ac.in/nicee/wcee/article/14_S21-015.PDF.

DesRoches, R., Comerio, M., Eberhard, M., Mooney, W. and Rix, G. J. (2011) 'Overview of the 2010 Haiti earthquake', *Earthquake Spectra*, 27(SUPPL. 1), pp. 1–21. doi: 10.1193/1.3630129.

Dhaka North City Corporation (2014) *Scenario based Ward level Spatial Contingency Plan*. Dhaka. Available at: http://www.adpc.net/igo/category/ID848/doc/2015-oTKv4A-ADPC-CP_Ward_No._11_of_DNCC_English_Full.pdf.

DWASA (2011) *Existing Situation & Service Delivery Gap Report Dhaka Sewerage Master Plan Project (Package DS-1A)*.

DWASA (2015) 'Annual Report 2014–2015', pp. 1–92.

EMI and World Bank (2014a) *Dhaka Earthquake Risk Guidebook*. Manila.

EMI and World Bank (2014b) 'Dhaka profile and earthquake risk atlas', *Earthquakes and Megacities Initiative*, (April).

Foster, T. (2011) 'Urban WASH Lessons Learned from Post-Earthquake Response in Haiti', *Oxfam Urban Wash Lessons*, (January), p. 11. Available at: http://policy-practice.oxfam.org.uk/publications/urban-wash-lessons-learned-from-post-earthquake-response-in-haiti-136538.

Government of the People's Republic of Bangladesh (2008) *Contingency Plan for Earthquake Hazard for Dhaka Water Supply & Sewerage Authority*.

Hoque, M. A., Hoque, M. M. and Ahmed, K. M. (2007) 'Declining groundwater level and aquifer dewatering in Dhaka metropolitan area, Bangladesh: Causes and quantification', *Hydrogeology Journal*, 15(8), pp. 1523–1534. doi: 10.1007/s10040-007-0226-5.

Hossain, M., Hossain, M. F., Anm, F. and Khan, S. (2016) 'Removal of Ammonia-N Pollution from Surface Water by Sustainable Environmental Techniques', (4).

IFRC (2012) *Contingency Planning Guide*. Geneva. Available at: http://www.ifrc.org/PageFiles/40825/1220900-CPG 2012-EN-LR.pdf.

International Rescue Committee (2016) *Pre-Crisis Market Analysis (Pcma)*.

Islam, N., Mahbub, A., Nazem, N. I., Angeles, G. and Lance, P. (2006) *Slums of Urban Bangladesh: Mapping and Census, 2005*. doi: 978-0-9842585-6-7.

Islam, S., Begum, H. A. and Nili, N. Y. (2011) 'Bacteriological Safety Assessment of Municipal Tap Water and Quality of Bottle Water in Dhaka City: Health Hazard Analysis', *Bangladesh Journal of Medical Microbiology*, 4(1), pp. 9–13. doi: 10.3329/bjmm.v4i1.8462.

Jimee, G. K., Guragain, R., Pahari, M., Robertson, L., Shrestha, S. N. and Dixit, A. M. (2008) 'Pre-Positioning of Water Supply Systems and Developing Earthquake Preparedness and Response Framework in Nepalese Cities', in *The 14th World Conference on Earthquake Engineering, Oct. 12–17 2008*.

Jones, L. M., Bernknopf, R., Cox, D., Goltz, J., Hudnut, K., Perry, S., Ponti, D., Porter, K., Reichle, M., Seligson, H., Shoaf, K., Treiman, J. and Wein, A. (2008) 'The ShakeOut Scenario', *USGS Open File Report 2008-1150 and CGS Preliminary Report 25*, p. 308.

Khan, A. (2005) *The 1885 Bengal Earthquake How prepared are we for any recurrence?*, *The Daily star*. Available at: http://archive.thedailystar.net/2005/05/28/d505281501106.htm (Accessed: 8 August 2017).

Khan, A. (2016) *Geophysical characterization and earthquake hazard vulnerability of Dhaka Mega City, Bangladesh, vis-à-vis impact of scenario earthquakes*, *Natural Hazards*. doi: 10.1007/s11069-016-2237-9.

Khan, T. A. (2012) 'Dhaka Water Supply and Sewerage Authority: Performance and Challenges', pp. 1–13. Available at: http://app.dwasa.org.bd/admin/news/Dhaka WASA Article-for BOOK.pdf.

Khatun, H. and Islam, S. (2015) *Awareness and Preparedness of Disasters in Bangladesh-A Study of Dhaka City Dwellers*. Dhaka, Bangladesh. Available at: http://geoenv.du.ac.bd/wp-content/uploads/2017/08/Awareness-and-Preparedness-of-Disasters-in-Bangladesh-A-Study-of-Dhaka-City-Dwellers.pdf.

Kouadio, I., Aljunid, S., Kamigaki, T., Hammad, K. and Oshitani, H. (2014) 'Infectious diseases following natural disasters: prevention and control measures', *Expert Review of Anti-infective Therapy*, 10(1), pp. 95–104. doi: 10.1586/eri.11.155.

Labib, S., Patwary, S. and Islam, I. (2017) 'Participatory Vulnerability Mapping : A case study on community based disaster management in (ward 13) Dhaka city , Participatory Vulnerability Mapping : A case study on community', in. Manchester.

Lemonick, D. M. (2011) 'Epidemics after Natural Disasters', *American Journal of Clinical Medicine*, 8(3), pp. 1–9. Available at: http://www.aapsus.org/wp-content/uploads/ajcmsix.pdf.

Miller, B. (2016) *Bangladesh: Hidden fault could trigger major quake*, *CNN news*. Available at: http://edition.cnn.com/2016/07/21/weather/bangladesh-earthquake-threat/ (Accessed: 20 July 2017).

MoFDM (2010) 'Standing Orders on Disaster', (April), p. 246. doi: 10.1097/00006199-195908020-00056.

Mutsaka, B. (2012) 'Emergency Market Mapping and Analysis Report: Water Market, Moyale Town, Ethiopia', (September), p. 215. Available at: http://emma-toolkit.org/get/download/.

Noji, E. K. (2000) 'The Public Health Consequences of Disasters', *Prehospital and Disaster Medicine*, 15(4), pp. 21–31. doi: 10.1017/S1049023X00025255.

NRRC Nepal Risk Reduction Consortium (2013) *Nepal's 9 Minimum Characteristics of a Disaster Resilient Community*.

O'Rourke, T. D. (1998) 'An overview of geotechnical and lifeline earthquake engineering', *Geotechnical Special Publication*, (75 II), pp. 1392–1426. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-0031636331&partnerID=40&md5=9a1b9b007db095bf50b7f0e3787a106b.

Patrick, J. (2011) 'Haiti Earthquake Response: Emerging Evaluation Lessons', *Evaluation Insights*, (1), pp. 1–14. Available at: http://www.alnap.org/resource/6125.aspx.

Paul, B. and Hossain Bhuiyan, R. (2009) *Urban earthquake hazard: Perceived seismic risk and preparedness in Dhaka City, Bangladesh*, *Disasters*. doi: 10.1111/j.1467-7717.2009.01132.x.

Rahman, S. (2017) *Residents in parts of Dhaka city face acute water crisis*, *Newage Bangladesh*. Available at: http://www.newagebd.net/article/13178/articlelist/323/index.php (Accessed: 20 August 2017).

Sanderson, D., Rodericks, A., Shresta, N. and Ramalingam, B. (2015) *Nepal earthquake appeal response review*. Available at: http://www.alnap.org/resource/21348.

Shaw, R. (2014) 'Urban Disaster Risk Reduction Framework: assessing urban resilience in World Vision project sites in Bangladesh, Indonesia and China (Final Report)', (February), p. 91.

Sohel, K. M. A., Chowdhury, M. A. I. and Ahmed, M. F. (2003) 'Surface water quality in and around Dhaka City', *Journal of Water Supply: Research and Technology – AQUA*, 52(2), pp. 141–153.

Steckler, M. S., Mondal, D. R., Akhter, S. H., Seeber, L., Feng, L., Gale, J., Hill, E. M. and Howe, M. (2016) 'Locked and loading megathrust linked to active subduction beneath the Indo-Burman Ranges', *Nature Geoscience*, 9(8), pp. 615–618. doi: 10.1038/ngeo2760.

Stott, C. and Nadiruzzaman, M. (2014) *From urban landscape analysis to opportunities for DRR integration*. Dhaka, Bangladesh.

Tappero, J. W. and Tauxe, R. V. (2011) 'Lessons learned during public health response to cholera epidemic in Haiti and the Dominican Republic', *Emerg Infect Dis*, 17(11), pp. 2087–2093. Available at: http://www.adhscourse.org/assets/grocery_crud/texteditor/plugins/filemanager/files/EID_Lessons_Learned_from_Cholera_Tappero-Tauxe_Nov_2011.pdf.

The Daily Star (2016) '6 Rivers Around Dhaka: Water turning untreatable?', *The Daily Star*. Available at: http://www.thedailystar.net/frontpage/6-rivers-around-dhaka-water-turning-untreatable-1325218.

The Sphere Project (2011) *Minimum Standards in Water Supply, Sanitation and Hygiene Promotion*, *Humanitarian Charter and Minimum Standards in Humanitarian Reponse*.

Uddin, A. and Baten, M. A. (2011) *Water Supply of Dhaka City : Murky Future the Issue of Access and Inequality*. Dhaka. Available at: http://www.unnayan.org/documents/RightsParticipation/water_supply_dhaka.pdf.

UNDP (2016) *Comprehensive Disaster Management Programme II*. Available at: http://www.bd.undp.org/content/bangladesh/en/home/operations/projects/All_Closed_Projects/Closed_Projects_Crisis_Prevention_and_Recovery/comprehensive-disaster-management-programme/CDMPHome.html (Accessed: 10 July 2017).

UNISDR (2005) 'Hyogo Framework for Action 2005–2015', *Strategy*, (January), pp. 1–25. doi: 10.1017/CBO9781107415324.004.

UNISDR (2017) *UNISDR's private sector mission*, *UNISDR*. Available at: https://www.unisdr.org/partners/private-sector (Accessed: 10 October 2017).

United Nations DESA (2014) *World Urbanization Prospects*, *United Nations*. New York. doi: 10.4054/DemRes.2005.12.9.

UNU-EHS (2016) *World Risk Report 2016*. Stuttgart. Available at: http://weltrisikobericht.de/wp-content/uploads/2016/08/WorldRiskReport2016.pdf.

Watson, J. T., Gayer, M. and Connolly, M. A. (2007) 'Epidemics after Natural Disasters', 13(1), pp. 1–5.

Wei-Haas, M. (2017) *How Mexico City's Unique Geology Makes Deadly Earthquakes Even Worse*, *The Smithsonian*. Available at: https://www.smithsonianmag.com/science-nature/how-mexico-citys-unique-geology-makes-earthquakes-even-worse-180964972/ (Accessed: 22 September 2017).

WHO (2004) 'Guidelines for Drinking-water Quality', 1, p. 513. Available at: http://apps.who.int/iris/bitstream/10665/42852/1/9241546387.pdf.

WHO/UNICEF (2006) 'Core questions on drinking-water', *World Health Organization*, p. 25.

WHO/UNICEF (2012) *Progress on Drinking water and sanitation 2012 update*, *Update*. doi: 978-924-1503279.

Wisner, B. and Adams, J. (2003) 'Environmental health in emergencies and disasters. A PRACTICAL GUIDE', *Environmental Health in Emergencies and Disasters: a Practical Guide*, pp. 92–126.

Young, P., Henderson, E., Phelps, L. and Brady, C. (2011) *The Haiti Earthquake: an urban solution*. Available at: http://www.alnap.org/pool/files/haiti9897.pdf.

Al zaman, M. A. and Jahan Monira, N. (2017) 'A Study of Earthquakes in Bangladesh and the Data Analysis of the Earthquakes that were generated In Bangladesh and Its' Very Close Regions for the Last Forty Years (1976–2016)', *Journal of Geology & Geophysics*, 6(4), pp. 6–10. doi: 10.4172/2381-8719.1000300.

Zohra, H. F., Mahmouda, B. and Luc, D. (2012) 'Vulnerability assessment of water supply network', *Energy Procedia*, 18, pp. 772–783. doi: 10.1016/j.egypro.2012.05.093.

Appendices

Appendix 1: Survey questions for water service stakeholders in Dhaka: Earthquake Preparedness

Introduction

I am a researcher working with Oxfam to better understand the drinking water market in Dhaka in the context of disaster preparedness. I am particularly interested in understanding preparedness for a large earthquake which could affect the city and the water resources available to its inhabitants. I am speaking to a wide range of people in order to uncover better ways for humanitarian organisations to work with and support local businesses and organisations in preparation for (and during) the event of an earthquake.

Interviewee Information

1. Occupation/position of individual:
2. Location:
   (GPS location if possible:)
3. Name of organisation (if applicable):
4. Organisation type:

Water Supplier	Landlord	Retailer	Government organisation
NGO	Water Vendor	Water Tanker supplier	Well maintenance
Other (list below)			
List other organisation type …			

Earthquake Awareness

1. Are you aware of the earthquake risk in Dhaka?
2. Do you know of the risks to water supplies in an earthquake?
3. If an earthquake struck the city do you know what affects this might have on your business?
4. Who are your main suppliers?
5. Who are your main customers?
6. Which organisations would you look to for support in emergencies?
7. How could an organisation assist you to get your business running after an emergency?
8. Would you be able to assist in supplying water to displaced people whose normal supply is interrupted?

Emergency Situations

1. Have your organisation experienced an emergency in the [study area/work location]?
   a. What type of emergency?
      i. Flood
      ii. Fire
      iii. Water shortage
      iv. Disease outbreak
      v. Earthquake
      vi. Other….

2. Did this emergency cause an interruption to your work/business?

   Yes No

3. If yes, how long did it take for your work [in the study area] to resume normal operation following the emergency?

   No interruption Several Hours
   1 day 3 days
   1 week 1 month or more

4. Name the top three reasons that explain the interruption period given above?

   a. …
   b. …
   c. …

5. How would you rate your organisation's preparedness for the emergency?

   Very High High Average
   Below average Low Very low

6. Describe the reasoning behind the rating given above:

Emergency Preparedness (non-hazard specific)

1. Does your organisation carry out a formal risk assessment for emergency situations? [in the areas you work in?]

Describe?

2. How would you rate your organisation's vulnerability to emergency situations in Dhaka?

   Very high means that the organisation is amongst the most 'at risk' in Dhaka

   Very low means that the organisation is not 'at risk' to an emergency/ disaster in Dhaka

   Very high Quite high Average
   Low Very Low

3. What aspects of your business are most at risk to emergency situations?

   a. …
   b. …
   c. …

4. Give a reason for each aspect above

   a. …
   b. …
   c. …

5. How would you rate your organisation's ability to react to emergency situations in Dhaka?

   Highly Quite good Average
   Below average Poor

6. Name three strategies your organisation has employed to be prepared for an emergency situation:

   Examples of strategies (but not limited to): carry out risk assessments, training of staff, building modifications, infrastructure modifications, researching evacuation procedures, contacting responsible organisations for advice.

   a. …
   b. …
   c. …

7. Of the people your organisation serves, please describe the groups of people who are most vulnerable to an emergency situation:

8. Please give a reason for identifying these groups as most vulnerable:

Earthquake preparedness

1. Does your organisation carry out a formal risk assessment for an earthquake in Dhaka city?
2. Are you aware of the hazards/dangers that will affect **your business** if an earthquake strikes affecting [the study area]?
   a. …
   b. …
   c. …
3. Are you aware of the hazards/dangers that will affect the **population** your organisation serves if an earthquake strikes affecting [the study area]?
   a. …
   b. …
   c. …
4. Would the supply chains serving your business be affected by an earthquake?
5. How many of your suppliers would you expect to be affected by an earthquake?

   Please specify which type of suppliers:
6. Which statement best describes your state of preparedness for an earthquake?
   a. I have not prepared but intend to in the next 6 months
   b. I have not prepared but intend to in the next month
   c. I recently began preparing
   d. I have been prepared for at least the past 6 months
   e. I do not plan to make any changes/preparations
7. What contingency plans do you have in place to protect your business from the effects of an earthquake in Dhaka city?
8. What have you done to protect your business from the effects of an earthquake in Dhaka city?
9. What have you seen other organisations doing to prepare for a potential earthquake in Dhaka city?
10. Are you aware of any training programmes which have been carried out to prepare businesses for an earthquake?
11. Are you aware of any training programmes which have been carried out to prepare individuals/community groups for an earthquake?
12. Do you know who to contact for assistance in the event of an earthquake? Please name them here:
    a. …
    b. …
13. Which organisation(s) are you aware of who can be called upon to assist you/your organisation in the event of an earthquake?
    a. …
    b. …
14. How would you contact the organisation(s) to ask for assistance in the event of an earthquake?

Face to face (in office)		
Face to face (in another location)	Text message	Email
Social Media	Phone calls	
Letters/mail	Other	

Do you know of other representatives in the industry who may be able to respond to this survey?

Name them here:

Appendix 2: Key informant interviews subjects

	Position	Affiliation
1	Chief Engineer/ O&M	DWASA
2	Superintending Engineer and deputy project director	DWASA / DWASA Development Project
3	Programme Director – Urban Resilience Project	DNCC
4	Programme Assistant	UNDP Early Recovery Facility
5	Project Manager ELNHA	DSK
6	Programme Officer	Aquasure Bangladesh
7	Assistant Director	Department of Disaster Management
8	Ward Councillor – Mirpur 11	DNCC
9	Plant Manager	DWASA bottling plant
10	Pump house operator	DWASA
11	Water vendors	Private business
12	Water delivery servicemen	DWASA
13	Operations staff	DWASA pumping station

This paper by Graeme English, Luiza Campos, and Jonathan Parkinson makes a valuable contribution to the last of these themes – coordinating urban disaster preparedness. By focusing on a specific and important sector – water – in the Bangladeshi capital, the paper draws attention to a range of preparedness measures that should take place prior to a major event such as an earthquake. The paper reviews current understanding of urban disaster risk reduction for domestic water resources and distribution. It indicates that stakeholders need to better understand water market systems in order to improve their responses and preparedness for an earthquake. It analyses the current situation related to resilience in the domestic water supply chain in Dhaka, and applies market-system mapping to highlight how stakeholders can work better with communities and market actors, as well as to highlight weak links in distribution chains.

Published December 2017

This paper is part of a series of research pieces produced under the Urban Crises Learning Fund managed by the Institute for Environment and Development.

This research was funded by UK aid from the UK Government, however the views expressed do not necessarily reflect the views of the UK Government.