The changing spatial extent of rivers and floodplains and its implications for flooding: The case of Kumasi, Ghana

Paul Amoateng

B.Sc. (Hons) Human Settlement Planning, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

A thesis submitted to Charles Sturt University for the degree of Doctor of Philosophy

School of Environmental Sciences,
Faculty of Science

Albury, NSW 2640
Australia

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Certificate of Authorship

I Paul Amoateng,

Hereby declare that this submission is my own work and to the best of my knowledge and belief, understand that it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Charles Sturt University or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by colleagues with whom I have worked at Charles Sturt University or elsewhere during my candidature is fully acknowledged.

I agree that this thesis be accessible for the purpose of study and research in accordance with the normal conditions established by the Executive Director, Library Services, Charles Sturt University or nominee, for the care, loan and reproduction of the thesis, subject to confidentiality provisions as approved by the University.

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Signature                                 Date
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Although many people have helped me during this research, I am solely responsible for all the ideas and views expressed in this research.
Ethics Approval

This research was approved by the Human Research Ethics Committee of Charles Sturt University on 27th May, 2013. The protocol number issued with respect to the research was 2013/080.
Publications arising from this research

Journal Articles


Conference Presentation

Abstract

The spatial extent of rivers and floodplains in urban areas is undergoing significant change despite efforts by national governments and international organisations to conserve and/or improve these inland water systems. The spatial alteration of the rivers and floodplains is pervasive in developing countries, and occurs concurrently with mega trends, such as urbanisation, urban land use or cover change and climate change, among others. The phenomenon is identified among the most apparent urban environmental transformations in recent times, and is often associated with flooding in cities in these countries. However, there has been little detailed research concerning the loss of the rivers and floodplains and its consequences for flooding, especially in urban Africa. This research addresses this gap by holistically explaining the spatial changes in rivers and floodplains in urban Ghana, with particular emphasis on trend, nature, drivers, and flood impacts of changes in the spatial extent of these inland water systems.

This research employed a pragmatic paradigm and mixed methods research approach, and used Kumasi, the fastest urbanising city in Ghana, as a case study. Spatial, socio-economic and hydro-meteorological data were combined to explain the multiple dimensions of the changes in the spatial extent of the rivers and floodplains. The spatial and hydro-meteorological data were obtained from secondary sources, while the socio-economic data were mainly collected using a mix of qualitative methods, such as institutional and property owners' semi-structured interviews, community focus group discussions and spatial surveys, during fieldwork between June and September 2013.

The research found that the spatial extent of the rivers and floodplains has drastically reduced, as shown by a decrease in the number and area of these inland water systems. Some rivers and floodplains were replaced with urban development through encroachment and land filling, while others were degraded by excessive pollution, eutrophication and/or sedimentation. The remaining rivers and floodplains in Kumasi can be characterised as a fragmented inland water network with poor ecological and hydrological vitality and functionality. The findings also revealed that the degradation and loss of the rivers and floodplains were underpinned by multiple but
interrelated anthropogenic drivers. These drivers were largely processes and manifestations of uncontrolled rapid urban development, as well as poor policy and institutional frameworks.

The research findings indicated that a key outcome of the loss of rivers and floodplains was an increased incidence of riverine flood disasters with extended retention of floodwater. The floods have had widespread adverse impacts on the wellbeing of victims, despite coping and adaption approaches being developed to accommodate these disasters. Plausible future scenarios analysis suggested that application of proactive water resources and urban management practices, informed by better legislation and policies, could alleviate the rapid loss of rivers and floodplains and the consequent flooding. Specific steps recommended by this research to address the loss of rivers and floodplains include developing context specific river basin plans that assign property rights and (alternative) uses to the water-related areas, (re)conceiving rivers and floodplains as urban green structures, and removing institutional/stakeholder segmentation in urban and water resources management.
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>ASTER</td>
<td>Advanced Spaceborne Thermal Emission and Reflection Radiometer</td>
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<td>CBD</td>
<td>Central Business District</td>
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<td>CEGSS</td>
<td>Centre for Geographic Information System</td>
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<td>DPSIR</td>
<td>Drivers, Pressures, State, Impacts and Response</td>
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<tr>
<td>EEA</td>
<td>European Environment Agency</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>FAO</td>
<td>Food and Agriculture Organisation</td>
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<td>FCG</td>
<td>Forestry Commission of Ghana</td>
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<tr>
<td>FRWB</td>
<td>Friends of Rivers and Water Bodies</td>
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<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
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<tr>
<td>GMA</td>
<td>Ghana Meteorological Agency</td>
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<td>GoG</td>
<td>Government of Ghana</td>
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<td>GPS</td>
<td>Global Position System</td>
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<td>GSS</td>
<td>Ghana Statistical Service</td>
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<td>GWCL</td>
<td>Ghana Water Company Limited</td>
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<td>HSD</td>
<td>Hydrological Service Department</td>
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<td>ILGS</td>
<td>Institute of Local Government Studies</td>
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<tr>
<td>ILO</td>
<td>International Labour Office</td>
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<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>IWMI</td>
<td>International Water Management Institute</td>
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<td>KMA</td>
<td>Kumasi Metropolitan Assembly</td>
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<td>LC</td>
<td>Lands Commission</td>
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<td>LTM</td>
<td>Landsat Thematic Mapper</td>
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<td>LUCC</td>
<td>Land Use/Cover Change</td>
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<td>MBID</td>
<td>Metropolitan Building Inspectorate Division</td>
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<td>MEA</td>
<td>Millennium Ecosystems Assessment</td>
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<td>MES</td>
<td>Ministry of Environment and Science</td>
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<tr>
<td>MLF</td>
<td>Ministry of Lands and Forestry</td>
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<tr>
<td>MWMD</td>
<td>Metropolitan Waste Management Department</td>
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<tr>
<td>MWRWH</td>
<td>Ministry of Water Resources, Works and Housing</td>
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<tr>
<td>NADMO</td>
<td>National Disaster Management Organisation</td>
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<td>NGO</td>
<td>Non-Governmental Organisation</td>
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<td>NOAA/NWS</td>
<td>National Oceanic and Atmospheric Association of National Weather Service</td>
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<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<td>POI</td>
<td>Property Owner Interviewee</td>
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<td>United Nations</td>
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<td>UNDESA/PD</td>
<td>United Nations Department of Economic and Social Affairs/Population Division</td>
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1.1 The Key Issue: changes affecting rivers, floodplains and flooding

A high level of urbanisation has been a dominant characteristic of the early years of the twenty-first century and has resulted in major environmental changes in many parts of the world (Njoh, 2003; Prasad, Rajan, Bhole & Dutt, 2009; United Nations Department of Economic and Social Affairs/Population Division [UNDESA/PD], 2012). Global urbanisation reached an unprecedented level in 2008 when for the first time in history more than half of the world’s population resided in urban areas (United Nations Human Settlements Programme [UNHABITAT], 2008). Consequently, the UNDESPA/PD (2014) reported that more than 54% of the world's population resided in urban areas in 2014, and also anticipated that this would reach about 66% in 2050.

Unfortunately, the fast pace of urbanisation has largely become a phenomenon of developing countries. It is estimated that about 90% of the world’s population growth in the foreseeable future will occur in urban areas of developing countries (Brockerhoff, 2000; UNDESA/PD, 2012). In particular, rapid urban population growth is pervasive in Africa, which is noted as the fastest urbanising region in the world with an average annual urbanisation rate of 3.6% in 2014 (UNHABITAT, 2010; UNDESA/PD, 2014). The urbanisation level in Africa was about 40% in 2014, and is expected to exceed 50% in 2040 and further increase to about 56% in 2050 (UNDESA/PD, 2014). As rapid urbanisation has been largely spontaneous and unplanned in developing countries, it threatens environmental resources and ecologically sensitive areas like inland water systems in urban areas (Millennium Ecosystems Assessment [MEA], 2005; McGranahan, Mitlin, Satterthwaite, Tacoli & Turok, 2009; Misilu, Shouyu & li Qin, 2010; United Nations Environment Programme [UNEP], 2012).

Inland water systems such as rivers and floodplains, are undoubtedly among the most essential natural resources on planet Earth (Finlayson et al., 2005; Ramsar
Rivers and floodplains provide valuable ecosystem services such as water supply for multiple purposes, conveying urban runoff, regulating climate, treating wastewater, beautifying towns, sustaining biodiversity, as well as serving as important recreational and cultural sites (Novotny, Clark & Griffin, 2004; MEA, 2005; Kromroy, Ward, Castillo & Juzwik, 2007; Everard & Moggridge, 2012). Consequently, the need to protect, conserve and manage these natural resources has been recognised by individuals, national governments and international organisations (Finlayson et al., 2005; Dudgeon et al., 2006; Sharma, Ranga & Sharma, 2010; Armenteras et al., 2012). The need to safeguard and improve the condition of these inland water systems in urban areas is manifested in international efforts and conventions such as the United Nations Conference on Environment and Development (UNCED), the United Nations Conference on Sustainable Development (Earth Summit 2012), the Convention on Biological Diversity, the African Convention on the Conservation of Nature and Natural Resources, the Ramsar Convention on Wetlands, the World Water Forums and the Vancouver Declaration on Human Settlements, among others. Despite this interest in managing and protecting rivers and floodplains, they remain among the most degraded and altered environmental resources and ecosystems in rapidly growing cities (MEA, 2005; Armenteras et al., 2012; Carpenter et al., 2011). These aquatic systems are exposed to severe pressures by a growing population irrespective of the level of technological progress or infrastructure development (Eppink, van den Bergh & Rietveld, 2004; Redman & Jones, 2005; Lee et al., 2006; Ramsar Convention Secretariat, 2007).

The rivers and floodplains in urban areas are changing in many ways, especially in spatial extent (Goonetilleke & Thomas, 2003; Prasada et al., 2009; Akumu, Pathirana, Baban & Bucher, 2010). The spatial morphology, morphometry and hydrology of the rivers and floodplains have been and continue to be altered in many cities (Patil, Auti & Mokashe, 2008; Islam, Rahman, Shahabuddin & Ahmed, 2010). Rapid urban population growth, uncontrolled urbanisation and urban expansion, poor urban planning and management, changing communal/local interests and climate change are among the factors accounting for the spatial changes in rivers and floodplains.
Flooding remains one of the most daunting socio-environmental challenges in many cities of developing countries (Douglas et al., 2008; Jha, Bloch & Lamond, 2011). This catastrophe is largely human-induced, and is increasing spatially and temporally (MEA, 2005; Intergovernmental Panel on Climate Change [IPCC] 2007). Previous studies have asserted that the development of human settlements in rivers and floodplains and associated eventual loss of these inland water systems fragments hydrologic networks, reduces the water retention and conveyance capacity of inland water systems, as well as creates permanent and/or intermittent flood damage zones (Dhar & Nandargi, 2003; Anil, Gupta & Nair, 2010; Islam et al., 2010). In such situations, the occurrence of flood disasters is likely to increase. Nevertheless, natural factors such as climate change, topographic and soil conditions are also cited as the triggers of flooding (IPCC; 2007; Douglas et al., 2008; Addo, Larbi, Amisigo & Ofori-Danson, 2011). As a result, the underlying reasons for the increasing scale and frequency of flooding, as well as its relationship with changes in the extent of rivers and floodplains in cities of developing countries, remain unclear. These uncertainties make research into the trends and drivers of the changes in the spatial extent of rivers and floodplains, as well as the adverse implications for flooding in cities in these countries, an imperative for holistically understanding and curtailing such socio-environmental problems.

1.2 Urban areas in Ghana as a case study

Ghana is an example of a country where there has been a significant shift in population from rural to urban areas. The urban population exceeded the rural population for the first time in 2010 (Ghana Statistical Services [GSS], 2013) by increasing more than eight fold from about 0.8 million (15%) in 1950 to about 13 million (51%) in 2010, and is further expected to nearly triple to 32 million (71%) in 2050 (GSS, 2013; UNDESA/PD, 2014). This high level of urbanisation has
accelerated the concentration of the population in the few major cities, such as Accra, Kumasi, Sekondi-Takoradi and Tamale (see Figure 1.1). As a result, the conditions and nature of physical developments, as well as their effects on the natural resources, particularly inland water systems within and beyond urban areas, have deteriorated over the past few decades (Farvacque-Vitkovic, Raghunath, Eghoff & Boakye, 2008; Songsore, 2009; Adarkwa, 2012; Amoateng, Cobbinah & Owusu-Adade, 2013). Thus, the co-existence of humans and inland water systems is under threat in cities in the country (Ahmed & Dinye, 2012).

Rivers and floodplains in urban areas in Ghana are being degraded from increasing urban development and pollution (Ministry of Works and Housing [MWH], 2006). There is a dramatic loss of these water areas in the cities. Natural and anthropogenic factors exert immense pressures on the urban rivers, which affect their spatial extent and water quality. The rivers and floodplains are subjected to over-exploitation, conversion, reclamation and conflicting uses in the process of urban development (Ministry of Lands and Forestry [MLF], 1999; Environmental Protection Agency [EPA], 2005; MWH, 2006). The resultant outcomes are high levels of urban encroachment, increased sediment loads and siltation, and hydrological and water quality changes to rivers and floodplains (Hen & Boon, 1999). In particular, the rivers are contaminated with microorganisms, heavy metals and toxic substances from diverse sources (Obiri-Danso, Weobong & Jones, 2005; MWH, 2006; Monney et al., 2013). The situation has rendered the inland water resources unsuitable for many purposes, and further increased the exposure to flood disasters in urban areas in the country, as the hydrological functions of these water areas are undermined and/or lost (Hens & Boon, 1999, MWH, 2006).

Ghana is one of the African countries that are highly exposed to flood hazards that threaten economic growth and development (Amoako & Ampofo, 2009; Okyere, Yacouba & Gilgenbach, 2012). Floods of different types and degrees of intensity but with increasing frequency and scale of occurrences have become widespread in large cities of the country in recent times (Karley, 2009; Campion & Venzke, 2013). The flood disasters occur annually during the rainy seasons, and are more pronounced in the informal settlements, which often lack adequate economic and physical capacity
to deal with the effects (Douglas et al., 2008; Okyere et al., 2012). The actual causes of the floods are largely unknown as they are linked to multiple causal factors which in certain cases combine to aggravate the consequences. Frequently attributable causes include natural factors such as topography, hydrology, soil, tides, precipitation variability and tropical cyclones, as well as human factors such as land cover/use change, settlement of floodplains and poor urban planning and management (Nyarko, 2000; Douglas et al., 2008; Karley, 2009; Addo et al., 2011; Okeyere et al., 2012; Campion & Venzke, 2013; Gyekye, 2013). Compounding the natural causes, flood disaster management approaches are largely unscientific and non-integrated, and as such lead to severe consequences such as the destruction of property and the loss of lives, as well as a slowdown of economic activities in urban areas (Karley, 2009; Okeyere et al., 2012).

Effective and sustainable policies and programmes for mitigating both the changing extent of the rivers and floodplains and the accompanying floods in urban areas are imperative and urgent. However, the understanding of the spatial changes in rivers and floodplains and flood disasters, as well as their interactions, is plagued with knowledge gaps, as very little research has been conducted on the phenomena. As a result, information about the nature and pattern of changes in the extent of rivers and floodplains and flood disasters is scarce and poorly documented in the country. This knowledge gap exists against the backdrop of increasing degradation of rivers and floodplains and occurrence of flooding, which are likely to continue and worsen in urban areas in Ghana, especially in the two major cities of Accra and Kumasi, due to rapid urbanisation and urban growth.

Kumasi, the fastest growing and second largest city in Ghana, is a good example of what is happening to urban areas in Ghana. The population of Kumasi increased from less than 1.2 million in 2000 to over 2 million in 2010 at an annual growth rate of 5.5%, the fastest rate of increase in the country (Cobbinah & Amoako, 2012; GSS, 2013). Kumasi’s rapid population growth, coupled with unregulated physical development and expansion, has posed enormous threats to the abundant natural resources, particularly rivers and floodplains present in the city (Abloh, 1972; Tipple, 1997; Ahmed & Dinye, 2012; Cobbinah & Amoako, 2012; Amoateng et al., 2013).
Rivers and floodplains in the city have been degraded by, and utilised for, unauthorised urban development with attendant problems of recurrent floods, which have become an annual disaster in certain suburbs of the city during the rainy season (Ahmed & Dinye, 2012; Campion & Venzke, 2013).

Although relevant research such as that investigating urban and peri-urban expansion and development (Brook & Dávila, 2000; Cobbinah & Amoako, 2012; Amoateng et al., 2013), water pollution (Obiri-Danso et al., 2005; Danquah, Abass & Nikoi, 2011; Ahmed & Dinye, 2012; Monney et al., 2013), rainfall variability, floods and adaptations (Fosu, Asare & Mensa, 2012; Campion & Venzke, 2013) and waste management (Kereita, Pay & Amoah, 2003; Dahlman, 2009) have been conducted in Kumasi, these further expose critical gaps in the understanding of urban growth, inland water systems degradation and floods in the city. There is practically no research that assesses the dynamics of change in spatial extent of rivers and floodplains and the implications for flood disasters in the city. As a consequence, the underlying drivers of the changing extent of rivers and floodplains, as well as the increasing frequency and intensity of flooding in the city are not well understood or addressed by researchers and practitioners alike, which is typical in many cities in developing countries. This claim is substantiated in the discussion of the research gaps in the subsequent section.
Figure 1.1 Map of Ghana showing the major cities
Source: Spatial Data Analysis Network (SPAN), Charles Sturt University (CSU), (2016)

1.3 Research gaps, questions and aim

The spontaneous and unsustainable growth of urban areas, the spatial alteration of rivers and floodplains and the resultant incidences of floods in cities in developing countries are widely recognised (Prasad et al., 2009; Du et al., 2010; Islam et al., 2010; Cobbinah, Erdiaw-Kwasie & Amoateng, 2015a; 2015b). However, recent studies reveal significant knowledge gaps in terms of limited geographic scope, conceptualisation and methodological processes in our understanding of the spatial changes in urban rivers and floodplains and the consequences for flooding (Pauchard, Aguayo, Peña & Urrutia, 2006; Baud & De Wit, 2008; Akumu et al., 2010; Carpenter et al., 2011). Therefore, there is a need for more in-depth investigation into the phenomena, especially in developing countries, in order to facilitate a holistic
understanding of the changes in the spatial extent of rivers and floodplains and flooding in rapidly growing cities (Pauchard et al., 2006).

Regarding the limited geographical scope, Baud and De Wit (2008) indicate that cities in developing countries have been relatively less studied in relation to the environmental transformation associated with their rapid and ill-planned urbanisation in comparison to those in the developed world. Much of the research that provides some evidence that the spatial extent of rivers and floodplains in urban areas is changing is from developed countries and a few Asian countries (Kromroy et al., 2007; Dewan & Yamaguchi, 2009; Akumu et al., 2010; Du et al., 2010). However, in addition to their limited geographical scope, these studies failed to ascertain the rates and trends of change in the spatial extent of these aquatic areas. Consequently, it is unclear whether the spatial changes in rivers and floodplains are consistent with historical, current or future rates in other developing countries, given that the incidence, forms and dynamics of urban growth and urbanisation differ spatially and temporally.

The methodological approaches used in the study of spatial changes in rivers and floodplains are limited, and this has resulted in vague and shallow explanations of the factors that drive the process (Prasad et al., 2009; Du et al., 2010; Islam et al., 2010; Carpenter et al., 2011; Deka et al., 2011). Most research undertaken in this regard has relied largely on remote sensing data, with little attention directed towards in-depth interpretation of the human factors that drive the change process. As a result, the studies have neither explicitly identified these factors nor ascertained their relative influence on, and interactions with the rivers and floodplains spatial change process.

It is often asserted that the reduction and disappearance of rivers and floodplains may contribute to an increased likelihood of floods (Dhar & Nadargi, 2003; Anil et al., 2010; Islam et al., 2010). While this claim is tenable, based on empirical evidence, studies that investigate changes in the extent of these inland water systems have not commonly ascertained the implications for flood disasters (Anil et al., 2010; Du et al., 2010; Prasad et al., 2010). The association between the spatial changes in rivers and floodplains and flooding is barely investigated in many developing countries,
thus undermining the conceptualisation of the relationship between these two phenomena.

Research aim

Given the limited geographical scope, lack of comprehensive methodological processes and weak conceptualisation of previous research on the degradation of rivers and floodplains, this research aims to better explain and understand the changing spatial extent of rivers and floodplains, and the implications for flooding in rapidly urbanising cities in developing countries. The process of explaining and understanding the phenomena involved establishing trends and analysing drivers of the spatial changes in the rivers and floodplains, as well as examining the incidence and intensity of floods. This examination and subsequent understanding provided a process to explore change scenarios and possible management responses, such as steps to prevent further decline of rivers and floodplains and to mitigate the adverse impacts of flooding in cities in developing countries, particularly in Ghana.

This research focuses on investigating and understanding the complex interactions between urban growth processes, loss of rivers and floodplains, and flood incidences in Kumasi (see Figure 1.2). In essence, it focuses on establishing the current spatial extent of rivers and floodplains, identifying and analysing the relative importance of the drivers of spatial changes in rivers and floodplains, as well as exploring the occurrence of flooding as an outcome of the loss of rivers and floodplains in Kumasi. As a result, the research is conceptualised using the European Environmental Agency's (1999) Drivers, Pressures, State, Impacts and Response (DPSIR) framework (see Chapter 2 for detailed discussion). Based on the principles of the DPSIR framework, this study postulates that rapid urban growth (e.g., population growth and urban expansion) in Kumasi in the midst of poor urban and environmental management practices (e.g., inefficient policies and enforcement institutions, and inadequate construction of storm drains) and natural factors (e.g., rainfall variability) have resulted in spatial changes in rivers and floodplains, which have led to an increased incidence and scale of flood disasters.
Based on these knowledge gaps and the research aim outlined above, three key questions and several sub-questions were identified to frame and guide this research:

1. How has the spatial extent of rivers and floodplains changed in Kumasi?
   i. What is the trend in the changing spatial extent of the rivers and floodplains?
   ii. What are the processes of river and floodplain spatial change?
   iii. What land use activities are rivers and floodplains converted into?

2. What are the anthropogenic drivers of change in the spatial extent of rivers and floodplains in Kumasi?
   i. What factors cause the change in the spatial extent of the rivers and floodplains?
   ii. What is the relative importance of these factors in the spatial change process?
   iii. How do these factors interact in the spatial change process?
3. How has spatial change of rivers and floodplains contributed to the frequency and intensity of flooding in Kumasi?

i. What is the frequency and intensity of flooding in the city?

ii. To what extent is the frequency and incidence of flooding linked to the change in the extent of rivers and floodplains in the city?

1.4 Research approach and methods

In order to contribute to the conceptual and empirical understanding of the reasons behind the degradation of rivers and floodplains and the adverse outcomes for local communities, this research adopted a pragmatic paradigm and used a mixed methods research approach. The mixed methods research approach was used to ensure an adequate focus on, and provide in-depth insights into, the various dimensions of the phenomena investigated (e.g., what has changed, how and why has it changed, and what are the effects of its changes), by placing emphasis on particular methods at different phases of the research process (Silverman, 1998; Johnson & Onwuegbuzie, 2004; Creswell & Plano-Clark, 2007). The case study research design was used for this systematic inquiry into the changes in the spatial extent of rivers and floodplains and flood occurrences because of its support for the application of multiple sources of evidence in single research (Yin, 1981). Thus, using Kumasi as a case study area, various data collection methods were used to gather primary and secondary spatial, socio-economic and hydro-meteorological data from diverse sources for a holistic understanding of spatial changes in rivers and floodplains, and enhanced reliability and validity of the research results (Yin, 2003; Chetty, 1996; Mohd Noor, 2008).

The primary socio-economic data were collected using qualitative social research methods, namely, semi-structured interviews and focus group discussions, with participants from institutions and property owners, during fieldwork conducted in June-September, 2013 in Kumasi, Ghana. First, semi-structured interviews were conducted with an official of each of the twelve institutions that undertake activities relevant to urban growth, water resources and flood management in Kumasi. This was followed by semi-structured interviews with forty property owners within 100 m of rivers and floodplains in eight purposely selected flood prone suburbs containing
rivers and floodplains. Finally, two focus groups with ten participants – local community leaders and property owners – were organised at two purposely chosen suburbs to elicit collective views on the state of the rivers and floodplains, and incidence of flooding. For the spatial data, Landsat Thematic Mapper (LTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images of Kumasi for the years 1985, 2000 and 2013 were obtained from the Forestry Commission of Ghana (FCG). The satellite images were supplemented with land use and topographical maps of Kumasi, as well as ground truth information collected with handheld Global Position System (GPS) to improve the accuracy of the results obtained (Islam et al., 2010; D’Souza & Nagendra, 2011). In addition, various forms of secondary data were obtained from literature, government policies and official reports, and used for better conceptual understanding of the phenomena studied.

ArcGIS software was used to process and classify the satellite images into three land use/cover categories as urban land, vegetation and rivers and floodplains, in order to derive land use/cover maps and statistics of Kumasi for 1985, 2000 and 2013. Transcripts of the interviews and focus group discussions were coded and analysed with NVivo software to locate themes, ideas and concepts, and were presented with qualitative narratives (story) and numerical statistical explanation. In addition, qualitative content analysis was used to summarise and interpret the informational aspects of the secondary data such as the policies, legislation and reports on urban growth, water resources and urban flood management in Kumasi and Ghana. Data on hydro-meteorological issues such as rainfall, temperature, runoff, water levels and water quality were analysed using quantitative descriptive statistics to ascertain their patterns and trends. Finally, narrative plausible scenarios of rivers and floodplains in Kumasi were developed based on anticipated and/or assumed changes in identified key change drivers/pressures to explore the future spatial changes in these inland water systems, and the associated flooding.
1.5 Thesis Outline

This thesis comprises eight chapters that are grouped in three broad parts: i) the background for the research; ii) the results from the case study area; and iii) discussion and conclusion.

Chapters One to Three form Part One of the thesis. Chapter One provides the background to the degradation of rivers and floodplains, as well as flooding in the rapidly growing cities in developing countries, with emphasis on the situation in Ghana. The chapter concisely states the research gaps, questions and aim, and briefly outlines the research methods employed. Chapter Two presents the literature review, which examines the current state of knowledge on the linkages between urbanisation, inland water systems, and flooding. The chapter presents the conceptual foundations of the research and identifies existing knowledge gaps that were used to frame the research questions. Chapter Three gives a detailed description of the methods used for this research with focus on the choice of research paradigms, data types and sources, data collection methods and data analysis techniques. An explanation of how these methods were used to address the research questions is also presented. The chapter further outlines the salient characteristics of Kumasi, and the justification for its selection as the study area.

Chapters Four to Seven comprise the second part of the thesis, and have been structured along the components of the DPSIR framework. Chapter Four reveals the state of the rivers and floodplains by presenting information on the spatial extent, physico-chemical and hydrological changes in the rivers and floodplains, as well as the processes and nature of land use activities development along and in these water areas in Kumasi. Chapter Five explores the pressures and processes which have led to changes in rivers and floodplains in Kumasi, with key issues covered including unregulated physical development, poor sanitation and unplanned urban agriculture. Chapter Six examines the drivers of change in the spatial extent of the rivers and floodplains, with emphasis on human induced factors, such as population growth, land ownership and delivery and management arrangements for urban growth, water resources and floods in Kumasi. Chapter Seven analyses the incidence, nature and effects of floods, as well as flood coping and adaptation strategies in Kumasi.
Chapter Eight makes up the third and final part of the thesis, and presents a discussion of the key research findings, plausible futures of rivers and floodplains, recommendations for effectively managing water resources, urban growth and flooding, as well as directions for further research. The chapter provides a conclusion and synthesis of the research by describing how the research questions have been addressed to achieve the broad research aim.
Chapter 2 - Literature review

2.1 Introduction

The twenty-first century has been characterised by unprecedented urbanisation levels and urban environmental changes. The increasing number and size of large cities has been accompanied by environmental changes that pose formidable challenges for urban residents, urban planners and environmentalists in many developing countries (MEA, 2005; UNDESA/PD, 2012; UNHABITAT, 2008). These urban environmental changes include loss of arable lands, air pollution, degradation and loss of inland water systems, and decline in natural vegetation cover among others. In particular, inland water systems have been identified among the most altered ecosystems in urban areas (Dudgeon et al., 2006; Carpenter et al., 2011; Everard & Moggridge, 2012). The existence of these aquatic systems in cities is under increasing threat as the cities expand physically and increase in population, posing further socio-environmental problems, such as flooding.

Literature on the linkage between urbanisation, inland water systems and flooding is reviewed in this chapter to provide a conceptual basis for this research. First, the characteristics of inland water systems, as well as their values in the urban fabric are explained. These discussions lead to a review of issues relating to changes in inland water systems through the influence of adverse socio-environmental changes in the urban areas. This is followed with a review of the concept, trends and dynamics of urbanisation, which has been done from the global level and then narrowed to the African region. Finally, flooding in urban areas is discussed as a potential consequence of the alterations in inland water systems.

2.2 Inland water systems

Inland water systems comprise water bodies such as lakes and rivers, marshes, swamps and floodplains, small streams, ponds, cave water and transitional water that occur on the land surface (European Commission, 2000; Finlayson et al., 2005). These surface waters cover approximately 0.8% of the Earth’s surface and hold just about 0.26% of total water resources on the planet (Dudgeon et al. 2006; Sharma et
al., 2010; Carpenter et al., 2011). Thus, a very small proportion of the water resource on the planet is held in forms – freshwater – that are accessible to humans and other terrestrial organisms. The water resource available from these inland water systems is further affected by the surrounding natural and human-induced conditions (Jackson et al., 2001; Lee et al., 2006; Du et al., 2010).

Spatially, inland water systems have a temporal dimension – perennial or ephemeral – and a dynamic dimension – flowing systems, standing waters or seasonal depth fluctuation waters – and they take different forms, sizes and shapes depending on local physiographic factors (Finlayson et al., 2005; Du et al., 2010). According to Everard and Moggridge (2012), these waters often serve as defining and founding features of human settlements. However, for the purposes of this research, inland water systems are broadly categorised as rivers/streams and floodplains, which commonly exist in urban areas, and are often reclaimed for and/or replaced with urban land uses due to their location and distribution (Du et al., 2010; Everard & Moggridge, 2012; Lerner & Holt, 2012).

Rivers and streams are surface waters that flow downstream from one place to another (Langbein & Iseri, 1995; Wetzel, 2001; Dodds, 2002). These flowing waters carry sediments, nutrients, and other materials through the landscape and into other aquatic systems, and provide vital linkages between the land, lakes, wetlands and oceans. Thus, rivers and streams are thus termed as the environment’s circulatory system (Wetzel, 2001; Dodds, 2002). Floodplains are described as transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin, Carter, Golet & LaRoe, 1979). These aquatic habitats represent a variety of shallow vegetated systems such as bogs, marshes and swamps, and commonly occur in areas where the water table is at, near, or above the land surface for a greater part of most years (MEA, 2005; Ramsar Convention Secretariat, 2007; 2010; Deka et al., 2011). This implies that floodplains are areas with a high water table that flood temporarily.

Rivers and floodplains are unevenly distributed in time and space as they are always in a state of flux and as such have variable spatial claim (Pinderhughes, 2004; Finlayson et al., 2005; Carpenter et al., 2011). This situation is further compounded
by their continual degradation by human inactions and actions (Prasad et al., 2009; Du et al., 2010; Carpenter et al., 2011). Nevertheless, these inland water systems provide services that are essential to the continued existence of humans and their environments.

2.2.1 Why inland water systems are important

Inland water systems offer multiple functions and values that support the growth and sustenance of mankind and cities (Bolund & Hunhammar, 1999; Mitsch & Gosselink, 2000; Ramsar Convention Secretariat, 2010; Carpenter et al., 2011). Although the true value of inland water systems is poorly scientifically ascertained and documented, key hydrological, social and environmental services provided by these waters are very noticeable and very beneficial to both the natural systems and human environment (Barbier, 1994; Finlayson et al., 2005). These ecosystem services are provided directly and/or indirectly, and the gains from them often exceed the gains of converting the water areas to any alternative use (Barbier, 1994; Mitsch & Gosselink, 2000).

An important hydrological service of inland water systems is mitigating storm damage and flood disasters, especially in urban areas which are dominated by impervious surfaces with an altered hydrological cycle and large runoff (Haughton & Hunter, 1994; Deelstra & Girardet, 2000; Carpenter et al., 2011). The rivers and floodplains serve as natural drainage channels and reservoirs for draining surface runoff in urban areas. Thus, these inland water systems ensure safe conveyance and infiltration of the runoff, hence reducing the risks of urban floods, which reduces the need to construct storm drains for the purposes of flood control in urban areas (Barbie, 1994; Bolund & Hunhammar, 1999; Deelstra & Girardet, 2000; Ramsar Convention Secretariat, 2007; 2010; Pauleit, Ennos & Golding, 2005; Grimmond, 2007).

Inland water systems provide ecosystem services of socio-economic importance. Surface waters are major sources of water for domestic, agricultural, commercial and industrial purposes. It is estimated that inland water systems supply three-quarters of the water withdrawn for human utilisation and goods production (Carpenter et al.,
Also, inland waters are utilised for fishing and aquaculture, for extracting and growing agricultural and horticultural products, for transport and as sources of energy resources (Biney, 1990; Mitsch & Gosselink, 1993; Barbier, 1994; Mortsch, 1998; Bolund & Hunhammar, 1999; MEA, 2005). According to Grimm et al. (2008) these socio-economic values of inland waters strongly influenced the development of many human settlements around rivers and other water bodies in the period of the Indus Valley Civilisation.

In addition, surface waters offer aesthetic and cultural values in urban centres and provide structure to the urban landscape (Ramsar Convention Secretariat, 2007; 2010; Mortsch, 1998). According to the Ramsar Convention Secretariat (2010) many inland waters have special attributes as part of the cultural heritage of humanity, and also are related to religious and cosmological beliefs, as well as of spiritual values. Consequently, inland water systems, if well maintained, serve as recreational venues which are essential for physical and psychological well-being of the beneficiaries (Ramsar Convention Secretariat, 2007; Mortsch, 1998; Bolund & Hunhammar, 1999).

Environmental and physical functions of inland water systems include micro-climate regulation, sewage treatment and conveyance, air filtering, and noise abatement (Finlayson et al., 2005; Pauleit et al., 2005; Akumu et al., 2010; Grimmond, 2007). These functions reduce environmental problems like heat islands, as well as assist cities to avoid or reduce the high cost of maintaining quality urban environment (Bolund & Hunhammar, 1999; Grimmond, 2007). In addition, the aquatic ecosystems provide natural ecological functions such as habitats for a diversity of species, especially migratory birds and other animals of high conservation value (Barbier, 1994; Ramsar Convention Secretariat, 2007).

The foregoing does not only reveal that inland water systems have many important ecological, economic and socio-cultural functions that protect or support lives of humankind, but also underscores the adverse trade-offs that could accompany the alteration and loss of these aquatic systems. Inland waters are valuable not only for the aquatic ecosystem, but also for the urban environment in its entirety as fundamental resources for life-support activities and processes, as well as spatial
quality and identity enhancement (Jackson et al., 2001; Du et al., 2010). Nevertheless, Mitsch and Gosselink (2000) and Carpenter et al. (2011) observe that the ability of these inland waters to provide these services is influenced by their spatial configuration – number, size, nature and distribution – and as such any spatial alteration has the potential to undermine their value especially in terms of flooding moderation. Unfortunately, the failures and/or difficulties in recognising these functional values have resulted in overexploitation or excessive degradation of inland water systems in urban areas (Barbier, 1994; Prasad et al., 2009; Du et al., 2010). As a consequent, inland waters are subjected to diverse forms and levels of spatial modifications, which inhibit their ability to function as “natural infrastructure” (Ramsar Convention Secretariat, 2007), especially as natural drains in the ever growing urban areas of developing countries (UNDESA/PD, 2012).

2.2.2 Change and loss of inland water systems

Inland water systems degradation and loss are among the obvious environmental changes in recent times (United States Environmental Protection Agency (USEPA), 2000; Pauchard et al., 2006; Carpenter et al., 2011). The degradation processes cause alterations in flow patterns, water quality, aquatic biodiversity, absorption capacity, channel morphology and spatial extent of the inland waters (Ito, 2004; Dudgeon et al., 2006; Prasad et al., 2009; Carpenter et al., 2011). The end result of these chemical, biological and physical disturbances is the eventual disappearance of the aquatic systems (Goonetilleke & Thomas, 2003; Prasad et al., 2009; Islam et al., 2010). Given the aim of this research, this review focuses on spatial changes or expressions of degradation in inland water systems, but first briefly outlines qualitative changes (physical, chemical and biological properties) in inland waters.

Comprehensive studies of the changes in the natural and ecological properties of inland waters have been undertaken by several researchers, with the consistent conclusion that water and habitat quality of these aquatic systems are significantly altered by pollution and eutrophication (Nana-Amankwaah & Bosque-Hamilton, 2001; Goonetilleke & Thomas, 2003; Ito, 2004). Literature indicates that inland waters are exposed to non-point and point source pollutants that are discharged into them through wet and dry atmospheric deposition as well as runoff from land and
other surfaces (Lerner & Holt, 2012). In particular, it has been emphasised that expansion of impervious surfaces increases surface runoff yield and capacity – volume and speed – to collect and transport these pollutants into these inland waters (Wang, Lyons, Kanehl & Bannerman, 2001; Pauliet, Ennos & Golding, 2005; Carpenter et al., 2011; Lerner & Holt, 2012). This leads to increased sediment loads that cause habitat alterations such as smothering of littoral habitats and clogging of river bottoms (Dudgeon et al., 2006).

Ample literature indicates that the accumulation of pollutants – excess nutrients – results in eutrophication often associated with invasive aquatic weeds that degrade the physical, chemical, and ecological conditions of inland water ecosystems (Grossman & Krueger, 1994; Pauchard et al., 2006; Prasad et al, 2009; Carpenter et al., 2011). Consequently, many researchers (e.g., Nsiah-Gyabaah, 2004; Ito, 2004; Patil et al., 2008) have reported that water quality parameters of inland waters in many cities in developing countries deviate from the World Health Organisation’s (WHO) standards. For example, Patil et al. (2008) in their analysis of water quality of Salim Ali Lake, India found levels of physico-chemical properties such as temperature, dissolved oxygen and pH, that exceeded the accepted standards of the World Health Organisation (WHO, 2006). Similar results have been reported in other studies which emphasised that such changes do not only affect drinking water quality and restructure biotic communities, but also degrade the spatial form and expression of the inland water systems, especially in urban areas, albeit this is scarcely studied (Grossman & Krueger, 1994; Pauchard et al., 2006; Prasad et al., 2009; Du et al., 2010; Carpenter et al., 2011).

The spatial extent of inland waters, just like other natural land cover, changes with the growth of urban areas or lands (Braimoh & Onishi, 2007; Prasad et al., 2009; Du et al., 2010; Deka et al., 2011; Erene, Duzgun & Yalciner, 2012). Previous studies assert that urban inland water systems such as lakes, rivers, swamps and floodplains are undergoing spatio-temporal changes (Finlayson, Davidson, Spiers & Stevenson, 1999; Zhou, Li & Kurban, 2008; Prasad et al., 2009; Du et al., 2010; Deka, et al. 2011). According to these studies, urban development spatially affects inland waters and their riparian zones either by size reduction or complete reclamation (Zhang &
Han, 2005; Du et al., 2010). For example, using satellite images, Du et al. (2010), report that the 4,039 hectares of surface water bodies (lakes and shallow waters) in Wuhan, China were converted to urban land uses between 1991 and 2004. Also, Dewan and Yamaguchi (2009), using topographic maps and satellite images, examined land use/cover changes in Dhaka, Bangladesh, and discovered that the spatial coverage of the rivers and wetlands in the city was reduced from 16,131.2 hectares in 1975 to 11,174.9 hectares in 2003, a decrease of about 31%. Similarly, Suresh (2001) in his systematic counting and assessment of lakes in Bangalore, found that while 51 lakes existed in the city in 1985, only 17 lakes were left in 2000.

Many researchers (Elmore & Kaushal, 2008; Du et al., 2010; Prasad et al., 2010; Deka et al., 2011) have reported that inland waters were converted into buildable lands to create space for the ever-growing human population and the concomitant economic activities. Du et al.’s (2010) study for instance showed that most of the conversions occurred in areas adjacent to existing built up areas, and were mainly used for housing and warehouse development for increasing population and industries in Wuhan, China. Spatial alterations involve encroachment, infilling and draining that expose inland water systems to morphometric and morphological changes, as well as a decrease in the density of the catchment drainage network of inland waters, with headwater streams the most vulnerable (Elmore & Kaushal, 2008). Consequently, the spatially altered inland water systems are often characterised by channel straightening, lack of riparian buffer, and banks and beds occupied with building structures (Lerner & Holt, 2012).

The literature indicates that the changes in spatial extent and disappearance of inland waters undermine their ecological (e.g., aquatic habitat imbalances), hydrological (e.g., reduced runoff holding and conveyance capacity), and socio-economic values (e.g., unavailability of water in river courses), with implications for the various facets of the urban environment. In particular, many researchers (e.g., Du et al., 2010; Islam et al., 2010; Deka et al., 2011) argue the conversion of inland waters to land (urban lands) leads to spatial fragmentation and breakdown of the connections in the surface water network. Pauchard et al. (2006) and Carpenter et al. (2011) further state that the natural channels of inland waters such as rivers are often narrowed and lined with
concrete (conversion to canals or ditches) and sometimes ultimately buried during the process of spatial alteration and loss. Literature indicates that these changes break down the water network, as well as reduce the retention capacity of inland waters, hence creating permanent and/or intermittent flood damage zones (Tu & Yuan, 2000; Joshi & Suthar, 2002; Islam et al., 2010).

Although it is evident from the foregoing discussion that inland water systems are under threat spatially, it is unclear whether the trends are consistent with historical rates, and whether the rates of inland waters conversion will continue into the future. This is especially the case in developing countries and Africa in particular where research on the phenomenon remains scanty, despite being characterised by intense urban environmental changes in recent times (MEA, 2005; Cobbinah et al., 2015a; 2015b). Studies investigating spatial changes in inland waters are not evenly distributed across regions, but are mainly concentrated in the developed regions and in Asia. In Africa such studies are virtually unavailable, although it is the region that is presently undergoing the fastest urbanisation in the world, with intense adverse impact on the water environment (UNDESA/PD, 2012). Research done elsewhere may not be applicable to Africa. In addition, management of inland water systems without strong empirical data and literature that describe changes in the physical availability and spatial extent of these aquatic areas, means that outcomes may be compromised (Wang et al., 2001). It is this important gap that this study seeks to fill.

Moreover, previous research on the spatial changes in inland water systems focused on detecting the change over two fixed periods in time, and as such neither assessed trend nor identified and ascertained the relative influences of the drivers of change. Also, existing studies largely relied on remotely sensed data to estimate the changes in extent of inland water systems without incorporating social science methods, hence the likely socio-environmental consequences, like flooding, have been inadequately investigated. As a result, there is limited understanding of the relative influence or importance of the underlying processes relating to changes in extent of inland waters. Consequently, Braimoh and Onishi (2007) express the need for studies of land use/cover change that ascertain spatial changes in these aquatic areas, as well as clearly identifying the factors that drive their spatial change. Such integrated
research might result in new insights into, and add to conceptualisation of the changes in the extent and/or loss of inland water systems, as well as the drivers and flooding implications of the change/loss in rapidly urbanising cities.

2.3 Urbanisation

Urbanisation remains a contested and an evolving concept (Frey & Zimmer, 2001), and any attempt to explain it is preceded by its underpinning term ‘urban’, which is even more elusive and volatile (Cohen, 2006; Owusu, 2005). While some researchers argue that population threshold (minimum range of 1,000-5,000) and density (minimum range of 400-1,000 persons/km²) are central to defining the term urban, (Qadeer, 2004; Siegel & Swanson, 2004), others regard legal boundary, agricultural employment and political function as primary in understanding the term (Pacione, 2009; United Nations Population Fund [UNFPA], 2007). Despite both a lack of clarity and a universally accepted definition of urban, recent studies have generally described an urban area as settlement that is city-like in terms of its demographic, economic, social and physical (built environment) characteristics (Owusu, 2005; Cohen, 2006; UNDESA/PD, 2012).

Consequently, the concept of urbanisation has been explained from various perspectives including: demographic, ecological, sociological and economic (Brown, Gray, Hughes & Meador, 2005; Tavernia & Reed, 2009; Misilu et al., 2010; Bao & Fang, 2012; UNDESA/PD, 2012). In conventional demographic thinking, urbanisation reflects a situation in which an increasing proportion of the population lives in urban areas, and occurs through multiplication of the size of population at various points of concentration (Firebaugh, 1984). Hope and Lekorwe (1999), further explain urbanisation as the annual rate of change of the proportion of the population living in urban areas, or the difference between the growth rates of the urban population and that of the total population. Consequently, these demographers (e.g., Firebaugh, 1984; Hope & Lekorwe, 1999; UNDESA/PD, 2012) describe the level of urbanisation as the percentage of the total population living in urban areas – urban population divided by total population for a region – and the rate of urbanisation as the rate at which the urban population grows.
In an ecological sense, urbanisation has been described as a process of increase in human population density in an area that leads to extensive alteration of the landscape (Tavernia & Reed, 2009). This perspective reveals urbanisation as the transformation that occurs in the natural environment of the geographic region through the conversion of land from rural to urban uses (Brown et al., 2005). Moreover, Pivo (1996), a sociologist, explains urbanisation as the processes of cultural and sociological change which involve a departure from a rural to an urban lifestyle. Adherents of this perspective state that the process of agglomeration of people of diverse social and cultural origins alters the various phases of social life, such as informal relationships to formal relationships (Marcus & Detwyler, 1972; Gilbert & Gugler, 1992). In addition, urbanisation has been explained from the economic perspective as a dynamic process that relocates the population from rural areas and transforms the economy from an agricultural to a manufacturing base (Brown et al., 2005; Misilu et al., 2010; Bao & Fang, 2012).

Nevertheless, it is often agreed that urbanisation generally results in a growing share of a region’s population residing in areas of high population density, albeit at varying rates/levels at different times and places (Pivo, 1996; Bao & Fang, 2012). Depending on the rate of urban population growth, urbanisation may be described as hyper urbanisation (>6%); over urbanisation (3%-6%); rapid urbanisation (1%-3%) or stagnant urbanisation (<1%) (Kojima, 1996). Although, different regions and countries have experienced these different forms of urbanisation at different times, rapid urbanisation and over urbanisation have become and would continue to be the dominant types of urbanisation around the world, especially in developing countries (Kojima, 1996; UNHABITAT, 2010; UNDESA/PD, 2012). Researchers (e.g., Kojima, 1996; Njoh, 2003, Cobbinah et al., 2015a; 2015b) argue that these types of spontaneous and close to inexorable urbanisation are socially, economically and environmentally unsustainable. This is because the urban population generally exceeds what the available resources can support, while the urbanisation process is often not accompanied by economic growth (Davis & Henderson, 2003; Bloom, Canning & Fink, 2008).
Based on the above, urbanisation is described as a multidimensional phenomenon that affects all facets of community development. It depicts the process of transformation of a settlement from rural to urban, involving changes in the physical, demographic, economic, and social characteristics of the former. In other words, urbanisation is a product of social, economic and demographic processes that concentrate people in large towns and cities, changes land use/cover, transforms economic structures (e.g., an increase in industrialisation) and alters social lifestyles and relations. Thus, urbanisation is described as a process of human movement and centralisation towards and into urban areas, with associated spatial expansion and increase in urban land use, which have enormous potential to alter the urban environment.

2.3.1 Global urbanisation patterns and trends
Globally, urbanisation reached unprecedented levels in 2008 when for the first time in history more than half of the world population lived in urban settlements (UNDESA/PD, 2012). This period marked the shift from a rural past to an urban future as virtually all of the world’s population growth over the next 40 years is expected to occur in urban areas. Global population statistics indicate that urbanisation levels increased from 5% in 1800 to 15% in 1900, 30% in 1950, 47% in 2000 and 54% in 2014 (UNDESA/PD, 2012; 2014). Correspondingly, global urban population increased more than nineteen fold from 200 million in 1900 to 3.9 billion in 2014, to mark the most dramatic transformation in the spatial distribution of the world's population. Thus, one in two people now live in an urban centre, up from about one in three in the 1950s and one in eight at the start of the 20th century (see Table 2.1). Regardless of a recent decline in the urbanisation rate (e.g., from 3.1% in 1950 to 2.1% in 2014), the global urban population is anticipated to increase from 3.9 billion (54%) in 2014 to 6.3 billion (66%) by 2050 (UNHABITAT, 2008; UNDESA/PD.; 2014). This is because the relatively slow rate of growth would be applied to an ever-increasing population base; hence a large population size would be added to the urban population each year (Brockerhoff, 2000). Unfortunately, a significant proportion of the urban population growth has been, and will continue to be, concentrated in developing countries, where urbanisation is described as
unplanned and unsustainable (Misilu et al., 2010; UNDESA/PD, 2012; Cobbinah et al., 2015b).

The 19th century upheavals in developed countries that diffused worldwide, through colonialism and trade, instigated the urbanisation process of developing countries in the 20th century (Fox, 2012). However, the dominance of colonial powers, through the imposition of restrictions on the migration of indigenous populations to urban areas, prevented many developing countries from experiencing substantial urbanisation in the first half of the 20th century (Songsore, 2009; Fox, 2012). Therefore, the population of these countries remained predominantly rural throughout the first half of the twentieth century with only one out of six persons living in urban areas in 1950 (see Table 2.1). Nevertheless, rapid urbanisation has become a developing country phenomenon since the 1950s, although these countries continue to lag behind developed countries in terms of economic development and modernisation (Gilbert & Gugler, 1992; Brockerhoff, 2000; Cohen, 2004; 2006; Fox, 2012). Between 1950 and 2000, the urbanisation level in developing countries more than doubled from 18% to 40%, with the level expected to exceed 50% by 2020, and reach 63% in 2050. The increasing urbanisation of developing countries is underscored by the high urbanisation rate, which ranged from 4.2% in 1950 to 2.7% in 2000, and is anticipated to drop to 2.0% in 2050, and yet remain higher than the global and developed countries urbanisation rates of 1.6% and 0.5% respectively (see Table 2.1).

It is true that in a variety of contexts, developed countries have experienced higher levels of urbanisation compared to developing countries, as presented in Table 2.1. However, recent studies indicate that the rapid urbanisation in terms of absolute population in developing countries has become a threat to the urban environment (Brockerhoff, 2000; MEA, 2005; UNDESA/PD, 2012; 2014). For example in 2014, although the developing and developed countries had urbanisation levels of about 48% and 78% respectively, their corresponding urban populations were 2.9 billion and 98 million (UNDESA/PD, 2014), highlighting the rapid growth of urban population in developing countries. This growth will continue, with over 90% of global population growth projected to occur in urban areas of developing countries.
over the next four decades. As a consequence, developing countries are considered to be at the crossroads of urban transition, with damaging implications for economic growth and poverty, as well as the shifting of environmental burdens such as degradation of urban inland water systems. This rapid urbanisation, which threatens the environment, natural resources, health conditions, social cohesion and urban functionality, has become increasingly palpable and pervasive in Africa — a predominantly developing region (MEA, 2005; Songsore, 2009; UNDESA/PD, 2012; 2014, Cobbinah et al., 2015a). This makes an in-depth understanding of Africa's urbanisation dynamic imperative, in the context of this research.

2.3.2 Urbanisation dynamics in Africa

In recent years, rapid urbanisation has become synonymous with Africa, despite the continent having a predominantly rural population (Brockerhoff, 2000; Fox, 2012). With an annual average urbanisation rate of 3.6%, Africa is now the world’s fastest urbanising region (UNDESA/PD, 2014). Official UN statistics show that Africa’s urban population increased from 32 million to 279 million between 1950 and 2000, and currently exceeds that of developed regions like North America (UNDESA/PD, 2012; 2014). As presented in Table 2.1, future projections are even more alarming, as nearly a quarter of the world’s urban population (1.3 billion) is expected in urban Africa by 2050. Consequently, more than two-thirds of the population growth between 2000 and 2050 in Africa is expected to be urban — the largest urban population growth of any region after Asia (UNDESA/PD, 2012).

Nevertheless, Africa’s urbanisation has been uneven across the various sub-regions and countries. For example, in 2014, Eastern Africa recorded an urbanisation level of 25% compared to 44%, 51%, 61% and 44% for Middle Africa, Northern Africa, Southern Africa and Western Africa respectively. These variations were further reflected at the country level, where countries such as Ghana, South Africa, Libya and Gabon had urban populations of 53%, 64%, 78% and 87% respectively in 2014 compared to 12%, 22% and 25% for Burundi, Chad and Kenya respectively (UNDESA/PD, 2014). With rapid urbanisation in Africa expected to persist and cross the urbanisation tipping point of 50% to reach about 56% by 2050 (UNDESA/PD, 2012; 2014), the region is now at the crossroads of urban transition, and this
transition poses enormous urban environmental threats (McGranahan et al., 2009; Cobbinah et al., 2015a; 2015b).

Africa's urban population is progressively concentrating in cities with million plus populations (see Table 2.2 & Figure 2.1). As at 2014, there were 55 such cities across the continent, and this is expected to increase to 95 by 2030 (UNDESA/PD, 2014). The UNDESA/PD (2014) report further indicates that cities in Africa are likely to experience rapid growth at average annual rates of between 1.8% and 5.2% by 2030, with cities such as Cairo (Egypt), Lagos (Nigeria) and Kinshasa (Democratic Republic of Congo) having over 10 million inhabitants. Although growth of large cities creates opportunities for economic, social and environmental advancement, the unguided nature of the process of urbanisation poses a development and environmental threats (McGranahan et al., 2009). The ensuing urban agglomerations are characterised by unsustainable exploitation of resources (e.g., inland waters), informal settlements, under provision of facilities, poor environmental sanitation and urban poverty (Boadi, Kuitunen, Raheem & Hanninen, 2005; MEA, 2005; UNEP, 2007). Thus, the growing cities are largely demographically driven with no resulting structural transformation but instead constitute some of the causes and symptoms of the social, economic and environmental crises that have enveloped the continent (Fay & Opal, 2000; World Bank, 2000; Nsiah-Gyabaah, 2004, Songsore, 2009). The next section explores the causes of urbanisation.
<table>
<thead>
<tr>
<th>Major area, region or country</th>
<th>Population (000)</th>
<th>Urbanisation Level (%)</th>
<th>Urbanisation Rates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>746,481</td>
<td>2,856,131</td>
<td>6,338,611</td>
</tr>
<tr>
<td>More developed regions</td>
<td>444,209</td>
<td>885,298</td>
<td>1,113,500</td>
</tr>
<tr>
<td>Less developed regions</td>
<td>302,272</td>
<td>1,970,833</td>
<td>5,225,111</td>
</tr>
<tr>
<td>Asia</td>
<td>244,574</td>
<td>1,392,740</td>
<td>3,313,424</td>
</tr>
<tr>
<td>Europe</td>
<td>282,965</td>
<td>516,827</td>
<td>581,113</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>69,335</td>
<td>396,276</td>
<td>673,631</td>
</tr>
<tr>
<td>Northern America</td>
<td>109,667</td>
<td>249,504</td>
<td>390,070</td>
</tr>
<tr>
<td>Oceania</td>
<td>7,906</td>
<td>22,013</td>
<td>41,807</td>
</tr>
<tr>
<td>Africa</td>
<td>32,034</td>
<td>278,770</td>
<td>1,338,566</td>
</tr>
<tr>
<td>Eastern Africa</td>
<td>3,728</td>
<td>53,484</td>
<td>378,763</td>
</tr>
<tr>
<td>Middle Africa</td>
<td>3,660</td>
<td>34,515</td>
<td>192,108</td>
</tr>
<tr>
<td>Northern Africa</td>
<td>12,807</td>
<td>81,901</td>
<td>201,744</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>5,873</td>
<td>27,666</td>
<td>55,422</td>
</tr>
<tr>
<td>Western Africa</td>
<td>59,666</td>
<td>81,203</td>
<td>51,0530</td>
</tr>
<tr>
<td>Burundi</td>
<td>40</td>
<td>550</td>
<td>7,025</td>
</tr>
<tr>
<td>Kenya</td>
<td>340</td>
<td>6,223</td>
<td>42,636</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>292</td>
<td>4,221</td>
<td>11,479</td>
</tr>
<tr>
<td>Chad</td>
<td>113</td>
<td>1,796</td>
<td>12,442</td>
</tr>
<tr>
<td>Gabon</td>
<td>54</td>
<td>981</td>
<td>3,004</td>
</tr>
<tr>
<td>Sudan</td>
<td>391</td>
<td>9,011</td>
<td>38,388</td>
</tr>
<tr>
<td>Libya</td>
<td>218</td>
<td>3,952</td>
<td>7,155</td>
</tr>
<tr>
<td>Tunisia</td>
<td>1,001</td>
<td>6,060</td>
<td>10,108</td>
</tr>
<tr>
<td>Botswana</td>
<td>11</td>
<td>934</td>
<td>1942</td>
</tr>
<tr>
<td>South Africa</td>
<td>5,778</td>
<td>25,513</td>
<td>49,103</td>
</tr>
<tr>
<td>Ghana</td>
<td>769</td>
<td>8,270</td>
<td>32,192</td>
</tr>
<tr>
<td>Nigeria</td>
<td>2,953</td>
<td>42,810</td>
<td>295,480</td>
</tr>
</tbody>
</table>

Source: Adapted from UNDESA/PD, (2012; 2014)
Table 2.2 Growth of selected cities in Africa with million plus populations

<table>
<thead>
<tr>
<th>Urban Agglomeration</th>
<th>Area/Country</th>
<th>Population (000')</th>
<th>Growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>2010-2014</td>
</tr>
<tr>
<td>All million plus cities</td>
<td>Africa</td>
<td>86,616</td>
<td>4.7</td>
</tr>
<tr>
<td>Cairo</td>
<td>Egypt</td>
<td>13,626</td>
<td>2.2</td>
</tr>
<tr>
<td>Lagos</td>
<td>Nigeria</td>
<td>7,281</td>
<td>5.7</td>
</tr>
<tr>
<td>Kinshasa</td>
<td>DR Congo</td>
<td>6,140</td>
<td>4.2</td>
</tr>
<tr>
<td>Abidjan</td>
<td>Côte d'Ivoire</td>
<td>3,028</td>
<td>3.2</td>
</tr>
<tr>
<td>Luanda</td>
<td>Angola</td>
<td>2,591</td>
<td>5.1</td>
</tr>
<tr>
<td>Addis Ababa</td>
<td>Ethiopia</td>
<td>2,377</td>
<td>2.1</td>
</tr>
<tr>
<td>Nairobi</td>
<td>Kenya</td>
<td>2,214</td>
<td>3.8</td>
</tr>
<tr>
<td>Accra</td>
<td>Ghana</td>
<td>1,668</td>
<td>2.1</td>
</tr>
<tr>
<td>Harare</td>
<td>Zimbabwe</td>
<td>1,379</td>
<td>0.6</td>
</tr>
<tr>
<td>Kampala</td>
<td>Uganda</td>
<td>1,097</td>
<td>3.8</td>
</tr>
<tr>
<td>Ouagadougou</td>
<td>Burkina Faso</td>
<td>921</td>
<td>7.3</td>
</tr>
</tbody>
</table>

Source: Adapted from UNDESA/PD, (2012; 2014)

Figure 2.1 Distribution and density of population in urban centres in Africa
Source: Pravettoni, (2011)
2.3.3 Causes of urbanisation

Three factors remain dominant in the debate on the causes of urbanisation: natural population growth, rural-urban migration, and reclassification of rural settlements as urban (McGranahan et al., 2009; Sporrek, 1985). These factors are however not mutually exclusive. For instance, the reclassification of rural settlements as urban, which involves annexation of adjoining rural areas by cities, is largely determined by natural population growth and rural-urban migration (McGranahan et al., 2009; Redman & Jones, 2005). Thus, the primary causes of urbanisation can be seen as natural population growth and rural-urban migration, and these are examined below.

2.3.3.1 Natural population growth

Urbanisation is mainly driven by natural population growth – birth rate exceeds death rate – which is often described as a socially and culturally conditioned factor (Sporrek, 1985; Watson, 2009). The UNDESA/PD (2012) estimates that natural increases account for about 60% of urban population growth in many countries. The importance of natural population growth in driving urbanisation is an outcome of a high fertility rate and an increasing life expectancy. According to the UNDESA/PD (2012), the fertility rate in many developing countries is about 5 children per woman, which is about double the rate in more developed countries. The youthful nature of the population, and socio-cultural conditions, such as the perception of children as security in old age in these countries, are commonly identified as factors influencing the high fertility rate and the resultant urban population growth (Boadi et al., 2005). Also, given recent advances in healthcare, disease control, technology and innovation and food production and supply, life expectancy and infant survival rates have considerably improved, contributing to natural population growth (Fox, 2012; McGranahan et al., 2009; Redman & Jones, 2005). For example, between 2000 and 2010, life expectancy at birth increased from about 52 years to 55 years, with a corresponding decline in the death rate from 14 to 12 per 1000 people in many African countries (UNDESA/PD, 2013). The significant role of natural population growth in the urbanisation process is underscored by Barke and O’Hare (1986), who observe that while the urban birth rate exceeded the rural rate in many cases in developing countries, the urban death rate is lower than the rural death rate. Alternatively, natural population growth in rural Africa often results in difficult conditions such as increased population pressure on land, land
tenure uncertainty, poor land use and environmental degradation, thus creating a pool of potential rural-urban migrants (Boadi et al., 2005; Cobbinah et al., 2015a).

2.3.3.2 Rural-urban migration

Recent studies increasingly recognise the complex role of rural-urban migration in the urbanisation process (Castells, 1974; Kojima, 1996; Nsiah-Gyabaah, 2004; Redman & Jones, 2005; McGranahan et al., 2009). According to Bloom et al. (2008), rural-urban migration is on the increase globally, and accounts for 40-50% of the total urban population in many countries. The increase in rural-urban migration is caused by a variety of pull and push factors. The pull factors include the perception of better life and economic opportunities in cities, and access to basic social services in urban areas. Another pull factor relates to the uneven spatial development of rural and urban areas. This is underscored by the report by many studies that development trajectories of many developing countries are skewed towards urban growth, with limited consideration of rural areas (Njoh, 2003; Boadi et al., 2005; Owusu, 2005; Fox, 2012). Regrettably, such urban biased development programmes tend to attract rural residents to the urban areas in search of a better life, contributing to rapid urbanisation (Bloom et al., 2008). On the other hand, some researchers argue that many developing countries are urbanising prematurely due to push factors, including unprofitable agriculture, limited livelihood options, and often poor conditions of infrastructure and basic services in the rural areas (Boadi et al., 2005; Redman & Jones, 2005; Rosado, 2008; Misilu et al., 2010; Turok & McGranahan, 2013). For example, Boadi et al. (2005) found that unprofitable agriculture due to its small scale-nature, unstable world market price for agricultural produce, poor soil fertility, limited government investment and inadequate access to fertiliser contributed to migration of rural farmers to urban areas in many African countries including Ghana, Gambia and Tanzania.

In addition to the above discussed causes of rural-urban migration, some studies indicate that the influence of the socio-political circumstances of certain regions, particularly Africa, on their rural-urban migration patterns, and for that matter urbanisation processes, cannot be overemphasised (Stren & Halfani, 2001; Clapham 2006; Iliffe, 2007). According to this view, the prevalence of political and ecological crises such as drought, civil wars and insecurity coupled with unhelpful socio-cultural
practices such as female genital mutilation (FGM) have considerably contributed to rural-urban migration. These authors indicate that civil strife and political instability in Africa increase internal displacements of population and the number of refugees in cities (e.g., Clapham, 2006; Iliffe, 2007; Stren & Halfani, 2001). A case in point is Sierra Leone, where the population of Freetown increased over 217% during the country's civil war between 1991 and 2001 (Africa South of the Sahara, 2002). Another example is the Horn of Africa (Somalia), where the 1984 drought disaster made about two-thirds of the population temporary refugees in cities (Hjort af Ornas, 1990). Unfortunately, the urban areas, especially in developing countries, lack the capacity to manage the rapid influx of migrants, and to provide better living conditions and livelihood options for them. Ultimately, what often results from such cases is rapid and over urbanisation, and its associated unsustainable land development and increased urban poverty (Misilu et al., 2010; Rosado, 2008).

Thus, although urbanisation has two main causes – natural population growth and rural-urban migration – these are underlined by diverse factors that interplay to relocate population to urban centres. Nevertheless, the rapid urbanisation of developing countries, particularly in Africa, can be considered as a product of inappropriate and uncontrolled socio-economic and environmental changes and exigencies in both the urban and rural areas. This highlights the need to better understand the consequential problems, like environmental resources degradation and societal change among others that may accompany the process.

2.4 Urban dynamics and inland water systems

The dynamics of the urbanscape is increasingly changing worldwide (MEA, 2005; UNEP, 2007; 2012; Adarkwa, 2012; UNDESA/PD, 2012). Urban areas are undergoing significant physical, social, economic and environmental changes. While some of these changes drive the urban growth process, the urban growth process also fuels their intensification in the urban landscape (Cobbinah et al., 2015a; 2015b). These changes tend to characterise urban areas, constitute the complex and interrelated forces that drive changes in urban environmental elements, particularly inland waters. The following subsections discuss the pertinent urban changes, as well as their interactions with inland water systems in urban areas.
2.4.1 Urban land use/cover change

Land use/cover change (LUCC) resulting from growth of built-up areas either through outward expansion, inward compacting or upward high rises is one of the most obvious changes that have characterised urban areas in recent times (Angel et al., 2005; Yang, 2006; Seto, Güneralpa & Hutyrac, 2012). LUCC is described as alterations of the Earth’s land surface attributes, and is one of the most sensitive indicators of the interactions between human activities and the natural environment (Lambin et al., 2001; Pauleit et al., 2005; Zhou et al., 2008). Specifically, land cover change connotes the alteration of the biophysical attributes of the Earth’s surface, while land use change refers to the modification of the human purpose for which the land is utilised (Turner et al., 1990; Lambin et al., 2001). These land transformations take the form of conversion of large amounts of non-urban land, usually agricultural and vegetative land, to built-up or urban land-use (Yin, Stewart, Bullard & MacLachlan, 2005; Xiao et al., 2006). Consequently, LUCC is manifested by an increase in urban land use, for residential, commercial and industrial purposes among others, and a decline in rural land use, such as for agriculture and forestry. For example, Erener et al. (2012) report that between 2006 and 2009, 136% LUCC was accompanied by a 29% loss of vegetation cover in the Göcek Coastal Zone of Turkey.

Recent studies indicate that the pace, magnitude and extent of urban LUCC through uncontrolled outward spatial expansion, technically termed urban sprawl, has been exceptional, especially in developing countries (Lambin et al., 2001; Angel et al., 2005; Seto et al., 2012). According to Angel et al. (2005), the built-up areas of nearly all urban areas around the world are expanding, on average, twice as fast as their populations. Consequently, it has been predicted that the global urban built-up area, which was 400,000 km² in 2000, will triple over the next three decades (Seto et al., 2012). This will be particularly pervasive in developing countries, where estimates indicate that urban extents will increase from the 2000 figure of 200,000 km² to 600,000 km² in 2030, with every new resident converting, on average, 160 m² non-urban to urban land (Angel et al., 2005; Seto et al., 2012). The urban land use/cover change is influenced by diverse and dynamic human and natural forces that interact at different levels to produce complex patterns (Braimoh & Onishi, 2007). The factors include geographical (e.g., natural beauty), biophysical, demographic (e.g., population...
growth) and socio-economic factors (e.g., industrialisation, automobile development, and infrastructure), as well as institutional or governmental policies that govern land use and spatial interrelations (Xiao et al., 2006; Serra, Pons & Saurí, 2008; Zhou et al., 2008; Seto et al., 2012).

While urban land use/cover change occurs to meet the rising demand for urban land, it eventually fragments the landscapes and threatens ecosystem elements and processes (Lambin et al., 2001; Braimoh & Onishi, 2007). Studies show that the replacement of fertile arable lands with pavements and buildings (impervious surfaces) affects the hydrological cycle of cities and their peripheries (Hardoy & Satterthwaite, 1991; Lambin et al., 2001; Nsiah-Gyabaah, 2004; Pauchard et al., 2006). The development of urban land enlarges impervious land surfaces, which decreases infiltration and increases surface runoffs with associated increased pollution loads, sedimentation and eutrophication, as well as disappearance of inland waters (Braimoh & Onishi, 2007; Shi et al., 2007). In addition, Hall, Leavitt, Quinlan, Dixit and Smol (1999) assert that the conversion of water catchments to intensive and irrigated urban farming causes degradation and loss of inland waters, with accompanying hazards such as flooding (Serra et al., 2008). Thus, as a terrestrial change indicator, LUCC has significant adverse environmental and socio-economic effects.

Therefore, it can be said that urban land use/cover change is a process that is characterised by a sharp increase in urban land use and a decrease in non-urban land uses. It however poses a threat to natural environmental resources, such as inland waters in urban areas, especially in developing countries, where it is very rapid but unregulated. Given that inland water systems are also part of the land cover, their modification poses environmental problems, yet an understanding of the extent of changes in this aquatic land cover, as well as linkages with general urban land use/cover changes remains unclear.

2.4.2 Urban economic dynamics

Urban areas are often touted as engines of growth, and as such are characterised by economic transformations such as industrialisation and commercialisation. Given the high agglomeration of diverse people, urban areas serve as centres for integration of entrepreneurial skills, professional expertise, financial know-how and specialised
research that spur economic development through low production costs and high returns (Njoh, 2003; Kessides, 2007; Turok & McGranahan, 2013). Urban areas are noted for the clustering of productive activities in industry and services that translate into high income levels and improved standards of living, in addition to sustained economic growth and development. For example, in Ghana, it is estimated that the proportion of the urban population living below the absolute poverty line of GH₵370.00 per annum is 10.8% while that of the rural areas is 39.2% (GSS, 2007), indicating that the urban population in general earn relatively higher incomes than their rural counterparts.

However, recent structural economic transformations in urban areas around the world, especially in developing countries, point to the growth of an informal economy. Consequently, their urban economies have become dualistic in nature, comprising formal and informal sectors, with the latter being the most dominant (Barke & O'Hare, 1986; Afrane & Ahiable, 2011). The informal economy is described as all income-earning activities by workers and economic units that are in law or in practice not covered and/or insufficiently covered by formal arrangements or state regulatory frameworks (Hart, 1973; Portes, Castells & Benton 1989; Feige, 1990; International Labour Organisation [ILO], 2009). Chen (2005) however, explains that different segments or parts of the informal economy are overregulated, de-regulated or under-regulated. Regardless of the difference in interpretation, it is generally agreed that informal economic activities are important and growing elements of contemporary urban economies in both developed and developing economies, and play diverse roles such as employment creation and revenue generation (Evans, Syrett, & Williams, 2006; Amoateng, Cobbinah & Ofori-Kumah, 2014). The International Labour Office (2009) for example, indicates that the informal economy accounts for over 60% and 41% of urban employment and Gross Domestic Product (GDP) respectively in sub-Saharan Africa.

The informal economic activities manifest in different guises, forms and at unexpected places (Chen, 2005). They comprise primary, secondary and tertiary activities and services such as petty trading, construction, crafts, textiles making, artisans, transport and agriculture among others (Hart, 1973; Roberts, 1994; Evans et al., 2006). The
emergence and growth of these informal economic activities is seen as economic adjustments orchestrated by the restructuring of the world economy that increasingly promotes these self-contained activities into mainstream economic and social spaces (Portes et al., 1989; Chen, 2005; Amoateng et al., 2014). However, in developing countries, pervasive poverty conditions such as unemployment and low income levels compel urban dwellers to engage in these informal activities as alternative livelihood and survival strategies (Chen, 2005; Songsore, 2009). In particular, agriculture, predominantly rural economic activity, has become a choice and not an option in many urban areas in these countries, as a response to a looming economic crisis and structural unemployment in the midst of rapid urbanisation (Zezza & Tasciotti, 2010; Obuobie et al., 2006; Mougeot, 2005).

Urban agriculture is defined as an industry located within (intraurban) or on the fringe (peri-urban) of a town, city or metropolis, which grows, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area (Mougeot, 2000; Mougeot, 2005). Thus, this subsector of the informal economy covers broad spectrum of production, processing and trading of farm products. The urban farmers mostly cultivate or raise food products (e.g., grain, root, vegetable and fruit crops, and livestock of all shapes and sizes) although a small proportion is involved in production of ornamental and agroindustrial plants, as well as aromatic and medicinal herbs (Rakodi, 1997; Mougeot, 2000; 2005; Aubry et al., 2012). Urban agriculture has undergone rapid expansion in recent times, with estimates suggesting that 200 million people worldwide, as well as about 40% and 50% of urban population in Africa and Latin America respectively, are engaged in urban farming (Mougeot, 2005; ILO, 2009). This rapid growth of urban agriculture is driven by a complex web of factors including urban poverty, unemployment and food insecurity among others (Mougeot, 2005; Obuobie et al., 2006; Zezza & Tasciotti, 2010; Aubry et al., 2012).

In recent urban planning literature, among the issues associated with the informal economy and its key subsector, urban farming, are the widespread environmental problems associated with their unregulated growth spatially (Obuobie et al., 2006;
According to Pahl (1988), informal economic activities require not only time, means of production and specialised skills, but also location where the production can take place. However, the space needs of the informal economy are often not considered in urban land use planning processes, especially in developing countries (Obuobie et al., 2006; Aubry et al., 2012). As a result, the informal economic activities, particularly urban farming, locate in rivers or streams courses, wetlands, lowlands or valleys and waterlogged areas that are zoned as undesirable for physical development on land use plans (Chen, 2005; Prasad et al., 2009; Islam et al, 2010). The occupation of ecologically sensitive zones depletes the stock of inland water systems through the various processes associated with these activities (Drescher, 1996; Mougeot, 2000; Chen, 2005). Meanwhile, intervening in this requires better understanding of how the informal activities degrade the inland waters, as well as integration of the informal economy and inland waters into urban planning practices.

2.4.3 Urban social change

Urban social change is the transformation in the social order in the era of modernisation, and pertains to changes in the nature of social institutions, behaviours, norms, lifestyles and relations in society (Leat, 2005). It entails fragmentation and dissolution of older forms of social solidarity through modernisation processes such as urbanisation or urban growth, as well as adaptation to improvement in a society’s technological environment (Pivo, 1996; Leat, 2005; Greenwood & Guner, 2008; Sharma, Ranga & Sharma, 2010). Through the agglomeration of people of diverse social and cultural origins, the urban areas assume socio-political configurations that bring profound changes – both positive and negative – in virtually every phase of urban social life (Wirth, 1938; Pivo, 1996). Often there is a retreat of outmoded and barbaric socio-cultural practices from the urban centres, as residents become aware of their environment through the process of modernisation and urbanisation (Cobbinah et al., 2015a). For example, while cultural practices such as female genital mutilation, wife swapping and witchcraft camps persist in rural areas of many African countries such as Ghana and Namibia, such practices are practically absent in urban areas.

Wirth (1938) in his article “Urbanism as a Way of Life,” points out that the modification of human behaviours, associations and values by the urban way of life
imposes challenges on the management and protection of environmental resources including inland waters. Communal ownership, usage and management of water bodies that evolve as part of social life is altered in urban areas due to modernity and societal change (Hardin, 1968; Sharma et al., 2010). Often there is a change of governance of these public commons from community management to state management, while the urban residents become less dependent on the inland waters for direct use. Meanwhile, government agencies are unable to maintain the water resources due to a complex governance structure and overlapping jurisdictions, while the urbanites dissociate themselves from the management of these communal resources and subject inland waters to undue exploitation (D’Souza and Nagendra, 2010; Islam et al., 2010).

Furthermore, unlike rural areas that have a socially compact society, where the mere knowledge of the importance of water bodies promotes their sustenance, there is a lack of community perception, irrational use, and widespread social negligence of conservation of these valuable resources in urban areas (Wirth, 1938; Beals, 1951; D’Souza & Nagendra, 2010). According to many researchers (e.g., Wirth, 1938; Botchie, Akabzaa, Gyasi & Sarpong, 2007; Greenwood & Guner, 2008) the social changes weaken and downgrade traditional approaches and local knowledge systems that are used to protect inland waters, especially as behaviours/activities that hitherto seemed abnormal eventually become conventional. For example, in Ghana water bodies and watersheds are traditionally and culturally perceived as "spiritual beings" and sacred groves respectively, and as such urban land uses have been forbidden, based on traditional norms and values and to forestall the wrath of the river gods. Although these traditional belief systems were effective in protecting and conserving the water areas for a long period (and still do in rural areas), urbanisation has resulted in a downgrading of traditional values, with urban dwellers regarding the aquatic areas as waste lands that are not worth protecting (Opoku-Agyemang, 2005; Botchie et al., 2007; Danquah et al., 2011; Mensah, 2014).

Thus, social change results in a cumulative accentuation of new and/or distinctive modes of life that may enhance urban quality of life or adversely affect inland water resources in urban centres. These changes break down communal approaches to
protecting water resources, with individuals pursing diverging interests like erecting structures in inland water areas. Although the social changes and associated modernisation create specialised institutions that take over communal management of the resources, these fail to perform effectively, in terms of controlling water degradation by changing public attitudes toward protection of the water resources.

2.4.4 Urban climate change

Globally, scientific evidence indicates that climate change is occurring, with the last decade of the 20th century and the beginning of the 21st century being described as the warmest period on record (IPCC, 2007; 2015; National Oceanic and Atmospheric Association of National Weather Service [NOAA/NWS], 2007; Cobbinah & Anane, 2015). Climate change is defined in the United Nations Framework Convention on Climate Change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Alternatively, climate change reflects any long-term significant shift in expected weather conditions of a region (NOAA/NWS, 2007). Climate change is identified by means of statistical tests that reveal changes in the mean and/or the variability of weather elements such as temperature and precipitation that persist for an extended period, typically decades or longer (Hegerl, 2007).

Accordingly, climate change is commonly evidenced by significant changes in temperature and precipitation, as well as the frequency of extreme weather events like floods, drought and cyclonic storms (IPCC, 2007; 2013; Cobbinah & Anane, 2015). Recent data from IPCC (2013), indicates that the global average temperature has increased over 0.72 ºC from 1951 to 2012, and this has been observed over the ocean, on the land and in the lower atmosphere (Smith & Reynolds, 2005; IPCC, 2007; 2013). In addition, the average water vapour content at both the Earth's surface and the atmosphere is increasing at 1-2% per decade, with attendant greater amounts and intensity of rainfall experienced in many regions around the world (Allan & Soden, 2008; Sherwood et al., 2010). The changing climatic conditions are largely attributable to anthropogenic factors such as fossil fuels usage, agricultural practices like fertiliser and manure application, land use practices including deforestation and urban
development, and industrialisation activities that increase greenhouse gases emissions e.g., carbon dioxide (CO$_2$), methane (CH$_4$) and ozone (O$_3$) (Allan & Soden, 2008; IPCC, 2007; 2013; Meinshausen et al., 2009).

Recent studies identify inland waters among the natural systems that are vulnerable to climate change, especially in urban areas where the aquatic habitats are already under severe pressure from other urban changes (MEA, 2005; Carpenter et al., 2011; IPCC, 2007; 2013). According to Carpenter et al. (2011), a changing climate alters all elements of the water cycle, including precipitation, evapotranspiration, soil moisture, groundwater recharge, and runoff. This affects inland water systems and their ecosystem services such as water supply, recreation, fisheries, and transportation. The aquatic impacts of climate change largely occur through changing weather patterns such as increased temperatures and greater variability of precipitation. For example, several researchers have reported that the uneven and erratic rainfall distribution occurring in the transitional zones across Africa has instigated chronic water stress in the region, while the extreme precipitation that has characterised North America has resulted in significant increases in annual stream flows (MEA, 2005; Vörösmarty, Douglas, Green & Revenga, 2005). Also, present and future climate models indicate that the warming temperature degrades aquatic habitat quality by reducing dissolved oxygen and increasing pollutant concentration in inland waters, which affects the growth rates, reproduction, and distribution of organisms and species; decreases the duration of the ice season and melts glaciers that in turn alter the mixing regimes, seasonality, magnitude and sources of river flows (IPCC, 2002; Carpenter et al., 2011).

Thus, climate change affects the chemical and biological processes, as well as the hydrology of inland waters, with the potential to instigate flora, fauna and spatial changes in these aquatic systems. However, the extent of change remains uncertain due to the inadequacy of existing data and knowledge (MEA, 2005). Consequently, it is still arguable whether or not climate change has already affected and/or is affecting inland waters, especially across climatic and geographic zones.

To sum up, it is clear that the urban environment is characterised by dynamics that affect several facets of inland water systems. Nevertheless, previous research has often failed to systematically and holistically identify how these dynamics drive changes in
the spatial extent of rivers and floodplains in the urban environment. As a result, as mentioned before, the relative influences of these processes, and the manifestations that accompany urbanisation of settlements, on the extent of inland waters within them, are not adequately examined and understood, despite being imperative in managing/protecting these aquatic systems. It is therefore necessary to critically uncover and explain how these urban dynamics drive spatial changes in inland water systems, as well as to ascertain their importance in the change process, which may have an effect on flooding in these areas.

2.5 Flooding in urban areas

Flooding, a natural event, has become a frequent and an increasing socio-environmental disaster in urban areas in response to changes in climatic and edaphic factors, channel characteristics of rivers and anthropogenic factors (Dhar & Nandargi, 2003; Prasad et al., 2009; Shi et al., 2007; Anil et al., 2010; Egbinola, Olaniran, & Amanambu, 2015). Flooding is generally defined as excess water on land that is habitually dry. It occurs when there is high flow or overflow of water beyond its defined channel or course to cover lands that are not meant for the water, and may be due to heavy rainfall events, sea level rise, storm surges, coastal degradation, glacial melt, snow melt and reduced ground infiltration (Leopold, Wolman & Miller, 1964; Cunningham, 2002; Jha et al., 2011). As a result, floods are grouped into different types as riverine flood, urban flood, flash flood and coastal flood (Cunningham, 2002; Satterthwaite, 2007; Jha et al., 2011). Although there are no clear distinctions between the types of floods, these categorisations are useful in considering not only the range of flood risks but also appropriate coping and adaptation strategies. The identifiable characteristics of the flood types are summarised in Table 2.3.
### Table 2.3 Types of floods and their characteristics

<table>
<thead>
<tr>
<th>Flood type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverine (Fluvial) flood</td>
<td>This occurs when rivers overflow their banks to cover built-up or bare lands following heavy rainfall, snow melt or ice jams. Floodwater accumulates slowly and remains for long periods (days or weeks) based on local topography, soil conditions and vegetation.</td>
</tr>
<tr>
<td>Urban flood</td>
<td>It occurs when water inundates a built-up area due to runoff exceeding the capacity of drainage systems after heavy rainfall, or when there is a lack of an adequate and effective drainage or sewage system to drain runoff generated by high intensity rainfall. Floodwater rises slowly, and has shallow depth and short duration.</td>
</tr>
<tr>
<td>Flash flood</td>
<td>This flood occurs when there is a sudden rapid and extreme flow of water (runoff) into built-up areas after a causative event (intense rainfall, dam failure, ice jam) due to inability of the ground (e.g., impervious or bare surfaces) to absorb it. Floodwater has high velocity, large debris and short duration with relatively high peak discharge and is very damaging.</td>
</tr>
<tr>
<td>Coastal flood</td>
<td>This is when extreme tidal conditions cause water to surge onshore to inundate low-lying land and/or built environment on the coast. Its severity is determined by strength, size, speed, and direction of the storm surge, as well as onshore and offshore topography, but it usually lasts for a short period of time (4-8 hours) after spreading over a large area.</td>
</tr>
</tbody>
</table>

Source: Adapted from Cunningham, (2002); Satterthwaite, (2007); Jha et al., (2011)

Flooding is generally seen as a disaster that disrupts the prosperity, safety and amenity of people. With increasing incidences and magnitude of inundations, flooding causes immense loss of lives and livelihoods, damage to property and infrastructure, spread of diseases and insecurity among others, with greater impact than many other similar disasters, especially in developing countries (UN-Water, 2011; Jha et al., 2011). Consequently, flooding remains a key development challenge, with many countries plagued by incidences of different devastation levels (Satterthwaite, 2007; Vos, Rodriguez, Below & Guha-Sapir, 2009). For example, in 1998, China suffered severe urban flooding that affected 230 million people, displaced 20 million, killed about 3,500 people and destroyed seven million homes at an estimated total economic cost of US$ 32 billion (Ramsar Convention Secretariat, 2007). Similarly, the West African Sub-region recorded over 52,000 cholera cases after a flood event, while floods in
Maputo the capital of Mozambique in 2000 rendered 500,000 people jobless (Naidoo & Patric, 2002). Exposure to, as well as incidences and impacts of floods are intensified by the increasing expansion of human settlements into watersheds and a lack of drainage systems, particularly in cities of developing countries (Anil et al., 2010; Egbinola et al., 2015).

Traditional flood control methods have entailed structural or engineering measures often limited to watershed level (Ikeda et al., 2005; Petroski, 2006; Kounsana & Takahashi, 2012). Some common structural approaches include storm drains, sandbags, embankments or levées, floodways or bypass channels, dams and regulating reservoirs among others. These structural approaches are aimed at eliminating floods caused by natural factors (e.g., rainfall), as well as minimising the effects when they occur (Ikeda et al., 2005). However, the measures do not only result in changes in flow regimes and fragmentation of surface water networks, but also in increased flood occurrences, particularly downstream (Griggs & Paris, 1982). A case in point is disastrous flooding in Santa Cruz in 1982 despite prior huge investments in control methods such as constructing lakes and levées, and dredging channels (Griggs & Paris, 1982). This suggests that floods can never be eliminated completely, and could be further compounded by poor maintenance of the physical interventions.

Nevertheless, many researchers (e.g., Dutta, Herath & Wijesekera, 2003; Jha et al., 2011) argue that vulnerability to flooding can be alleviated by an integrated management approach. Consequently, there is a shift to integrated flood management with the object of flood avoidance, flood tolerance and flood resilience (Anil et al., 2010). Integrated flood management is holistic and combines structural and non-structural approaches to reduce susceptibility to flood damage and encourage living with floods, rather than focusing on futile efforts to eliminate them (Kundzewicz & Takeuchi, 1999). In practice, non-structural approaches such as land use planning and zoning, natural inland systems conservation, institutional and policy frameworks, flood proof structures, forecasting and early warning systems and flood insurance, as well as structural approaches are harmonised in an iterative manner to avoid floods, and to reduce impacts of, and recovery time from floods (Ikeda et al., 2005; Douglas et al., 2008; Takeuchi, 2009; Jha et al., 2011). Thus, integrated flood management reflects a
prudent and proactive approach to mitigate and respond to floods by considering the causes, types, characteristics of victims and impact areas of the floods.

Some literature argue that conservation of inland water systems that serve as natural drainage systems remains a key approach for achieving the purpose of integrated flood management (Shi, Ge, Yuan & Guo, 2005; Anil et al., 2010). Dutta et al. (2003) and Shi et al. (2005) explain that relying on inland waters for flood mitigation and control encourages people to “live with the rivers” and “give the rivers the room they need”. The potential of inland water systems for flood mitigation is contingent upon spatial configuration, conditions of floodplains and water absorption capabilities of soils of inland waters, which could be maintained through risk sensitive land use planning and zoning. However, rapid urbanisation, unregulated land cover changes and ineffective urban management, particularly in developing countries, impair the flood control potential of the inland water systems through intrusion of incompatible developments beyond acceptable limits of the aquatic systems (Petak & Atkisson, 1982; Afeku, 2005). Unfortunately, the extent of the influence of loss of inland water systems on recurrent floods has not been systematically determined, and remains inadequately known or understood. This study therefore seeks to ascertain how spatial changes in inland water systems affect flooding, and suggest ways for mitigating the phenomena.

2.6 Land use/urban planning practices and inland water systems management

Land use planning emerged in the 19th century as a conscious activity and profession for devising strategies to regulate and manage human activities (e.g., built-up areas development, industrialisation etc.) and their impacts on the natural environment (Rydin, 1993; Wegener, Button & Nijkamp, 2007). Land use planning is generally described as a systematic process for arranging and allocating land resources to satisfy the spatial demands of human activities, based on the principles of sustainable development (that is, economic development, social equity and environmental protection) (FAO, 1993; Tao, Tan & He, 2007). This notion of land use planning was given much practical relevance by the 1992 Earth Summit in Rio de Janeiro, which underscored the need for ecological and environmental goals and requirements to be
considered throughout the spatial planning process and at all spatial levels (that is, strategic to action levels) (Kates, Parris & Leiserowitz, 2005). As a result, modern land use planning practices primarily aim at promoting human development processes/activities that integrate protection of, and/or at least do not endanger life-supporting environmental and ecological features like inland water systems (FAO, 1993; Kates et al., 2005; Wegener et al., 2007).

Consequently, land use planning practices have in recent times attempted to consider inland waters, with the object of achieving a balance between inland water systems protection and human development within natural and economic constraints. In many developed countries, spatial planning based approaches such as buffer zones, infiltration surfaces and trenches, permeable pavements, green open spaces, and bio-retention basins have been applied to mitigate the degradation of inland water systems (Randolph, 2004; Perez-Pedini, Limbrunner & Vogel, 2005). Previous literature indicates that these practices, when well integrated into land use planning, are important for sustaining the status of inland water systems by trapping pollutants from surface runoff, stabilising the banks of inland waters, maintaining lower water temperatures, and preventing unwanted urban runoff from reaching receiving waters (control of urban runoff at the source) (Sliva & Williams, 2001; Randolph, 2004; Perez-Pedini et al., 2005). However, the effectiveness and practicality of these water sensitive planning measures rest on local concerns, interests and awareness about utilisation and health of these communal resources (Hardin, 1968; D’Souza & Nagendra, 2011). As a result, public participation and consensus building are recognised at all phases of the land use planning process, to gain the needed social support and cooperation for achieving water conservation objectives.

Unfortunately, in practice, implementation of land use planning approaches for inland water management has been very challenging, due to the continued pursuit of land use planning and water resources management as separate fields, managed and dominated by different institutions and expertise (Du, 2010). In addition, these separate institutions perform poorly in their distinct sectors — spatial planning or water management — because of internal constraints like low capacity, as well as conflicting regulations and roles. Recent studies indicate that many cities, especially in developing
countries, are faced with urban planning problems that degrade the inland water areas within them. As a consequence, growth of urban areas in these countries outpaces institutionalised urban planning systems and practices, leading to non-contiguous or leapfrogging physical development, as well as the emergence of informal settlements or urban slums in ecologically sensitive water areas (Angel et al., 2005; Cobbinah & Amoako, 2012; Seto et al., 2012). This is compounded by poor urban sanitation management practices, which result in uncontrolled disposal of both solid and liquid waste into aquatic areas and other open environments (Jain, 2007; Khatri & Vairavamoorthy, 2007). Thus, with poor urban planning, inland water systems may be prone to reclamation and conversion to unwarranted uses that have far reaching implications on the integrity of the urban environment. The priority of this research in this regard therefore, is to ascertain the nature and extent of the influence of failures in urban planning and water management practices on inland water systems.

The growth of urban areas presents waste generation and disposal challenges that elude urban planning and management systems to the detriment of inland waters. According to the World Bank (2011), urban growth – demographic, physical and economic – changes the waste stream in terms of quantity, types and management requirements. A recent study by World Bank (2011), indicates that any marginal increase in urban population hastens waste generation in these areas by over 7% per year globally. However, such high waste generation levels are not accompanied by a commensurate expansion and improvement in urban planning and waste management practices, especially in developing countries, resulting in uncontrolled dumping and discharge of both solid and liquid wastes into the environment (Pongrácz & Pohjola, 2004; Jain, 2007; Khatri & Vairavamoorthy, 2007). For example, the World Bank (2011) estimated that 30%-60% of urban solid waste in developing countries is uncollected and ends up being dumped or transported by surface runoff into open areas and inland waters. The outcomes of these practices, which are mainly the product of inadequate urban planning, may include channel sedimentation, clogging and pollution of inland waters.

In recent years, there has been a rapidly growing application of geographic information systems (GIS) and remote sensing to land use planning and inland water systems
management. These technologies offer quick and cost-effective opportunities to undertake large spatial and temporal scale inventory, monitoring and evaluation of LUCC, including inland waters, to inform land-water management policies and practices (Serra et al., 2008; Dewan & Yamaguchi, 2009; Prasad et al., 2009). Thus, GIS and RS have become viable alternatives to conventional survey and ground-based urban mapping methods, and have been applied in urban land cover change studies, urban planning, climate change modelling and water resources monitoring among others (Jensen, 1996; Serra et al., 2008; Dewan & Yamaguchi, 2009). Application of these technologies in urban inland water systems management, however, is still very limited because of the unavailability and high cost of hyper spectral and spatial resolution data required for such purposes. Nevertheless, results of recent studies suggest that although the available low to medium resolution satellite data may have deficiencies, when complemented with ground truth information (spatial survey), they provide significant evidence of spatial and temporal variations in urban land covers including inland waters, that can inform urban planning decisions (Dewan & Yamaguchi, 2009; Prasad et al., 2009; Du et al., 2010; Islam et al., 2010).

Unfortunately, very few studies in Africa, with none in Ghana, have applied these technologies to ascertain changes in urban inland water systems (Braimoh & Onishi, 2007), making this research timely and significant in the context.

2.7 Towards a conceptual framework for this research

A review of the literature revealed that a key question that arises in efforts to analyse environmental change is how to frame such research. However, building on the foundation of empirical research, a number of researchers have created frameworks for environmental management, planning and policy. As a result, frameworks for analysing changes in environmental elements continue to evolve. For example, Kuznets (1973) developed the Environmental Kuznets Curve (EKC) to explain the systematic relationship between income and change in environmental quality. McGranahan, Songsore and Kjellén (1996) and McGranahan, Jacobi, Songsore, Surjadi and Kjellén, (2001) proposed the Urban Environmental Transition Model (UETM) for an integrated understanding of urban environmental problems and the balance between human needs and a healthy environment and sustainability concerns.
Long and Arnold (1995) provided a Life Cycle Model (LCM) for studying sequential stages of environmental change right from the source. However, while models such as the aforementioned may be useful for ascertaining the direction and nature of environmental change, they unsuitable not for accurate portrayal of how and why environmental change processes actually occur. This is because contemporary urban environmental change is a complex, interactive process without beginning or end, given the numerous and diverse changes that are occurring in urban centres.

Consequently, the European Environment Agency (EEA) developed a broad framework – the Drivers, Pressures, State, Impacts and Response (DPSIR) framework – that provides a useful way for identifying and evaluating the complex and multidimensional interactions between factors in society and environmental degradation (EEA, 1999; 2001). The roots of the DPSIR framework can be traced to the Stress–Response framework originally introduced in the late 1970s by Statistics Canada (Rapport & Friend, 1979), and further developed into the Pressure–State–Response (PSR) framework in the early 1990s by the Organisation for Economic Development and Co-operation (OECD) (OCED, 1991; 1993). In the late 1990s, EEA enhanced and modified the PSR into the present DPSIR model, which introduced more steps (see Figure 2.2), for robust and systematic analysis of environmental problems (EEA, 1999). Ultimately, the DPSIR framework was developed based on a concept of causality, and embraces linkages in the processes and indicators of environmental change (OECD 1993; EEA, 1999; Mangi, Roberts & Rodwell, 2007).

The primary objective of the DPSIR framework has been to highlight the dynamic characteristics of environmental systems and socio-economic changes and to clarify multi-sectoral relationships (EEA, 2001; Elliott, 2002). The framework focuses on Drivers, Pressures, State, Impacts and Responses, and these constitute the five distinct components/steps of the framework. The Drivers comprise the natural processes and anthropogenic activities that cause pressures. Pressures represent the ways the direct stresses deriving from the drivers are actually expressed, and the specific ways the environment and its elements are perturbed. The State reflects the physical, chemical and biological conditions of the environment and natural systems that may change or degrade due to pressures. The Impact is the measure of the effects due to changes/degradation in the state of the environment or natural systems. The Response
comprises actions such as regulations and education oriented to intervene in the whole environmental change/degradation process (OCED, 1991; 1993; EEA, 1999; 2001; Pirrone et al., 2005; Borja et al., 2006; Mangi et al., 2007). Thus, the logic of the DPSIR framework is that driving forces exert pressure on the environment, which causes changes in the state of the environment, leading to impacts on human and ecosystems health that may elicit a societal response that targets the driving forces, pressures, state or impacts (EEA, 1999; 2001).

Figure 2.2 The Driver, Pressures, State, Impacts, Responses framework
Source: Adapted from EEA, (1999; 2001)

According to Niemeijer and de Groot (2006), the DPSIR framework has made an important contribution by emphasising the importance of causality. A key strength of the DPSIR framework is its ability to capture, in a simple manner, the complexities of environmental change into variables that stress the cause and effect relationships between factors that exert pressure on the environment, the condition of the environment, and society’s response to the condition (Mangi et al., 2007; Svarstad, Petersen, Rothman, Siepel & Wätzold, 2008). The framework does not only provide an understanding of the elements of environmental change, but is also useful in communicating such knowledge between researchers from diverse disciplines, as well as between researchers on the one hand and policy makers and stakeholders on the other (Svarstad et al., 2008). The framework has however been criticised for its
inability to provide a direct proportional relationship between causes and effects, take into account the dynamics of the system it models, as well as its reliance on linear unidirectional causal chains that could hinder good understanding of environmental indicators (Mangi et al., 2007; Niemeijer & de Groot, 2006; Svarstad et al., 2008).

Today, DPSIR has become the most popular causal chain framework for structuring integrated research programmes and assessments regarding issues of human interferences in, and efforts to manage the environment (Elliott, 2002; Bürgi, Hersperger & Schneeberger, 2004). It is widely accepted and increasingly used as an interdisciplinary conceptual framework for deriving and communicating knowledge on the state and trends, causal factors and effects of socio-environmental issues (e.g., degradation of inland waters and flooding). Some applications of the DPSIR framework in interdisciplinary research have been undertaken recently, with improved understanding of the interdependencies and interactions of the multiple environmental change variables (Turner et al., 1999; Casazza, Silvestri, Spada & Melley, 2002; Elliott, 2002; Bowen & Riley, 2003; Pirrone et al., 2005; Borja, 2006; Mangi et al., 2007; Henrique et al., 2015). As a result, the DPSIR framework is recognised as a meta-conceptual model that can be used to identify key variables/components of environmental change without limiting the analysis to any particular theory (Bürgi et al., 2004). The DPSIR framework is therefore appropriate for this research which is problem oriented, and in practice not restricted to a specific conceptual framework or theory.

As discussed in Chapter 1, the conceptual basis and aim of this research is to explain and understand the changing spatial extent of rivers and floodplains and its implications for flooding in Kumasi, a rapidly urbanising city in Ghana. This research explores four key issues in relation to rivers and floodplains: changed state/conditions of rivers and floodplains, drivers of the changed state/conditions of rivers and floodplains, consequences/impacts of the state/conditions of rivers and floodplains (flooding) and responses to the rivers and floodplains change processes and impacts. The DPSIR framework is best suited for addressing these issues, which cut across multiple disciplines. The DPSIR framework provides a basis for ascertaining the status of natural systems and cause-effect relationships, as well as highlighting possible ways of intervening in the whole system. Therefore, the DPSIR framework has been used in
this research to explicate the dynamics and complexities of the changing spatial extent of rivers and floodplains, using a combination of spatial, socio-economic and hydro-meteorological analyses.

In applying the DPSIR framework perspective to this research, the rivers and floodplains are treated as the environmental elements, with pressures from an array of drivers that affect their state to cause adverse impacts, amid responses being pursued by the society. In this research, the drivers are conceived as the large-scale urban socio-economic and physical trends such as climate change and LUCC discussed earlier, and these exert pressures on the rivers. The pressures that build up on the rivers and floodplains via the drivers cause observable changes in the dynamics and functions of the rivers and floodplains. As a result, the state of the rivers and floodplains display deteriorated physico-chemical properties and spatial extent expressions among others, with adverse socio-economic impacts.

The impacts, which are the changes in socio-economic and environmental benefits linked to rivers and floodplains, are manifested in reduced values and services of the rivers and floodplains, increased incidence and intensity of flooding, increased prevalence of waterborne and water-related diseases, biodiversity and ecosystem services loss as well as micro-climate alterations. The responses deal with institutional and local level actions undertaken to address changes in the rivers and floodplains, and are primarily driven by changes in the state, as well as impacts. Responses to improve the conditions of the rivers and floodplains comprise structural measures (e.g. construction of storm drains and channelling of streams), formulation of policies and legislation, establishment of institutions and creation of buffer zones; some of which tend to worsen the pressures and state of the rivers and floodplains, as well as the impacts in certain cases. Thus, this research seeks to investigate the changing spatial extent of the rivers and floodplains, and its flood impacts, in order to inform measures for responding to these phenomena.

2.8 Summary

The issues discussed in this chapter have provided a conceptual basis for assessing the loss of urban inland water systems and its potential for instigating flooding in urban
areas. The literature review revealed that although inland water systems remain invaluable elements of the urban environment, they are exposed and/or subjected to diverse forms of degradation, especially in developing countries. These occur simultaneously with the rapid urbanisation that has characterised these countries, particularly in Africa in recent times. Complicating the pressures on the urban inland water systems are processes such as climate change, urban land use expansion, societal change and changing economic systems, which are all related to urbanisation and urban growth. Of critical concern is the impact of these urban dynamics on the inland water systems spatially, and the consequential floods.

Although the literature provides some evidence of spatial changes in inland water systems, there remain gaps in terms of the conceptualisation, methods and contexts. The literature shows that these spatial changes involve a complex web of diverse urban dynamics and processes that are at best vaguely identified by previous research. One area of research that appears underdeveloped is an in-depth investigation of the relative influence and interactions of the factors that account for the spatial deterioration of inland waters. Also, given that the incidence, forms and dynamics of urbanisation and the associated urban changes differ spatially and temporally, it is unclear whether the spatial changes in inland waters observed in the literature are consistent with historical, current and future rates in other contexts. This is a significant knowledge gap, with studies on changes in land cover, and inland waters in particular, being particularly limited in Africa, despite it being a region that is in the midst of an urban transition, with its population and economic activities increasingly becoming urban. Hence the need for further investigations to add new insights into and conceptualise the loss and/or spatial change of inland water systems, as well as to enhance the application or otherwise of existing literature in many contexts.

This research presents an example from Kumasi, Ghana, in order to improve the understanding of loss of inland water systems and its potential to influence flooding. The research approach, as well as data collection and analysis methods used in this research, are elaborated in the next chapter.
Chapter 3 - Methods

3.1 Introduction

A systematic and rigorous research approach is a requisite for conducting quality research (Fossey, Harvey, McDermott & Davidson, 2002). However, with the availability of various approaches to research, researchers are faced with the difficult task of choosing the appropriate methods to address the research questions being raised (Creswell & Plano-Clark, 2007). Pragmatic paradigm and mixed methods approach were chosen to guide and frame this research (Johnson & Onwuegbuzie, 2004; Scott & Briggs, 2009), and these allowed different appropriate research methods to be combined and integrated to provide systematic and in-depth explanation and understanding of the research questions.

A detailed description of the methods used in this research is provided in this chapter. It commences with a discussion of research approaches, to establish a theoretical framework and reasoning behind the methods adopted in this research. This covers an explanation of the purpose of research, pragmatic paradigms, mixed method research approach, and case study research design. This is followed by a discussion of the required data types, as well as the data collection instruments and analysis methods. Other issues discussed include validity and reliability of data, ethical considerations, and the role of the researcher in the research.

3.2 Research theory and purpose

Research traditionally encompasses efforts to gain knowledge and gather information about a phenomenon (Bailey, 1982; Sarantakos, 1998; Somekh et al., 2005). It involves systematic enquiry to produce results for addressing knowledge gaps and generating or validating theory (Bailey, 1982; Amaratunga, Baldry, Sarshar & Newton, 2002). Research aims to explore, explain, predict or evaluate reality; develop and/or test theories; understand phenomena; and offer a basis for criticising a reality or solving problems (Sarantakos, 1998; Somekh et al., 2005). It therefore has long-established traditions, as well as proven relevance in academia and life in general (Amaratunga et al., 2002).
Research may be descriptive, exploratory or explanatory and these constitute the philosophical frameworks that drive a research (Punch, 1998; Sarantakos, 1998). This present research aligns with explanatory research, given that it focuses on explaining and understanding ‘how’ and ‘why’ the spatial extents of rivers and floodplains in urban areas are changing, as well as the implications for flood disasters. In the view of Neuman (2003), explanatory research unravels how or why things are as they are. The explanatory research model or approach moves beyond a mere description to offer explanation of trends and patterns that are observed (Punch, 1988; Neuman, 2003). Thus, this research has been perceived as an organised enquiry to explain and understand socio-environmental phenomena, and/or how an array of social, environmental and physical processes and activities influence the phenomena.

3.3 Understanding research paradigms: A focus on pragmatism

Research paradigms, also termed “worldviews” or “shared understandings of reality” (Rossman & Rallis, 2003), are a set of beliefs, values and techniques common to members of a scientific community that guides them to decide problems to be investigated, as well as how to interpret research findings (Kuhn, 1970; Denzin & Lincoln, 1994). Paradigms explain how to perceive reality, and inform researchers about what is reasonable to inquire into and the methods of inquiry (how to know) (Sarantakos, 1998; Neuman, 2003). May (2001) explains that research paradigms indicate and direct the orientation, aims and nature of research. The paradigm ensures the conduct of quality research by providing the platform for linking the abstract issues to concrete research techniques (Neuman, 2003). Thus, research paradigms constitute the framework of ontological and epistemological assumptions or claims, as well as the methodology (procedure) of research (Denzin & Lincoln, 1994).

There are as many different paradigms of research as there are groups of like-thinking researchers and methodologists (Sarantakos, 1998; May, 2001). Some of the commonest research paradigms are positivism, interpretivism and critical-realism among others. Although the individual research paradigms are underpinned by different theories and research methodologies, Blaikie (1991) argues that they are not mutually exclusive classifications of research approaches, but rather a revelation of tensions and dilemmas associated with strictly adhering to one of the various
methodological traditions to understand and explain a phenomenon. According to Neuman (2003), the availability of several research paradigms is in itself an indication of the non-existence of an absolutely correct singular approach to research. Many authors (e.g., Patton, 1980; Guba & Lincoln, 1989; May, 2001) therefore advocate for a more practical research paradigm that synthesises aspects of the various perspectives, and promotes integration of methods (building of bridges), hence the emergence of the pragmatic paradigm or pragmatism.

Pragmatism or ‘paradigm of choices’ was proposed as a new guiding paradigm for supporting research that combines different methods, and as a way to redirect attention to methodological rather than metaphysical and mechanical concerns in research (Patton, 1990; Johnson & Onwuegbuzie, 2004; Morgan, 2007). Pragmatism adopts a middle-ground stance in the philosophical dogmatisms on how to understand and explain a phenomenon (Johnson & Onwuegbuzie, 2004). For the pragmatist, philosophical assumptions are independent and can be mixed to achieve the most appropriate combination for investigating a particular problem (Greene & Caracelli, 1997). For instance, pragmatism rejects positivism and interpretivism, on the claims that the former denies meaningful moral choices while the latter encourages indifference to morality in the interpretation of realities (Smith, 1984). The pragmatist asserts that reality can be known by action, based on experience and by exploration of more useful ways to know about the world (Smith, 1984; Morgan, 2007). Thus, to the pragmatist, knowledge about a phenomenon can be derived through experience and/or construction (Johnson & Onwuegbuzie, 2004).

Although pragmatism is not the perfect solution to the limitations inherent in the classical paradigms, it aids in bridging the metaphysical, epistemological, axiological (e.g., ethical and normative) and methodological incompatibilities between these purist positions (Johnson & Onwuegbuzie 2004). The pragmatic paradigm improves communication among researchers from different paradigms as they attempt to advance knowledge through shared meanings and joint actions (Maxcy, 2003; Morgan, 2007). As a result, pragmatism emphasises intersubjectivity and transferability as tools for building bridges, ensuring mutual understanding and sharing knowledge between multidisciplinary researchers (May, 2001; Morgan, 2007). Pragmatism therefore creates a range of new opportunities for thinking about methodological issues in
research; promotes flexibility in the use of investigative techniques; and enhances collaboration among researchers regardless of their philosophical orientations (Onwuegbuzie & Leech, 2005).

The pragmatic paradigm endorses a middle position, and a pluralistic and an eclectic research methodology (Patton, 1990; Johnson & Onwuegbuzie, 2004; Morgan, 2007). Pragmatism advocates for, and supports integration of practical and action-oriented methods of inquiry to accomplish the aims of a research (Johnson & Onwuegbuzie, 2004). The proponents argue that the emphasis of methodology should be on how to appropriately and fruitfully mix research methods to suit the particular phenomenon under investigation, instead of a one-sided approach (Blaikie, 1991; Hoshmand, 2003; Johnson & Onwuegbuzie, 2004). They further argue that the purported dichotomy between research approaches (such as qualitative and quantitative approaches) is forced and unproductive as there are common grounds for integrating various approaches (that is, they represent an interactive continuum) (Patton, 1980; Newman & Benz, 1998; Maxcy, 2003). Consequently, pragmatic research uses a mixed methods approach, and applies abductive reasoning, where inductive results from one approach are extracted and used to construct indices for deductive goals of another approach (Johnson & Onwuegbuzie, 2004; Morgan, 2007).

Pragmatic research focuses on the outcome of the research, and considers research questions as the most important basis for determining what methods are most appropriate (Creswell & Plano-Clark, 2007). Neuman (2003) argues that while there is a strong link between research purpose and research methods, the link between philosophy and method is weakened. According to Cook and Reichardt (1979), there is no paradigm-method link, but rather a method-reality (research questions) link. This suggests that the essential criteria for making method/design decisions should be practicality, contextual responsiveness and consequentiality. Thus, under pragmatism the choice of research method is based on research questions and value-orientation rather than on ontological and epistemological beliefs (Datta, 1997; Onwuegbuzie & Leech, 2005).

Based on the foregoing explanation, this research was guided by a pragmatic paradigm because of its flexibility, openness and support for combining interdisciplinary
approaches. This was consistent with the research questions, which focused on real problems and as such required use of multiple approaches in addressing them. The pragmatic position adopted offered a platform for selecting and combining different appropriate methods for answering the various research questions, without strict adherence to any prescribed standards or logic. Thus, research processes and methods used for this research were driven by the research questions and purpose. The next section explains mixed methods research approach and its usefulness in this research.

3.4 Theory and application of the mixed methods research approach

Research approaches are products of the principles entailed in research paradigms, and they determine the tools of data collection and analysis in research (Sarantakos, 1998). There are various research approaches as there are many paradigms, and they are largely assessed in terms of their relative usefulness for a particular research purpose. All the research approaches however, represent attempts to understand the complexities or nature of the ‘world’, as well as the range of possible relationships in that world. According to many researchers (e.g., Sieber, 1973; Newman & Benz, 1998; Amaratunga et al., 2002; Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Leech, 2005), research methods are consistent in objectives, scope, and nature of inquiry. Consequently, the use of different research approaches in single research, technically termed as a mixed methods research approach, is evoked as a pathway for producing quality research results (Amaratunga et al., 2002; Onwuegbuzie & Leech, 2005).

The mixed methods approach is a methodology in which the researcher combines and applies different and interdisciplinary research techniques, concepts or languages in a single study. The methodological philosophy of the mixed methods approach emphasises a pragmatic combination of different methods at different phases of the research process, based on the research questions (Johnson & Onwuegbuzie, 2004). Proponents of the approach argue that epistemology does not dictate data collection and data analytical methods, but rather the research questions should drive the method(s), as different aspects of reality lend themselves to different methods of inquiry (Onwuegbuzie & Leech, 2005). Yin (1994) explains that the type of questions posed, the researcher’s control over actual behavioural elements and the degree of
focus on historical or contemporary events should serve as the basis for the choice of methods. According to Patton (1990), by mixing different appropriate research methods, researchers are able to conduct quality research based on the situation and available resources.

The main aim of mixed methods research is to maximise strengths and minimise the weaknesses of various approaches in a single study, as well as across studies (Sieber, 1973; Newman & Benz, 1998; Johnson & Onwuebguzie, 2004). Through this, the approach expands the scope of research, deepens insights obtained from research, as well as supports complex research designs for understanding the complexity of social phenomena (Sandelowski, 2000a). In addition, the mixed methods approach helps to initiate discovery of new knowledge by revisiting and re-framing research questions, as well as promote convergence, verification and corroboration of results from different methods, which reduces biases and enhance validity of the research (Greene, Caracelli, & Graham, 1989; Blaikie, 1991; Yin, 1994; Onwuebguzie & Leech, 2005). The logic of inquiry of mixed methods research therefore entails induction, deduction and abduction (Johnson & Onwuebguzie, 2004).

This interdisciplinary research adopted a mixed methods approach by combining and integrating social and natural sciences methods. This approach was adopted because it ensures a more complete and better understanding of the multi-disciplinary issues such as degradation of rivers and floodplains, as well as impacts of flooding studied in this research (Sieber, 1973; Johnson & Onwuebguzie, 2004). The mixed methods approach supported the complex research design that was needed to understand and explain the complexities in the drivers of changes in rivers and floodplains, as well as the resultant floods in Kumasi (Sandelowski, 2000a; 2000b). In essence, the approach entailed combining and applying: (i) spatial and statistical methods to study land use/cover changes; (ii) explanatory qualitative methods to understand the study phenomena from the perspective of the study participants (e.g., reasons for occupying water areas, flood experiences); and (iii) hydro-meteorological approaches/data to understand physico-chemical conditions of the rivers and other natural factors related to the studied phenomena. Thus, different methods were used to study different dimensions of the phenomena under investigation to ensure better insight.
In sum, a combination of empirical precision and descriptive precision was applied to holistically explain the phenomena studied. The approach provided a basis for: addressing confirmatory and explanatory questions simultaneously, acquiring and presenting a greater range of diverse evidences, as well as making stronger inferences. Although the mixed methods research approach has been criticised for requiring more time, resources, and effort to organise and implement, as well as sometimes leaving out useful details (Teddle & Tashakkori, 2003; Johnson & Onwuebguzie, 2004), the use of different methods in this research provided a more workable approach and superior insights, as the different methods complemented each other by focusing on different aspects of urban growth, rivers, floodplains and flood issues in Kumasi.

3.5 The research process and methods used

This explanatory research adopted a pragmatic research paradigm by combining available appropriate practical methods, due to the interdisciplinary nature of urban growth, water resources and flood management (Patton, 1980; Bryne et al., 1973). This position has been based on the argument that effective combination of multiple methods to triangulate multiple evidences from a variety of sources is useful in achieving a research purpose (Blaikie, 1991; Hoshmand, 2003). As indicated by Patton (1990), the selection of appropriate research methods must effectively match the research questions and objectives. The mixed methods approach adopted in this research utilised qualitative and quantitative social data, spatial data analysis and hydro-meteorological data to achieve the research aim of explaining and understanding the spatial changes in rivers and floodplains and the contribution to flooding. Thus, empirically observed social, economic, physical and hydro-meteorological realities have been used to identify and explore the driving forces of spatial change in rivers and floodplains and the occurrence of floods in urban areas.

Essentially, a case study research design was adopted to operationalise this mixed method research. This design type was employed to acquire useful data and to generate deeper insight into spatial changes in rivers and floodplains, and incidence of floods from the local level. Kumasi, the fastest growing and second largest city in Ghana, was adopted as the case study area of this research (Yin, 2003; Pawar, 2004). Multiple sources of evidence and perspectives regarding the changes in rivers and floodplains,
and incidence of flood disasters were collected from both local people and institutions through fieldwork that used a variety of data collection techniques. In this research, qualitative information such as expression of opinions, feelings and perceptions on the state of rivers and floodplains, causes of degradation of rivers and floodplains, flood intensity and damage and physical development in water areas were collected through interviews, focus group discussions and direct observations (Punch, 1998; Sandelowski, 2000a; Amaratunga et al., 2002; Neuman, 2003).

Quantitative information useful for describing phenomena in a systematic and comparable way was collected about important variables such as rainfall, flood cases, stream flow, and water quality from relevant institutions through semi-structured interviews (Punch, 1998; Sandelowski, 2000b). The quantitative information, together with spatial information obtained from satellite images and physical survey, was used to determine the changes in the rivers and floodplains, as well as understand the change drivers and the effects on flood occurrences. Also, information on legislation, policies and challenges in urban growth, water resources and flood management in Kumasi were collected from relevant institutions and secondary sources including published and unpublished documents. Thus, the case study research design helped the researcher to document local understanding of phenomena, as well as move beyond a mere description to explain and examine them in a broader context.

This research used both deductive and inductive approaches to data analysis (Johnson & Onwuebguzie, 2004). According to Miller and Brewer (2003), deductive and inductive approaches are not antithetic but reveal different ways of making intelligent meanings from observations, and as such can be integrated for holistic interpretation. The adoption of these approaches was therefore premised on the argument that understanding and explaining the drivers of spatial changes in rivers and floodplain, as well as the incidence and intensity of flood based on empirical observations and logical reasoning, significantly contribute to developing concepts and/or testing existing concepts (Miller & Brewer, 2003). Essentially, data analysis in this research followed a best practice approach in which different methods were used to analyse different data. The specific data analysis methods and techniques used were narratives and content analysis for interview results and qualitative information; descriptive statistics for quantitative data; and ArcGIS and Erdas for processing and analysing
spatial information or data. Thus, this research is best described as an applied research, which has wider and better practical implications for addressing the phenomena studied.

The process used in this research involved five major iterative stages (see Figure 3.1). The first stage was a review of relevant literature on urbanisation and urban growth, inland waters systems and flooding, which provided the conceptual background to the research (further literature review and refinement of the conceptual framework occurred throughout the research process). Published and unpublished documents on issues pertaining to urban growth, inland waters and flooding in the broader study context were also reviewed to understand the local conditions. The second stage was the development of the research questions and aim based on the gaps identified in the literature review, as well as local conditions. However, the research aim and questions were modified as the research progressed.

The third stage involved designing the research and collecting the data. The research was designed based on a pragmatic paradigm using a mixed methods research approach within the framework of case study research design, by combining appropriate practical methods to collect the multiple sources of evidence needed to address the research questions. A range of data collection methods such as semi-structured interviews, focus group discussions and spatial survey were used to collect multiple data that addressed different aspects of the research questions, and also stimulated rigorous analysis (Patton, 2002). The fourth stage was the presentation and analysis of the data. The analysis entailed triangulation, corroboration and verification of data from multiple sources. The final stage of the research process presented a synthesis of research findings, plausible scenarios, as well as recommendations and conclusions of the research.
Literature review and Secondary data collection & analysis (e.g., satellite images, rainfall, temperature, water quality, and discharge data)

Figure 3.1 Summary of overall research process
3.5.1 Using a case study research design

This research was conducted using the case study research design. Yin (1981) defines a case study as a systematic inquiry into a contemporary phenomenon within its real life context, especially when the boundaries between the phenomenon and context are not clearly evident. A case study research design focuses on understanding and explaining the dynamics present in processes or phenomena as they occur in their contexts (Amaratunga et al., 2002). A case study is particularly appropriate for understanding a process or complex real-life activities in great depth, especially where one can identify cases rich in information (Rossman & Rallis, 2003; Mohd Noor, 2008). The cases that are studied could be individuals, groups, organisations, events or geographical units (Neuman, 2003). Thus, a ‘case study’ is used both as a research design and a data-collecting approach (Pawar, 2004).

For this research, the contemporary nature of the study phenomena and the associated diverse socio-environmental effects on the urbanscape warranted the use of case study design for in-depth understanding and examination. The application of the case study design allows an in-depth probing of research topics that ask and address ‘how’ and ‘why’ questions, as well as provide rich explanation of the phenomena studied (Yin, 1981; Ellram, 1996). According to Yin (1994), the case study design is effective in establishing operational links for answering trend types of questions. Thus, in this research, the case study design was useful in establishing trends of spatial extent of rivers and floodplains, water quality, river discharge and rainfall among others.

The interdisciplinary nature of this research required triangulation of data to answer the research questions so that results could be confirmed, as well as generalised to conceptual propositions. A case study design is known to support the combination and application of diverse methods to collect multiple sources of evidence (Yin, 1989). For example, Chetty (1996) observes that the multiple sources of evidence used in case study research design assist in the prevention of subjective bias in the conclusions drawn from the research. As a result, socio-economic, spatial and hydro-meteorological data used in this research were collected using different techniques including interviews, documentary reviews and physical surveys (Ellram, 1996;
Mohd Noor, 2008). The multiple data sources provided a holistic view of the change in extent of rivers and floodplains and its drivers, and the implications for flooding.

The flexibility and openness of the case study approach allows one to study a complex issue through interaction, as well as understand and interpret it from the perspective of the research participants (Sarantakos, 1998). Therefore, the case study design in this research was used as a pathway for extensively investigating the changing extent of rivers and floodplains and flood disasters as evolving real-life challenges within their contexts, through use of in-depth probing and information rich cases (Yin, 1989). Many authors (e.g., Yin, 1994; Ellram, 1996; Pawar, 2004) have indicated that careful selection of an appropriate case study area is an important ingredient of good research as it helps to avoid the possible drawbacks of the case study approach (O'leary, 2006). For the purpose of this research, Kumasi, Ghana's second largest city and capital of the Ashanti region of Ghana, as well as an important commercial city in the West African sub region, has been selected as the case study area.

**Reasons for selecting Kumasi as the case study area**

Kumasi, the administrative capital of the Ashanti region of Ghana, is located in the tropical rain forest about 270 km north-west of Accra, the national capital, and stretches between latitudes 6°38’N and 6°45’N and longitudes 1°32’W and 1°41’W (see Figures 1.1 and 3.2). The strategic location of the city at the crossroads between the northern and southern sections of Ghana has made it a major destination for many migrants across the country and beyond (Kumasi Metropolitan Assembly [KMA], 2006; Dahlman, 2009). Although Kumasi is not a global city just like many African capital cities (Kearney, 2016), its recent dramatic and spontaneous population growth and physical expansion have led to the degradation and loss of the natural environment, which presents an interesting case for this study. The city is currently confronted with socio-environmental issues such as uncontrolled growth, inland water degradation and flood disasters among others. The reasons that make Kumasi a suitable study area for this research are outlined below.
First, the Ashanti Region in which Kumasi is located (see Figure 3.2) is the second most urbanised region (60.6 %) in Ghana, after Greater Accra (90.5%). Consequently, Kumasi is noted to be the fastest growing city in the country, with an estimated total population of 2,035,064 and an annual growth rate of 5.5% (GSS, 2013a). The fast rate of urbanisation is further confirmed by the fact that 48%, 46% and 6% of the city are urban, peri-urban and rural respectively (KMA, 2010). The city's population represents about 16% and 43% of the national and Ashanti regional urban population respectively, and contributed 20.2% to the country's urban population growth in 2010. Given its population, Kumasi is classified as one of the global million plus cities which are characterised by fast growth and also known to create formidable environmental challenges (UNDESA/PD, 2012; GSS, 2013a). Such high rates of urbanisation and population growth have generated enormous urban growth management and socio-environmental challenges, as well as overexploitation and degradation of environmental resources in and beyond the city.

Second, Kumasi is confronted with a myriad of environmental problems, including the degradation of inland waters. Extensive irreparable degradations have occurred to many rivers and floodplains, as well as their riparian zones in the city. The rivers are utilised for urban developments, as well as polluted from human activities, such that many have disappeared and/or are on the brink of extinction. Again, much of the floodplains and riparian areas have been cleared for developmental and agricultural purposes, promoting chemical pollution and siltation of the rivers (KMA, 2010). Thus, human activities such as physical development, indiscriminate waste disposal and urban farming, have adversely affected surface water systems, as well as greenery nature reserves that earned Kumasi the accolade "Garden City of West Africa". This situation makes Kumasi a suitable area for undertaking in-depth investigations into spatial changes in rivers and floodplains, a problem that plagues many developing countries in Africa.

Third, flooding has become one of the most rampant and destructive natural disasters in Kumasi in recent times. Certain suburbs of the city are affected by this disaster annually due to reasons which are still unclear. The problem is highly reported by the media who perceive it an impact of climate change, and has had several negative
consequences for the residents. Although the flood incidences, as well as destructive effects in the city are widely acknowledged, few academic studies have been undertaken to comprehensively understand the phenomenon.

Finally, the researcher has resided in the study area and as such possesses an in-depth local knowledge of the city. The researcher studied and worked at the Kwame Nkrumah University of Science and Technology which is located in the study area. This period of study and work offered the researcher the opportunity to be involved in a number of research activities, some of which are related to the issues under investigation in this research. This personal and professional background helped the researcher to establish good rapport with staff of some of the institutions which were involved in this research. This pre-existing rapport was advantageous, as it facilitated the data collection process of this research (Johnson & Turner, 2003).

Following the selection of the study area, it was imperative to choose suburbs in Kumasi with particular characteristics of interest for the research as data collection sites (Sarantakos, 1998). This entailed a sequence of steps which aimed at selecting communities that are typically characterised by degraded rivers and floodplains and flood disasters. First, an initial consultation with three key institutions (that is, Town and Country Planning Department [TCPD], Water Resources Commission [WRC] and National Disaster Management Organization [NADMO]) in Kumasi was used to identify the suburbs in the city which are noted for heavy encroachment upon rivers and floodplains and high incidences of floods (see Figure 3.3). This was followed by preliminary visits to the identified suburbs to observe the levels of encroachment and degradation of the rivers and floodplains, as well as to get acquainted with the problematic nature of flooding in the areas through informal talks.

Based on the information obtained from the institutions, as well as the researcher's observations during the initial visits to the identified flood prone suburbs in Kumasi, eight suburbs were chosen as data collection sites. The selected data collection suburbs were Kronum, Asuoyeboa, Dichemso, Moshie Zongo, Atonsu, Ahinsan, Kokode and Adiembra (see Figure 3.3). The choice of these suburbs from the other identified suburbs was based on the high intensity of physical development in and along rivers and floodplains, and frequent incidence of floods that characterised
them. Also, the locations of the data collection suburbs represented an even spatial distribution of the data collection sites across Kumasi, so that the study results are a true reflection of the phenomena under investigation for the whole city.

Figure 3.2 River network and towns in Ashanti region
Source: SPAN, CSU (2016)
3.5.2 Data types and sources

Mixed methods research advocates for the collection of multiple data sources using different strategies and methods, in a way that the resulting mixture leads to complementary strengths and non-overlapping weaknesses (Brewer & Hunter, 1989). The use of several sources of evidence ensures generation of quality and superior results, expansive understanding of the subject matter and derivation of singular conclusions that can be held in greater confidence (Johnson & Onwuebuzie, 2004). To explain the changing extent of the rivers and floodplains in Kumasi, this study utilised spatial, hydro-meteorological and socio-economic data obtained from both primary and secondary sources (see Appendix 1). These multiple data revealed the changes in rivers and floodplains, explained the drivers of the changes, and provided information on the implications of the spatial changes for flooding in the city. The data types used in this research are explained below.
3.5.2.1 Spatial data

Landsat Thematic Mapper (LTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images of Kumasi were obtained from the Forestry Commission of Ghana, and used to map the land use/cover of the city for the years 1986, 2000 and 2010. The selection of these years was based on the availability of clear and cloud free images. The satellite images used were taken in January of the respective years. The spatial resolution of the ASTER and Landsat images were 20 m and 30 m respectively, and this was due to the unavailability of high resolution images for the study area. Nevertheless, these images have been successfully used in many similar studies elsewhere (Dewan & Yamaguchi, 2009; Prasad et al., 2009; Islam et al., 2010). These images constituted the main data used to detect and measure the changes in the spatial extent of rivers and floodplains, as well as general land uses/cover changes in Kumasi over a thirty year period.

Also, relevant maps of Kumasi such as land use (1:2500 scale), topography (1:50,000 scale) and GIS hydro, roads and settlements layers were obtained from TCPD, Survey Department and Centre for Geographic Information System (CEGSS) in Ghana respectively, and used as reference data, as well as for accuracy assessment (Zhang, Ma & Wang, 2008; Islam et al., 2010). In addition, ground truthing and physical information on the types, characteristics and nature of land use activities along the rivers and floodplains, as well as widths of some of the important rivers and their buffers were acquired through a spatial survey using handheld GPS and digital camera (photographs). These physically observed data helped to verify and confirm information on the satellite images, as well as providing additional information that could not be obtained from the satellite images (D’Souza & Nagendra, 2011).

3.5.2.2 Socio-economic data

Socio-economic data from both primary and secondary sources were collected and used in this research. The primary data provided first-hand information on the urban growth, changes in rivers and floodplains, and incidence of floods in Kumasi. The primary socio-economic data were collected using qualitative social research data collection methods such as semi-structured interviews and focus group discussions through fieldwork which was undertaken in June-September, 2013. The primary
socio-economic data covered issues such as land use activities along rivers and floodplains, description of conditions of rivers and floodplains, reasons for development in rivers and floodplains, flood incidences and experiences, property damage and lives lost to floods, as well as flood coping and adaptation strategies.

Additionally, data were collected on land ownership and administration practices, population growth patterns, growth of informal economic activities, waste management practices, and policies and legislation for physical development control, water resources and flood management. These primary socio-economic data were collected from owners of properties along rivers and floodplains, as well as governmental institutions and non-governmental organisations whose activities are related to urban development, water resources and flood management in Kumasi. Also, secondary socio-economic data in the form of annual reports, project reports, development policies and plans and newspaper publications on urban growth, inland water systems degradation and floods were obtained from some of the institutions. This myriad of socio-economic information was important in explaining and understanding the drivers of the changes in rivers and floodplains, and occurrences and intensity of floods in Kumasi.

3.5.2.3 Hydro-meteorological data

Data on hydrological and meteorological issues such as rainfall, river flows/discharge and physico-chemical parameters or water quality of rivers were obtained from appropriate institutions. Daily rainfall and temperature data for Kumasi from 1961 to 2013 were collected from the Ghana Meteorological Agency (GMA) to investigate their patterns and trends, as well as determine their contribution to the changes in rivers and floodplains, and flood disasters in Kumasi. Water quality data of selected rivers (Subin, Sisa, Aboabo, Daban, Wiwi and Owabi) for the years 1991, 2001 and 2012 were obtained from the Environmental Protection Agency [EPA]. In addition, water levels and discharge measurement data of rivers from 1993 to 2012 were acquired from the Hydrological Services Department. The water quality and river discharge data were important in further establishing the deteriorating conditions of rivers in Kumasi.
3.5.3 Data collection process and methods

Good data collection methods are integral to obtaining valid and reliable measures and results in research (Neuman, 2003). Mixed methods research requires a combination of different but appropriate data collection methods based on the research questions. An effective combination of the different instruments constitutes a concrete operation at the technique level, as this is useful for fully describing the study phenomenon, as well as validating research results (Sandelowski, 2000a). Accordingly, four data collection methods were combined in this research for the purposes of in-depth description, complementarity (elaboration, enhancement, illustration and clarification) and triangulation (corroboration and convergence). The data collection methods included semi-structured interviews, focus group discussions, spatial survey/direct observation and secondary data/documentary analysis (see Appendix 1). The use of these different but largely qualitative social research data collection methods was important in obtaining expansive, valid and reliable data for explicating the changing extent of rivers and floodplains, and the related floods in Kumasi.

Data collection was conducted during a four month fieldwork programme between June and September, 2013 (see Table 3.1). The data collection was conducted with the aim of gaining local and institutional understanding of the changes in extent of rivers and floodplains, drivers of the changes in extent of rivers and floodplains as well as the incidence of floods in Kumasi. Consequently, the triangulation technique was used to collect data at different levels and from different sources. The fieldwork data collection activities followed a systematic process with the activities at each stage being partially informed by that of the preceding stage (see Figure 3.1). The process proved useful in providing the researcher with a deeper understanding of the changes in spatial extent of the rivers and floodplains in Kumasi, and how such changes contribute to the frequency and incidence of floods in the city. The subsequent sections examine the data collection methods and activities for this research.
Table 3.1 Schedule of activities for data collection fieldwork

<table>
<thead>
<tr>
<th>Week of Activity</th>
<th>Location of Activity</th>
<th>Nature of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Kumasi, Ashanti, Ghana</td>
<td>Introductory visits and pre-testing of interview guides</td>
</tr>
<tr>
<td>3-6</td>
<td>Kumasi, Ashanti, Ghana</td>
<td>Institutional semi-structured interviews</td>
</tr>
<tr>
<td>7-15</td>
<td>Kumasi, Ashanti, Ghana</td>
<td>Property owners semi-structured interviews and spatial survey at chosen suburbs</td>
</tr>
<tr>
<td>15-16</td>
<td>Kumasi, Ashanti, Ghana</td>
<td>Follow up on institutional interviews and focus group discussions</td>
</tr>
</tbody>
</table>

Source: Researcher’s Fieldwork Diary, (2013).

3.5.3.1 Pre-testing

The data collection was preceded by a pilot pre-test exercise to assess the consistency of the research instruments. Pre-testing is the use of a small proportion of research participants to ascertain the suitability of a research instrument to accurately measure variables and address research questions (Hunt, Sparkman Jr & Wilcox, 1982). In this research the interview guides were pre-tested with three officials from relevant institutions (TCPD, WRC and NADMO), as well as six residents in two flood prone suburbs (Bremang and Ahinsan Estate) in Kumasi. The results and feedback from the pre-testing were incorporated, and used to refine the interview questions to derive the final interview guides for the actual data collection.

In addition, introductory visits were made to the relevant urban growth, water resources and flood management institutions to seek permission and assistance to undertake the data collection. There were also preliminary visits to a number of flood prone suburbs to observe the intensity of land use activities in and along the rivers and floodplains. The observations made through these visits were used to select the data collection suburbs and revise the spatial survey observation checklists. These community visits were useful in gaining the permission and support of the community leaders, as well as establishing rapport with the community residents to ensure smooth data collection.
3.5.3.2 Semi-structured interviews

A semi-structured interview is an open-ended method for exploring the respondent's point of view, feelings and perspectives on a topic or area of inquiry through oral questioning (May & Pope, 1993; Kvale, 1996; Sarantakos, 1998; Neuman, 2003). In this research, semi-structured interview was used to collect data on urban development, river and floodplain conditions and flood disasters from the relevant institutions and property owners in Kumasi. Semi-structured interview was chosen for this research because it presents considerable flexibility to adapt interview styles and questions to the context and/or interviewee; allows the interviewer to probe for more information and clarification; and has high response rates (Denzin & Lincoln, 1994; Mohd Noor, 2008). Also, the interaction-based nature of the instrument minimises problems of meaning, interpretation and uncertainty of research issues (Somekh & Lewin, 2005).

Interview guides comprising pre-determined open-ended questions were developed and used to ensure that interviews were systematic and focused enough to collect relevant information (Bryman, 2004). The questions followed a logical order that stimulated and sustained the interest of the interviewee, and also allowed the researcher to intensely probe for deeper meaning and understanding of the responses. Separate but related interview guides were developed for respondents from the different institutions, while the same guide was used for all the property owners, based on the research purpose (see Appendices 2 & 3). The semi-structured interviews produced precise, rich, non-directional, in-depth and contextual (told in “stories” of their own right) (Veal, 1997; Flick, 1998) information.

**Sampling and data collection**

A purposive sampling technique was used to select institutions and property owners for the semi-structured interviews. Purposive sampling, a type of non-probability sampling, involves the selection of sampling units with the characteristics of interest and relevance to the phenomenon being studied from within the study population (May & Pope, 1993; Guarte & Barrios, 2006). The cases and/or interviewees are purposefully selected because they are information rich, and as such can provide
important, reliable and valid information that cannot be obtained from other sources (Neuman, 2003; Guarte & Barrios, 2006; Teddlie & Yu, 2007).

Twelve urban growth, water resources and flood management related institutions comprising government agencies and non-governmental organisations were purposefully selected and involved in the research. The institutions were the Water Resources Commission (WRC), Town and Country Planning Department (TCPD), Environmental Protection Agency (EPA), National Disaster Management Organisation (NADMO), Friends of Rivers and Water Bodies (FRWB), Metropolitan Waste Management Department (MWMD), Hydrological Services Department (HSD), Metropolitan Building Inspectorate Division (MBID), Ghana Water Company Limited (GWCL), Lands Commission (LC), Ghana Meteorological Agency (GMA) and Kumasi Metropolitan Assembly (KMA). These institutions were selected because they possess relevant knowledge and information on the research issues, as their activities are directly and indirectly concerned with the physical development and water resources and flood management of Kumasi. A total of twelve officials comprising eight males and four females, with one from each of the selected institutions, were interviewed (see Table 3.2). The representatives, who were mainly institutional heads and/or deputies, were purposefully sampled based on their knowledge and ability to provide relevant information, interest in the research, as well as availability for an interview.

At the local community level, five property owners within 10 m to 100 m along rivers and floodplains (the standard buffer zone width in Ghana) were purposefully selected from each of the eight data collection suburbs (see Section 3.5.1). A total of forty property owners comprising twenty-seven males and thirteen females were purposefully recruited and involved in this research (see Table 3.2). The selection of the interviewees was based on the location and type of their properties or activities, as well as past flooding experiences, to ensure the use of an information-rich sample, and thus enhance validity and reliability of the research findings. The interviewees comprised people from different socio-economic backgrounds and status, which also improved the quality of the responses obtained.
In addition, two traditional leaders from Atonsu and Dichemso (data collection suburbs) were purposefully selected to provide information on land allocation and development, water resources management and flood incidences in their communities. The traditional leaders are the custodians of lands, and as such considered important stakeholders in development issues such as physical development, water resources and flood management in Kumasi and Ghana as a whole (Botchie, Akabzaa, Gyasi & Sarpong, 2007). The involvement of the traditional leaders provided in-depth understanding of the effects of uncontrolled land delivery and development on rivers and floodplains, as well as flood intensity and damage in the communities.

All the interviews were conducted by the researcher, and the questions were asked in a systematic and consistent order, although the interviewees were allowed freedom to digress, while the researcher often probed further for in-depth explanation of responses. The interviews focused on the interviewees’ awareness of the spatial changes in the rivers and floodplains, views on causes of the changes in extent of rivers and floodplains, perceptions on the effects of changes in rivers and floodplains, and flood incidences and intensity in Kumasi. The interviews further explored programmes, policies and challenges for physical development control, water resources and floods management in Kumasi. Interviews with the institutional interviewees were held at their offices and conducted in English; while that of the property owners took place at their homes and/or workplaces, and were largely conducted in Akan Language [the local language] except in few cases where the interviewees could speak English. The interview durations ranged from one to two hours depending on an interviewee’s interest and knowledge in urban, water resources and floods management, as well as availability for the interview. The interviews were tape recorded with the consent of the interviewees, which enabled the researcher to obtain a full and accurate record of the responses and perspectives of the respondents while focusing on exploring the research issues. In addition, notes were taken during the interviews to flag interesting points raised, and these allowed the researcher to go back to such points of interest and explore issues in-depth without interrupting the flow of conversation.
Relevance and limitations of the method

The semi-structured nature of the interviews provided the interviewees with a better opportunity to openly share their experiences and views about the research issue. The interviews generated detailed information on local understanding and perceptions of the extent of degradation of river and floodplain, drivers of the degradation of rivers and floodplains, flood incidences, as well as actions and policies for controlling or managing these in Kumasi. The data collected addressed parts of all the research questions. In relation to research question one, the interviews provided perceptions on the nature and rate of spatial changes in rivers and floodplains, understanding of the nature and process of land use development in and along rivers and floodplains, and views on the present state or conditions of rivers and floodplains in Kumasi. For research question two, the instrument provided information on perceived causes of spatial changes in rivers and floodplains with emphasis on the nature of population growth, physical expansion and development, water resources and urban growth management practices and policies, waste generation and disposal practices, land ownership and administration, as well as informal economic activities. Finally, the interviews collected data on flood incidences and experiences, views on causes of the floods, flood damage and flood coping and adaptation measures, which were used to address research question three.

However, conducting the semi-structured interviews was time consuming, as the partially unstructured nature allowed the respondents to often digress to express opinions on unrelated issues. Also, the interview processes were sometimes distracted by the interviewees making phone calls or talking to other people nearby. Nevertheless, the effects these limitations could have had on the research was overcome through systematic probing and reiteration of the main research issues by the researcher to obtain quality and consistent responses from interviewees. Also, the purpose of the research was continually emphasised, to enable the interviewees provide the required responses/information, which enhanced the quality of the research results.
3.5.3.3 Focus group discussions

According to Barker and Rich (1992), a focus group is a group discussion organised to explore a specific set of issues on a phenomenon under investigation. A focus group provides a forum for community interaction that creates synergistic group effects. This process serves as a platform for collecting a broad range of data required in relation to a research topic, by producing ideas and responses not expressed in other one-to-one methods (Pawar, 2004). The number of participants in a focus group discussion usually ranges from five to ten, and are selected based on their particular interests, expertise and/or positions (Kitzinger, 1994; Sarantakos, 1998).

This research used focus groups to elicit collective views on the changes in the extent of rivers and floodplains and associated floods. The use of focus group discussion in this research was based on the view that inland water systems such as rivers and floodplain are communal properties while floods are disasters with communal impacts, and as such a group setting could provide a common understanding of these issues (D’Souza & Nagendra, 2011). An interview guide containing open-ended questions arranged from the more general to the more specific and in their relative importance to the research issues, was developed to frame and direct the discussions (see Appendix 4). The focus group discussions generated new information that broadened the understanding of the degradation of rivers and floodplains, and flood incidence, and also clarified the issues raised during the semi-structured interviews. This strengthened the validity of the research results.

Sampling and data collection

Two separate focus group discussions were held at two suburbs, which were purposefully selected from among the data collection suburbs. The suburbs were Asuoyeboah and Moshie-Zongo, which were selected because of the occurrence of severe floods in these suburbs in 2013 [data collection year]. The residents in these communities were therefore in a good position to recount the flood incidents and their accompanying effects with ease, as it was fresh in their minds. The support of the community leaders of these suburbs, coupled with time and resource constraints, also contributed to the selection and conduct of two focus groups. There were ten participants per focus group, comprising seven property owners who participated in
the semi-structured interviews and three purposefully selected community leaders (see Table 3.2). The participants of each of the focus groups comprised six males and four females, and they provided a broad and detailed explanation of the changes in the rivers and floodplains and flood incidences through intensive brainstorming and discussions.

The focus group discussions were facilitated by the researcher, with the assistance of one interviewer who mainly compiled the responses. The researcher delivered a detailed briefing on the research to the assistant interviewer, to ensure that she had the skills required for the role, and to guarantee the collection of reliable data (Fowler & Mangione, 1990). The focus group discussions were conducted in a relaxed manner with minimal intervention by the researcher, which enabled the participants to freely express their views and experiences on the degradation of rivers and floodplains and incidence of floods in their communities. The questions posed during the focus groups explored the state of the rivers and floodplains, type of land use activities developed in and along rivers and floodplains, factors contributing to the frequency and intensity of floods and the effects in their communities. The focus group discussions were held at the community centres and lasted for two hours in both cases. The Akan Language [the local language] was the medium of communication, and the discussions were tape recorded with the consent of the participants. Extra notes were taken by both the researcher and the assistant interviewer, which ensured effective probing to gain deeper understanding of spatial changes in the rivers and floodplains and flood incidences, with minimal interruption of the discussion process.

Relevance and limitations of the method

The focus group discussions were effective in providing reliable information that verified and validated the responses from the interviews within a reasonably short period of time. The views of the focus group participants offered much broader and insightful information on, and understanding of, the phenomena under study, especially with regards to the incidence and intensity of floods. Data collected with this method were used to address aspects of all the research questions. For research question one, data were collected on the participants’ views on the importance and
state of the rivers and floodplains, as well as awareness of the types and processes of land use development in rivers and floodplains. In the case of research question two, the method provided data on perceived causes of loss of rivers and floodplains, physical development control practices, waste management challenges and land ownership and administration issues. For question three, the focus groups provided a broad understanding of the frequency, severity, perceived causes and effects of floods in the communities and Kumasi in general.

Nevertheless, the method had shortcomings. Some of the participants tended to dominate the discussion at the early stages, but the facilitator intervened so that other participants could express their views. Again, some participants, especially the community leaders, were reluctant to discuss the reasons for the development in the rivers and floodplains due to their apparent involvement in the unacceptable allocation of land to the developers. The negative effects these limitations could have had on the research results were addressed by emphasising the purpose of the research, and encouraging all participants to freely express their views. The researcher also probed further to obtain in-depth explanations of responses from the focus group participants. These yielded results that deepened the researcher’s understanding of the study phenomena, and ultimately improved the quality of the research findings.

Table 3.2 Research participants

<table>
<thead>
<tr>
<th>Research Activity</th>
<th>Male</th>
<th>Female</th>
<th>Total Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
</tr>
<tr>
<td>Institutional semi-</td>
<td>8</td>
<td>67</td>
<td>4</td>
</tr>
<tr>
<td>structured interviews</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property owners’ semi-</td>
<td>27</td>
<td>78</td>
<td>13</td>
</tr>
<tr>
<td>structured interviews</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional leaders semi-</td>
<td>2</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>structured interviews</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focus Group Discussions</td>
<td>12</td>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>Overall Total</td>
<td>49</td>
<td>66</td>
<td>25</td>
</tr>
</tbody>
</table>

Source: Researcher’s Fieldwork Diary, (2013)
3.5.3.4 Spatial survey

Spatial survey is a physical/direct observation and systematic recording of the conditions of a phenomenon in its usual environment without altering that environment. Spatial survey is used to supplement other data collection methods, such as interviews, focus group and remote sensing images when the phenomenon or situation under study has physical manifestations that can be readily seen (Dewan & Yamaguchi, 2009; D’Souza & Nagendra, 2011). In this research, spatial survey was conducted as part of the fieldwork to collect ground truth information to supplement and validate the satellite images, especially the 2013 image, as well as collect additional physical information on conditions of the rivers and floodplains, environmental problems and occurrences of floods. The spatial survey proceeded throughout the fieldwork, and was guided by the study objective and observation checklists (see Appendix 5), which helped the researcher to collect the relevant information while avoiding biases and deviations.

The spatial survey was undertaken within 100 m from many rivers and floodplains in Kumasi from June-September, 2013. A hand-held Global Position System (GPS) (Nomad) with false coloured 2013 Aster image and GIS rivers, roads and land use plan layers, as well as a Google map of Kumasi installed on was used to facilitate the spatial survey. The spatial survey was used to collect ground truth information on the width of rivers and floodplains, as well as identify and record the types, characteristics and nature of land use activities in and along the rivers and floodplains. The widths of most rivers and their riparian buffer zones were systematically and accurately recorded at various sections along their courses using the GPS. In all, about 300 reference data points representing coordinates of the extent of rivers and floodplains, as well as important physical features were recorded.

In addition, photographs of salient physical features such as houses, refuse disposal sites, farmlands in and along rivers and floodplains, as well as floodwater inundation marks on buildings and infrastructure like storm drains were taken with a Digital Camera. Notes were also taken to describe in detail the observed physical conditions and environmental problems. The physically observed information was used to produce a ground truth map to locate training pixels that were used for assessing the
accuracy of the satellite images (Dewan & Yamaguchi, 2009). The spatial survey, however, showed no major errors or inconsistencies in the satellite images.

**Relevance and limitations of the method**

The spatial survey helped the researcher to physically appreciate and acquire deeper understanding of, as well as gather more information on the changes in spatial extent of the rivers and floodplains and the flooding situation, in a way that could not be achieved through the other methods like interviews and focus group. The data collected was used to validate the information on the satellite images and other maps, as well as address parts of research questions one, two and three. Regarding research question one, the method provided data on the extent of the rivers and floodplains and anthropogenic activities along the rivers and floodplains. For research question two, physical evidence was obtained on the weakness of urban management practices, which helped to explain the drivers of the changes in the rivers and floodplains. In relation to research question three, the method provided data on floodwater inundation coverage and levels, physical manifestations of flood effects and flood coping and adaptation measures.

The major limitations of this method related to biases in observations and human errors in the recording of information with the GPS. The likely negative effects of these limitations on the research results were addressed by triangulating multiple sourced data.

3.5.3.5 Secondary data collection

Secondary data consist of information which is collected by other individuals or organisations and archived in a range of forms (Stewart, 1984). These data, which are contained in published and unpublished documents, are useful sources of information for determining the focus and guiding the conduct of meaningful research (Merriam, 1998). Secondary data were collected to supplement the primary data and enhance the understanding of the key conceptual underpinnings of urban growth, changes in inland waters and flood disasters in Kumasi and Ghana as a whole. Secondary data were used in this research because of its ability to support, cross validate and enrich information gathered with other methods such as semi-structured interviews, focus
group and spatial survey, making the researcher more confident about the research results (Paton, 1990; Mohd Noor, 2008). Other advantages of using secondary data in this research included low cost, time saving and ease of access to high quality data.

The secondary data for this research were largely obtained from the urban growth, water resources and flood management institutions in Ghana, and Kumasi in particular. The documentations collected included National Urban Policy and Action Plan, National Environmental Policy and Action Plan, Buffer Zone Policy, National Wetlands Conservation Strategy and Action Plan and National Disaster Management Plan among others. Other secondary data collected were Medium Term Development Plan (2010-2013) and Disaster Management Plan of Kumasi Metropolitan Assembly, relevant newspaper publications, annual and project reports of relevant institutions such as EPA, HSD, NADMO and FRWB, as well as land use plans and maps from TCPD. Most of the secondary information was collected prior to the interviews, which allowed the researcher to relate interview responses to them, and also seek clarifications on certain information in the documents. The documentary evidence was cross-referenced with the primary data collected with the other methods, which enhanced the validity and reliability of the research findings.

Relevance and limitations of the method

The secondary data provided detailed and useful information on the changes in rivers and floodplains, as well as flood incidences at the national level, and in Kumasi. The secondary data were used to address various parts of all the research questions. They were useful in answering research question one by providing information on discharge and water quality of rivers, and the types and processes of urban land use development in water areas. For research question two, the secondary data provided information on strengths and weaknesses of the policies and legislation, rainfall and temperature patterns and trends, urban expansion, physical development and population growth among others, which was used to explain the drivers of the changes in rivers and floodplains. With regards to research question three, data were collected on recorded flood cases and damage, as well as flood coping and adaptation strategies within the city. Nonetheless, there were time gaps and inaccurate presentation of facts in some of the secondary data which affected the pace of the
research, as the researcher had to rationalise such data from multiple sources before using them for the research.

3.5.4 Data analysis

Data analysis is the process of making intelligent and coherent meaning from the research data within the context of a conceptual or theoretical framework (Dzurec & Abraham, 1993). The data analysis process aims to generate descriptive summaries, yield working concepts and establish hypothetical relationships (Neuman, 2003; Onwuegbuzie & Leech, 2005). The interdisciplinary nature of this research required analysis of different data types, and as such multiple data analytical methods were used to appropriately address the research questions. The analytical methods used in this research comprised qualitative (narratives and content analysis), quantitative (descriptive statistics) and spatial (ArcGIS) analysis techniques (see Appendix 1), and these enhanced the making of meta-inferences from the data (Teddlie & Tashakkori, 2003). The development and selection of the analytical processes and methods occurred logically and sequentially, with the research questions being the main drivers. The subsequent sections explain the methods used for analysing the data for this research in detail.

3.5.4.1 Spatial analysis

The processing, manipulation and analysis of the spatial data (satellite images) was done using algorithms supplied with the ArcGIS software and Erdas Imagine. The spatial analysis was done to detect and measure the land coverage of rivers and floodplains, as well as other land uses/covers in Kumasi. The spatial analysis established the trend and nature of the changes in the spatial extent of the rivers and floodplains and other land use/cover changes in the city, over the thirty year period. Prior to the analysis, the satellite images were geometrically rectified and radiometrically corrected to reduce unsystematic geometric errors and atmospheric differences respectively using Erdas Imagine (Yu & Ng, 2007; Deka et al., 2011). The images were also transformed to a common datum – the Ghana Metre Grid – to enhance the positional accuracy of features.
The corrected satellite images were analysed and classified using the ArcGIS Desktop software. Given the medium spatial resolution of the images (20 m) and the predominantly urban land use characteristic of the study area, a hybrid classification scheme was adopted to classify the images into the desired land uses/covers. The hybrid classification approach used in this research was comprised of iso-cluster unsupervised, supervised and visual interpretation classification techniques (Prasad et al., 2009; Islam et al., 2010). First, an iso-cluster unsupervised classification was used to classify the images into twenty land use classes based on their spectrum signatures on the remote sensing images (Du et al., 2010). Using reference data such GIS river layers, land use and topographic maps of Kumasi, and the ground truth information obtained through the GPS assisted spatial survey, one-hundred training samples for each of the twenty land use/cover classes were selected and assessed to determine classes that could be merged.

A supervised classification was subsequently used to refine, rename and merge the classes into three land use/cover classes. The aggregated land use/cover categories derived for the purposes of this research were: urban and bare land-settlements (including residential and industrial areas), vegetation cover (including grassland, forest and woodland) and rivers and floodplains (including rivers, streams, ponds, swamps, wetlands, riparian buffers and valleys). The supervised Maximum Likelihood Classification (MLC) algorithms were applied to the images to produce visually the three land use/cover classes on the images. Further, a post-classification refinement was done using thematic information, ground truth data, visual analysis and interpretation, reference data, as well as local knowledge to correct misclassified land use/cover categories to improve the accuracy of the classification (Dewan & Yamaguchi, 2009).

Finally, the post-classification comparison method was employed to examine changes that have occurred in rivers and floodplains and other land uses/covers, because of its insensitivity to radiometric variations between the scenes, which minimises seasonal impacts of images (Mas, 1999). Consequently, the classified binary raster images were masked out and vectorised for further analysis with the ArcGIS domain to detect and measure the changes in the land uses/covers. The
vectorised multi-temporal land use/cover maps were overlaid to determine the gains and losses in the land cover/use types. Based on the results of overlay analysis, a land use/cover transfer matrix was produced to clearly determine the different land use types that rivers and floodplains are converted to. The land use change matrix showed the extent of the three main land use/cover classes for the three periods, as well as the change in extent of the land uses/cover between 1985 and 2000, 1985 and 2010, and 2000 and 2010.

3.5.4.2 Content analysis and narratives

Content analysis and narratives were used to analyse the textual and documentary data collected in this research. These methods were used for the semi-structured interviews, focus groups and secondary data. There are two types of content analysis, namely qualitative and quantitative content analysis, and both were used in this research (Sandelowski, 2000a). While Morgan (1993) explains qualitative content analysis as a form of reflexive and iterative analysis which summarises the informational aspects of verbal or documentary data; quantitative content analysis involves counting the number of times a particular response is given by research participants from a research instrument (Sandelowski, 2000a; Neuman, 2003). Content analysis was chosen for this study because it enhances probing, revelation and discovery of the full content of research data, as well as accommodating new data and insights about the phenomenon under study (Neuman, 2003).

On the other hand, narrative is an analytical strategy in which the meaning of research data is presented in a story form, using the terminology and concept of the people being studied (Punch, 1998; Neuman, 2003). The use of narratives was based on its ability to capture a high degree of complexity in simple terms, and also to present specific concrete details and explanation of the phenomenon being studied in its natural setting (forestalls the problem of fragmentation and decontextualisation) (Punch, 1998; Neuman, 2003).

The content analysis and narratives focused on categorisation, pattern matching and explanation of the textural data through an inductive and deductive coding process (Rubin & Rubin, 2003). The NVivo software was used to facilitate this process (Kvale, 1996; Rossman & Rallis, 2003). The data were coded using the NVivo
software to identify patterns, themes and ideas that point to conceptual understanding of changes in rivers and floodplains, and incidence of floods. Reflexive notes and memos were made to flag key thematic categories, connections between codes and different data types and any personal reflections. In addition, axial coding was done in order to establish relationships between categories and sub categories. The thematic categories and sub categories were oriented towards the main research aspects and contextual issues, namely changes in rivers and floodplains, drivers of changes in rivers and floodplains, and frequency and intensity of floods. However, the codes and categories were not static, as some were merged and refined to curtail inconsistencies that arose (Bryman & Burgess, 1994). The identified thematic categories and sub categories, as well as the established relationships, were presented and analysed as narratives (storylines) and numerical statistics to explain the changing extent of rivers and floodplains, drivers and flood incidences from the perspective of the research participants. Because the aim of qualitative analysis is to understand issues from the interviewees' point of view, excerpts and quotes from the interviews and focus groups were included within each section to provide examples.

3.5.4.3 Descriptive statistical analysis

Descriptive statistics is a data analysis technique used to summarise and present the basic features of data in a simple but meaningful way (Punch, 1998; Neuman, 2003). They are useful for showing patterns in data and simplifying interpretation. Descriptive statistics was employed to analyse the quantitative data that were collected from institutions and secondary sources, with the aid of Microsoft Excel. The descriptive statistics used in this research included percent, mean, graphs, Mann-Kendall test (Z) and Sen’s slope (Q) among others, and these provided insights into the patterns and trends of many aspects the phenomena studied. In particular, the non-parametric Mann-Kendall test (Z) and Sen’s slope estimator test (Q) were used to detect and evaluate trends in hydro-meteorological parameters such as discharge of rivers, rainfall and temperature in Kumasi (Kahya & Kalaycı, 2004; Yu, Zou & Whittemore, 1993; Babar & Ramesh, 2014). Both Mann-Kendall test (Z) and Sen’s slope estimator test (Q) stipulate that positive values signify an increasing trend and negative values indicates a decreasing trend (Xu, Li & Liu, 2007; Farsani, Roshan, Vahbzade & Solaimani, 2013; Babar & Ramesh, 2014). However, a Z value for the
Mann-Kendall test greater than $Z_{\alpha/2}$ obtained from standard cumulative distribution tables as 1.96 at the standard significance level ($\alpha=p=0.05$), indicates that the observed trend is significant, while Q value for the Sen's slope test depicts the change per unit of time, which is change per year in this research. These tests were preferred in this research as they remain unaffected by outliers/seasonal variations, gross data errors and missing values or data gaps (Xu et al., 2007; Babar & Ramesh, 2014), and both were calculated at the standard confidence level of $\alpha=p=0.05$ in this research.

### 3.6 Development of plausible future scenarios

Scenarios are descriptions of plausible futures along divergent pathways based on ‘if and then’ assertions (Alcamo, Leemans & Kreileman, 1998; Bennett et al., 2005). Scenarios paint pictures of the possible futures of real-world systems and decisions that cannot be predicted by extrapolation of past and current trends (Cork et al., 2005; Rothman et al., 2007). Many authors (e.g., (Alcamo et al., 1998; Bennett et al., 2005; MEA, 2005; Raskin, Monks, Ribeiro, van Vuuren & Zurek, 2005) argue that scenarios widen perspectives, provide insight into critical uncertainties and illuminate the scope of the possible futures to ensure informed and rational environmental decision making and actions now and tomorrow. As a result, scenarios are recognised as valuable tools for looking ahead in time to more distant goals in urban and environmental resource management, and have been extensively utilised in recent local and international environmental assessments (Bennett et al., 2005; MEA, 2005; Rothman et al., 2007; Ozkaynak et al., 2012; Henriques et al., 2015).

In this research, two scenarios, namely Reactive and Proactive Scenarios, were developed to explore plausible futures for rivers and floodplains in Kumasi. As the name imply, the Reactive Scenario emphasises a future with a reactive management approach, while the Proactive Scenario focuses on a future with a proactive management approach. Reactive management is explained as an approach in which rivers and floodplains degradation problems are given low priority, ignored or addressed with ad hoc solutions only after they become apparent. On the other hand, proactive management is an approach in which degradation of rivers and floodplains is duly recognised and addressed with well-planned and tested practices before it becomes severe in the long term. Based on these explanations, the nature of the
scenarios developed were largely characterised by the pathways to, and timings of approaches and actions for managing rivers and floodplains. Thus, by developing the two scenarios, strategies for achieving a sustainable environmental future including the preservation of rivers and floodplains in the city was revealed and emphasised in the preferred scenario (Ozkaynak et al., 2012).

To develop the scenarios, change drivers and pressures were first selected based on their demonstrated significant contribution to the changes in rivers and floodplains in Kumasi (see Chapters 5 & 6). On the basis of revelations in the Chapters, the drivers/pressures selected were population, urban expansion, urban agriculture growth and waste management as well as institutional and socio-political arrangements. However, climate (rainfall and temperature) change and variability were included to determine the possible future impacts of changes in these natural factors. The pressures/drivers were consistent for both scenarios to ensure comparability of future changes in the rivers and floodplains. In general, other change drivers such as regulation of river flow by dam features were held constant across the scenarios, and are not anticipated to affect the rivers and floodplains in Kumasi within the scenario period.

Subsequently, a coherent set of qualitative assumptions or judgments were made about the chosen drivers/pressures, based on an assessment and interpretation of the dynamics of the drivers and the nature of policy frameworks and stakeholder actions learned in Chapters 5 and 6. As a result, the assumptions were informed by the present trends of the drivers/pressures observed in the analysis, and they highlight expectations about the nature of future changes in, and critical uncertainties of, the drivers/pressures under the scenarios. The underlying assumption of the scenarios development was that a change in the current urban, river and floodplain management frameworks in Kumasi could lead to less environmentally deleterious changes in the drivers/pressures. Based on anticipated/assumed changes in the drivers/pressures, scenarios were formulated as Reactive (management framework not changed) and Proactive (management framework changed) (see Table 8.1). These were presented as qualitative judgments since it was not feasible to present in natural
units due to inadequate appropriate data, albeit reflecting the approach of most recent scenario exercises (Alcamo et al., 2005; Bennett et al., 2005).

Finally, narrative storylines that described and explained what drivers/pressures are changing, how and why the drivers/pressures are changing, and the implications of the changing drivers/pressures for the future of rivers and floodplains in Kumasi by 2050 were developed for the two scenarios. The year 2050 was selected to help reasonably reveal future effects of changes in the driving forces on the rivers and floodplains, as well as associated floods (Alcamo et al., 2005; Bennett et al., 2005).

3.7 Reliability and validity of research data

Reliability and validity of data are important and legitimate issues in research, as these indicate the extent to which the researcher counteracts the weaknesses inherent in the adopted research methods (Kvale, 1996; Maxwell, 1992). While reliability relates to the dependability or consistency of measures or research findings under identical or similar conditions, validity refers to the degree of correctness or truthfulness of the match between measures or research findings and conceptual ideas (Neuman, 2003; Bryman, 2004). Reliability and validity have been long established as important determinants of the authenticity, truthfulness, credibility, transferability and/or confirmability of research findings (Adcock, 2001; Neuman, 2003; Onwuegbuzie & Johnson, 2006). Thus, reliability and validity influence the suitability and acceptability of research results as a basis for explanation of a phenomenon, policy formulation or an action (Kvale, 1996; Maxwell, 1992; Amaratunga et al., 2002).

The validity and reliability of data and results of this research were achieved and strengthened in a number of ways. First, the research instruments were pre-tested in a pilot exercise to check consistency and address design errors before their final application in the data collection. The pre-testing provided the researcher with the opportunity to refine the research instruments to ensure that they measured the right concepts to address the research questions. Second, multiple data collection methods (e.g., interviews, spatial survey and focus group) were employed, which allowed the researcher to corroborate, clarify and validate results of one method with that of the
other (Patton, 1990). The reliability and validity of the data gathered from these methods were further strengthened by clearly outlining the purpose of the research to research participants, as well as ensuring that participants understood the questions and provided consistent responses, through refining and probing as the process (that is, interviews and focus groups discussions) progressed.

The use of multiple sources of evidence to address the research questions also enhanced reliability and validity through triangulation and complementarities (Ellram, 1996; Yin, 2003). In particular, secondary data such as policies, legislations and reports were collected from relevant institutions to supplement, triangulate and cross-reference the primary data in order to reduce biases, as well as obtain a holistic, valid and reliable understanding of changes in rivers and floodplains and the associated floods in urban areas. Besides generating new and broader ideas, the focus groups were further used to discuss and validate the initial results of the interviews and spatial survey. Thus, although mixed methods research has been criticised on the grounds that the multiple methods can give rise to contradictory data which threaten validity and reliability (Maxcy, 2003), the various methods used for this research did not produce contradictory evidence, but rather evidence that explored different facets of the phenomena studied.

Moreover, the preliminarily research findings were sent to the interviewees from three relevant institutions namely, Town and Country Planning Department (TCPD), Water Resources Commission (WRC) and National Disaster Management Organization (NADMO) to confirm interpretations, seek clarification and to address any inconsistencies that had occurred. The verification of the preliminary findings by these institutions enhanced the reliability and validity of the results. Finally, the research findings were presented to different audiences at the Charles Sturt University Faculty of Science Annual Higher Degree by Research Symposium. This process provided an opportunity for other academics to assess the appropriateness of the research methods applied, as well as the consistency and accuracy of research results.
3.8 Ethical considerations

A researcher’s decisions and research processes are accompanied by ethical issues (Patton, 1990). Minichiello, Aroni, Timewell and Alexander (1995) define ethics as the system or code of morals that are used to guide a researcher’s actions and research processes. Consequently, ethics are crucial for ensuring the safety of both the researcher and research participants during and after the research activity (Patton, 1990; Minichiello et al., 1995). The Charles Sturt University Human Research Ethics Committee ethical code of conduct was applied to guide this research. The committee granted the ethical approval for this research with protocol number 2013/080, with the main ethical considerations in this research being consent, voluntary participation and confidentiality of the research participants (see Appendix 6). As a result, the researcher obtained the informed consent of all research participants before their involvement in the research, and also assured and ensured their confidentiality and anonymity throughout the research. The various ways in which the ethical issues of this research were handled are discussed below.

Informed consent was gained from the research participants before their involvement in the research in any form or level through a consent form (see Appendix 7). The researcher provided information about the type, nature and purpose of the research to all participants prior to the conduct of interviews and focus groups via the information sheet (see Appendix 8). The research participants at the institutional level were given the information sheet and consent form to read and sign before the interviews commenced. However at the community levels, the researcher translated the informed consent and the information sheet into Akan Language [the local language] for participants who could not read and understand English, before commencing interviews and focus groups. The researcher is a native of the study region and his understanding of the local language was invaluable in this regard. This ensured that the research participants fully understood the purpose of the research, the nature of their involvement in the research, and major uses of the information they provided, which enabled them to grant their informed consent to participate in the research.
The researcher ensured that participants were involved voluntarily. The participants were made aware that their involvement in the research was voluntary, and that they were free to withdraw from the research at any time without affecting the research processes and outcomes, or being subjected to any penalty or discriminatory treatment. Again, photographs of land use activities and interesting features were taken only after obtaining the consent and permission of the relevant research participants and community residents.

Finally, the researcher adopted approaches that ensured privacy, anonymity and confidentiality for all research participants. Confidentiality and anonymity were assured for all the participants and their consent was obtained before the interviews and focus group were tape-recorded. Hard and soft copies of the information were stored in a locked cabinet and on a Charles Sturt University password-protected computer respectively at the researcher’s office. The research participants were identified by loose categories and pseudonyms, and no direct quotes were accompanied by any identifying information in this thesis.

### 3.9 Role of the researcher

The researcher is an integral part of the research process, and his/her role is crucial throughout the research process. The researcher is part of the enquiry, and influences the choice of method, as well as construction of meaning (Greene et al., 1997). For instance, the professional background, as well as the theoretical inclination of the researcher may influence the choice of research topics, geographical scope of study, research paradigms and data collection and analysis methods, which have profound implications for the research process and outcome (Punch, 1994; Breen, 2007). As a result, it has become increasingly imperative for researchers to explicate their roles in the research process for the purposes of credibility, dependability, confirmability, and transferability of research results (Patton, 2002; Breen, 2007).

In this research, the researcher is a native of the region in which the study area is located. The researcher was born and grew up in a village that is located in the same region as the study area. The researcher therefore had the opportunity to visit the study city on several occasions for economic and social purposes while growing up.
as a child in his hometown. For about a decade, the researcher stayed in the study area, and as such has in-depth local knowledge about the city. The researcher pursued his undergraduate studies at the Kwame Nkrumah University of Science and Technology, which is located in the study area. The researcher also worked as a Research and Teaching Assistant in the same university for a year. The researcher is a trained Human Settlement Planner, and has been involved in a number of research projects about the study area, some of which are related to the issues under investigation in this research. The personal association with the study setting and the background interests of the researcher made him consider himself an insider (that is, studying a group or place he belongs to) (Breen, 2007).

The professional background, as well as the personal and ethnic connections of the researcher, had both advantages and disadvantages during this research. The interest in urban river and floodplain degradation and flooding was borne out of the researcher’s observation of the upsurge of unauthorised developments mainly in and along inland waters in cities in Ghana. The rapid and unregulated development of structures in these water areas has made flooding common disasters in many cities in the country (Ahmed & Dinye, 2012). However, little research has been undertaken to ascertain the dynamics of spatial changes in inland waters and the implications for floods, despite the general acknowledgment and awareness (Adarkwa, 2011). As a result, the phenomenon is not well understood by academia and practitioners. This observation spurred the researcher’s interest in exploring how the growth of such uncontrolled land use activities have changed the inland waters into urban lands, and the effects thereof on floods in cities.

The researcher’s long association with the study area coupled with his training as an urban planner was advantageous, in that it provided him with intimate knowledge and general awareness of the incidence of haphazard and unauthorised physical development and floods in the city, as well as the suburbs noted for such occurrences. This was particularly helpful in the conduct of the spatial survey. Again, the researcher’s common ethnic background and awareness of traditional methods of seeking permission helped to establish contacts and networks with the stakeholders in urban growth management of the study area, which facilitated the data collection
(Johnson & Turner, 2003). In addition, the common lineage was also instrumental in boosting the participation and response rate in the research. The researcher’s prior knowledge of the local situation and subject of the study assisted in the selection and adaptation of appropriate data collection methods to suit the study context. Finally, the researcher’s training and extensive knowledge of the array of urban growth management issues, such as environmental, disaster planning and management issues enhanced the data analysis and construction of meanings.

Nonetheless, the researcher’s personal association and familiarity with the study area had potential disadvantages in the research. According to Pitman (2002) the illusion of sameness and familiarity can lead to inadvertent erroneous assumptions with potentially disastrous results. In this research, the researcher’s apparent sense of belonging to the study area, and prior knowledge and/or experience made it difficult to retain ‘objectivity’. Again, the awareness of the researcher’s background by some of the research participants made them appear aggravated sometimes when the researcher was probing for information, as they perceived the researcher already knew the answers.

However, the researcher adopted measures to address the potential negative effects these challenges could have had on the research results. First, the conduct of the research was strictly based on the research procedures without any variations as elaborated earlier. Second, the researcher employed multiple sources of evidence for the purposes of triangulation and complementarity, which helped to eliminate potential biases and subjectivity. The researcher has provided a detailed description of the research participants for the purposes of assessment of the credibility and transferability of the research outcomes by the readers (Breen, 2007). It is hoped that these approaches have eliminated biases, and improved the quality of the research results for wider application in urban growth, water resource and flood management.

### 3.10 Summary

This chapter has explained the research processes and methods employed in this research. This research adopted a pragmatic paradigm to deal with the complexities that were involved in looking at the broader perspectives. A mixed methods research
approach was used by combining and integrating appropriate social science and spatial analysis methods to address the research questions. A case study design was employed, using Kumasi, the second largest city in Ghana, as the study area, from where multiple sources of evidence were gathered to gain deeper and holistic insights into spatial changes in rivers and floodplains and incidences of floods. The mixed methods approach and case study design ensured data triangulation and complementarity, which enhanced reliability, validity and generalisation of the results.

This interdisciplinary research utilised socio-economic, spatial and hydro-meteorological data which were obtained from both primary and secondary data sources. The primary data was collected using semi-structured interviews, focus group discussions and spatial survey through fieldwork undertaken in June-September, 2013. The semi-structured interviews were conducted with twelve officials of relevant institutions involved in urban growth, water resources and flood management in Kumasi, and forty property owners within and along rivers and floodplains in the city. The semi-structured interviews provided insights into land use activities along rivers and floodplains, conditions of the rivers and floodplains, flood cases and damage, as well as policy, legislative and institutional frameworks for managing these phenomena.

The spatial survey was useful in observing and appreciating the nature of changes in spatial extent of the rivers and floodplains, land uses developed in the water areas, and physical manifestations of the effects of flooding, while the focus groups validated information gathered from all the above methods and further offered a much broader of understanding of the study phenomena. In addition, secondary data such as policies, legislation, annual and project reports, as well as newspaper publications were collected to cross-reference the primary data and enhance the researcher’s understanding of the key conceptual underpinnings of urban growth, changes in rivers and floodplains and floods in Kumasi.

A combination of ArcGIS spatial analysis, qualitative narratives and content analysis, and quantitative descriptive statistical analysis was used to interpret the data for this research. The spatial analysis was done using algorithms supplied by ArcGIS.
software to detect and measure changes in the extent of rivers and floodplains and other land uses/covers. Both content analysis and narratives were used to analyse the interviews and focus groups, as well as the qualitative aspects of the secondary data, with the aid of the NVivo software. Descriptive statistics was used to summarise and explain the patterns and trends of quantitative socio-economic and hydro-meteorological data obtained from relevant institutions and secondary sources. The next chapter presents results of the analysis of the state and trends of rivers and floodplains in Kumasi, which essentially address research question one and the State component of the DPSIR framework adopted to frame this research.
Chapter 4 - State and trends of rivers and floodplains in Kumasi

4.1 Introduction

As discussed in Chapter 2, previous studies allude to changes in surface waters, particularly urban rivers and floodplains, in developing countries. These studies indicate that rivers and floodplains are being degraded in terms of spatial extent, water quality and hydrology, and are classified among the most altered ecosystems in these areas (Goonetilleke & Thomas, 2003; Patil et al., 2008; Du et al., 2010; Carpenter et al., 2011). The changes in the spatial extent of rivers and floodplains have particularly attracted the attention of researchers, urban planners and city authorities in recent times because of the resultant damaging flood disasters. It is clear that the spatial extent of rivers and floodplains has been altered through conversion into different land uses and/or degradation of these environments by human and natural factors (Prasad et al., 2009; Du et al., 2010; Islam et al., 2010; Carpenter et al., 2011). Unfortunately, these changes are not holistically understood, as previous research has not clearly established the trends and nature of changes in the spatial extent of rivers and floodplains.

This chapter triangulates data to establish and understand the state of the spatial extent, water quality and hydrology of rivers and floodplains in Kumasi. The results presented in the chapter examine the trends and patterns of changes in rivers and floodplains in the above areas, and address the research question: "how has the spatial extent of rivers and floodplains changed in Kumasi?" In this chapter, changes in the spatial extent of rivers and floodplains over time, as well as the resultant urban land uses, are discussed. Data on the physico-chemical and hydrological characteristics of the rivers are also collated and analysed. In sum, the analyses presented in this chapter reveal the state of rivers and floodplains in Kumasi, and thus address the State component of the DPSIR framework used to frame this research.

Findings are based on data obtained from satellite images, institutional and property owners' semi-structured interviews, focus group discussions and spatial survey. This
chapter again draws on the literature and secondary data on water resources in urban areas in Ghana, and in Kumasi in particular. The spatial data have been used to show the extent of the rivers and floodplains, while interviews and secondary data have provided a description of the state of the rivers and floodplains in terms of their physical extent, water quality and hydrology, as well as the processes by which these are changed. The data were analysed with the aid of software packages ArcGIS and Nvivo, and the results are presented with maps, tables, charts, as well as narratives, which explain the issues from the research participants’ point of views.

4.2 Physical and hydrological characteristics of Kumasi

4.2.1 Topographic and soil conditions

Topography and soil are among the physiographic conditions that influence the exposure to and incidence of flash floods in an area. The topography determines the direction of overland flow while infiltration rates depend largely on the soil conditions (Okyere et al., 2012). Analysis of Kumasi using the Digital Elevation Model (DEM) reveals that the topography is undulating, with lowlands and occasional hills interspersed across the landscape (see Figure 4.1). Elevations range from 250 m to 300 m above sea level, and slopes are generally gentle, mostly less than 5%. There are flat topped interfluvial ridges with widths varying from 1500 m to 2500 m, and they predominantly run in a north-southward direction, causing the greater majority of the city's rivers and surface runoff to flow in that direction. The irregular terrain of Kumasi is explained by its location within the forest dissected plateau physiographic region of Ghana that is prone to advanced tertiary erosion, hence the predominance of dissected landforms in the city (Holland, Kasanga, Lewcock, & Warburton, 1996; JICA, 2013).

The predominant soil type in Kumasi belongs to the Forest Ochrosol soil group that has nearly impermeable sub horizons near the surface (Adjei-Gyapong & Asiamah, 2002). The soil is further divided into six soil associations: Kumasi-Offin Compound Association, Bomso-Offin Compound Association, Nhyanao-Tinkong Association, Bomso-Suko Simple Association, Bekwai-Oda Compound Association and Bekwai-Akumadan-Oda Compound Association (see Figure 4.1). The soils are deeply
weathered with high clay accumulation that is dominated by kaolin, and the texture is silty clay loam. As a result, the soils have high base saturation and are moderately slow to slowly permeable, which leads to fairly high runoff yield (Adjei-Gyapong & Asiamah, 2002; Campion, 2012). The high runoff potential of the soils is because they formed from the weathered lower Birimian System of metamorphosed sediments of Middle Precambrian Rock origin, which has little or no primary porosity (Kesse, 1985; Adjei-Gyapong & Asiamah, 2002).

Figure 4.1 Topographic and soil map of Kumasi. The soil associations are A: Bekwai-Akomadan-Oda Compound Association, B: Bekawi-Oda Compound Association, C: Bomso-Offin Compound Association, D: Bomso-Suko Simple Association, E: Kumasi-Offin Compound Association, and F: Nhyanao-Yinkong Compound Association.

Although the soft and gritty topsoil, as well as the low absorptive capacity of the soils in Kumasi makes the city susceptible to floods, this is countered by the undulating landform. In other words, while runoff cannot flow upward to the relatively higher grounds to cause floods, the runoff generated on those higher grounds and other lowland areas in the city is decelerated by, and/or accumulated in the valleys (Holland et al., 1996; JICA, 2013). These physiographic conditions have largely
remained unchanged over the years, and can partly explain the seasonal waterlogging in valleys, and erosion of topsoil in many parts of the city (Aldrin, 2005).

4.2.2 Patterns and trends of runoff

The mean annual runoff of Kumasi over the period 1961-2013 was 683 mm, suggesting that about 50% of the city's annual rainfall is converted into runoff. As illustrated in Table 4.1, the mean monthly runoff was lowest for January (10 mm) and highest for June (50 mm), which is consistent with the monthly rainfall distribution (see Section 6.6). The coefficient of variation of the annual runoff was 0.32 and this indicates the runoff variability is high by global standards (McMahon et al., 2007). The Mann-Kendall test of the trends of runoff of Kumasi detected a statistically discernible upward trend for the annual runoff of $Z=5.67$), as shown by Figure 4.2. The actual trend of the runoff, as determined using a Sen’s slope estimator, indicated an increase of more than 10 mm per year ($Q=10.36$), accumulating into an increase of 538 mm over the entire period. Additionally, Figure 4.3 reveals an increasing the annual runoff ratio — the proportion of the rainfall that becomes runoff — and this trend was found to be significant based on the Mann-Kendall and Sen’s slope estimator test results of $Z=10.47$ and $Q=0.81$ respectively. Alternatively, the runoff ratio of the city is increasing 0.81% per year, with a cumulative increase of about 42% between 1961 and 2013.

**Table 4.1 Descriptive statistics of runoff in Kumasi (1961-2013)**

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean (mm)</th>
<th>Standard Deviation</th>
<th>Average Runoff Ratio (%)</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>10.54</td>
<td>15.46</td>
<td>52.82</td>
<td>1.47</td>
</tr>
<tr>
<td>February</td>
<td>29.02</td>
<td>22.86</td>
<td>49.04</td>
<td>0.79</td>
</tr>
<tr>
<td>March</td>
<td>58.55</td>
<td>29.88</td>
<td>48.59</td>
<td>0.51</td>
</tr>
<tr>
<td>April</td>
<td>73.19</td>
<td>40.05</td>
<td>50.38</td>
<td>0.55</td>
</tr>
<tr>
<td>May</td>
<td>86.48</td>
<td>38.72</td>
<td>49.19</td>
<td>0.45</td>
</tr>
<tr>
<td>Jun</td>
<td>106.34</td>
<td>55.61</td>
<td>49.77</td>
<td>0.52</td>
</tr>
<tr>
<td>July</td>
<td>71.28</td>
<td>47.08</td>
<td>48.83</td>
<td>0.66</td>
</tr>
<tr>
<td>August</td>
<td>40.35</td>
<td>31.74</td>
<td>48.00</td>
<td>0.79</td>
</tr>
<tr>
<td>September</td>
<td>84.06</td>
<td>53.34</td>
<td>49.83</td>
<td>0.63</td>
</tr>
<tr>
<td>October</td>
<td>79.61</td>
<td>40.66</td>
<td>50.04</td>
<td>0.51</td>
</tr>
<tr>
<td>November</td>
<td>29.93</td>
<td>20.21</td>
<td>47.14</td>
<td>0.68</td>
</tr>
<tr>
<td>December</td>
<td>13.67</td>
<td>14.79</td>
<td>51.13</td>
<td>1.08</td>
</tr>
<tr>
<td>Annual</td>
<td>683.01</td>
<td>215.95</td>
<td>49.41</td>
<td>0.32</td>
</tr>
</tbody>
</table>
The results of the interviews affirm the increasing runoff yield revealed by the statistical analysis, and attribute the trend to the rapid physical expansion of the city. The interviewees indicated that it is common to observe high volumes of water...
flowing through gutters, as well as on bare lands and backyards, following a few minutes of rainfall in the city. Some of the interviewees said that:

“The runoff that passes here is very much. The gutter and most of the places get full few minutes after it starts raining” Property Owner Interviewee [POI] 37, September 2013.

“You know urbanisation in general generates a lot of runoff and Kumasi has been growing fast recently. So because most of the vegetation in the city has been removed by physical expansion, the rainwater doesn't infiltrate much and most of it turns into runoff” Hydrological Services Department [HSD], July 2013.

Thus, runoff generation in Kumasi is increasing due to rapid expansion of built-up areas and their accompanying impermeable surfaces (see Section 5.2), as well as the low absorptive capacity of the soil that hinders rainwater from percolating easily and quickly. This is further underscored by the significant increasing trend of the runoff ratio despite the decreasing rainfall and increasing temperature trends (important determinants of runoff yield [Chen et al., 2015]) as discussed in Section 6.6. The increasing runoff yield in Kumasi is consistent with the claims that impervious surfaces decrease infiltration and increase overland flow, leading to quicker catchment response to rainfall events, and hence increased runoff and peak flows (Douglas et al., 2008; Campion & Venzke, 2013).

4.2.3 Spatial distribution and patterns of rivers

Kumasi falls within the Pra Basin, a sub basin of the South-Western Basin system of Ghana, and is drained by several rivers with dendritic drainage patterns. The rivers form six basins, namely; the Daban (Kwadaso) Basin, Subin Basin, Aboabo Basin, Sisa Basin, Wiwi Basin and Owabi Basin. With the exception of the Owabi basin which orients in a north-western direction, the river basins are oriented in a north-southward direction through the city centre, and converge to form the Sisa Basin which joins the Oda about 9 km south of Kumasi (see Figure 4.4). Floodplains and marshy areas exist along the courses of some rivers, especially those areas that have been statutorily declared as green belts in the city's land use plan. The spatial pattern of the major rivers, which are the Sisa, Subin, Aboabo, Daban, Wiwi and Owabi Rivers are described below.
The Sisa River is the main river in Kumasi and the majority of the rivers join it as tributaries. The Sisa River originates from Kenyase in the Ejisu-Juaben Municipal and enters Kumasi from Duase and Sepe-Timpon in the north-east. The Sisa flows southwards and meanders through the industrial areas of Asokwa, Ahinsan and Kaase in Kumasi. The Aboabo, Subin and Wiwi Rivers join the Sisa River at Asokwa, Atonsu and Ahinsan respectively on its way southward before it merges with the Oda River at Asago, a village about 9 km south of Kumasi. The watershed and length of the Sisa River that lies within Kumasi are about 109 km² and 15 km respectively, making it the longest river in the city. An extensive part of the river’s catchment is low-lying and liable to floods, considering that the rivers receive runoff from the majority of rivers draining the city (Danquah et al., 2011). Given that the catchment of the Sisa River is home to about 80% of Kumasi’s population (GSS, 2013), vigorous land uses such as residential, commercial and industrial have developed within it, increasing anthropogenic induced water pollution of the river.

The Subin River is an urban river that rises out of a spring in the north central part of Kumasi, and runs through the commercial centre of the city. The Subin flows...
southward through the city centre to Asafo and the Kaase Industrial Area and then merges with the Sisa River at Atonsu. It covers a distance of about 11 km from the source to the downstream end. The watershed of the Subin River is about 34 km² and supports about 46% of Kumasi's population, and also highly industrialised and urbanised. Accordingly, Obiri-Danso et al. (2005) report that the Subin River receives untreated waste from breweries, health facilities, an abattoir, wood processing plants, homes, and leachate from a landfill site in the city.

The Aboabo River originates from Tafo-Pankorono along the northern border of Kumasi, and flows southwards to connect with the Sisa River at Asokwa. It has a length of 10 km and catchment area of 24 km² within Kumasi. The Aboabo largely flows through undulating land, with flatter land in the downstream parts which are also marshy and liable to floods. The catchment of the Aboabo River is highly developed and accommodates about one-third (30%) of the city’s population (GSS, 2013). The river's catchment is home to many informal settlements including Aboabo Anloga, Moshie-Zongo, Dichemso, Amakom, Aboabo, Manhyia and Asokwa, as well as several informal economic activities like wood processing industries, auto mechanic shops and washing bays among others, thus exposing the river to extensive pollution.

The Daban River is located in the western portion of Kumasi and rises from the ridges at the central part of the city. It flows in a south-east direction and merges with the Subin at Sokoban. It has a total length of about 9 km, and catchment area of 18 km² that is inhabited by more than a quarter (26%) of the population of Kumasi. However, the catchment has been mainly developed into residential land uses, except around the confluence at Sokoban which falls within the Kaase Industrial Area. The Wiwi River originates from the north-eastern part of Kumasi and flows in a south-west direction. The river runs through the forested area within Kwame Nkrumah University of Science and Technology (KNUST) to join the Sisa at Ahinsan. It has a total length of 11 km, and catchment area of 238 km² which is settled by just 6.4% of the city’s population. The catchment of the river largely lies within a Botanical Garden, with only a small proportion under urban development.
The Owabi River originates from Penkyenmu beyond the north-western boundary of Kumasi and flows through agricultural lands upstream before it eventually enters Kumasi. The Owabi then flows along the north-western margins of Kumasi where it is joined by other tributaries such as the Akose River before emptying into the Owabi reservoir, which is used to supply pipe-borne water to the city. The catchment area and length of the Owabi River within Kumasi are 37 km$^2$ and 5 km respectively, and it is home to one-fifth (20%) of the city's population. A spatial survey found that the catchment area of the Owabi River that falls within Kumasi is developed into several urban land uses, including a small-scale vehicle repair industrial enclave, increasing the potential discharge of effluent into the river.

It is clear that almost all the rivers in Kumasi run through densely populated communities with intensive urban land uses developed within their catchments. This makes them urban rivers (Lerner & Holt, 2012), which are often susceptible to spatial extent, water quality and hydrologic changes.

4.2.4 Physical regulation of water flow

The main form of physical water flow regulation in Kumasi and its environs is the damming of surface waters to supply water for human needs such as domestic, irrigation, and industrial uses. There are two major dams — Owabi and Barekese dams — and an estimated 165 fishponds and reservoirs in and around Kumasi (see Figure 4.5). The Owabi and Barekese Dams are used to abstract and supply water to Kumasi and its environs while the fishponds and reservoirs, which have average depth and length of about 5 m and 10 m respectively, are used for small-scale fish rearing and irrigation (KMA, 2010). The Owabi Dam is located about 10 km North-West of Kumasi on the Owabi River, which is a tributary of the Offin River, a sub basin of the Pra Basin, and has reservoir storage and installed water abstraction capacities of 6.2 million m$^3$ and 13636 m$^3$/day respectively. The Barekese Dam, constructed in 1971, is located about 16 km North-West of Kumasi on the Offin River, a sub basin of the Pra Basin, with reservoir storage and installed water abstraction capacities of 35.3 million m$^3$ and 218000 m$^3$/day respectively. The capacities of the dams suggest that a relatively large quantity of surface water is stored in and withdrawn from the two dams.
However, analysis of interview results reveals that dam and reservoir constructions have not had any impacts on the hydrologic regime of the rivers in Kumasi, due to their location on the North-Western corner away from the city. It was apparent that runoff that flows into rivers within the city is not trapped by any of the dams, which means that the rivers receive all the available hydrologic inputs (runoff). Also, given the locations of the dams and direction of flow of the rivers, water flows in the majority of the rivers are not interrupted by dams/reservoirs in their journeys downstream of the city (see Figures 4.4 & 4.5). Underscoring the low likelihood of the adverse impacts of water flow regulation on the flow regime of the rivers in Kumasi, a close look of Kumasi's drainage map (Figure 4.4) shows that the few north-westerly flowing rivers that empty into the Owabi Dam complete their course by joining the Owabi River as tributaries before eventually emptying into the Owabi

**Figure 4.5 Dams and fishponds/reservoirs in Kumasi**

However, analysis of interview results reveals that dam and reservoir constructions have not had any impacts on the hydrologic regime of the rivers in Kumasi, due to their location on the North-Western corner away from the city. It was apparent that runoff that flows into rivers within the city is not trapped by any of the dams, which means that the rivers receive all the available hydrologic inputs (runoff). Also, given the locations of the dams and direction of flow of the rivers, water flows in the majority of the rivers are not interrupted by dams/reservoirs in their journeys downstream of the city (see Figures 4.4 & 4.5). Underscoring the low likelihood of the adverse impacts of water flow regulation on the flow regime of the rivers in Kumasi, a close look of Kumasi's drainage map (Figure 4.4) shows that the few north-westerly flowing rivers that empty into the Owabi Dam complete their course by joining the Owabi River as tributaries before eventually emptying into the Owabi
Reservoir. In addition, the interview results and drainage map analysis showed that overflows and spilled water from the dams do not affect the flow regime of rivers and runoff in Kumasi, as this excess water flows in a south-westerly direction along the course of the Offin River outside Kumasi. The WRC interviewee explained that:

“The rivers have not been affected by dam constructions. The major dams are located outside the city [Kumasi] and the majority of water impounded in the dams is from rivers beyond the city [Kumasi]….Even spillages from the dams flow through river courses outside city [Kumasi] and those rivers do not overflow to cause flooding...” Water Resources Commission [WRC], June 2013.

Thus, despite the presence of large dams in Kumasi, these do not impact the flow regime of rivers in the city because of the location of the dams, and sources and directions of flow of the rivers. This indicates that loss of rivers caused by physical regulation of stream flow is unlikely in Kumasi. Nonetheless, observable spatial changes have occurred in rivers and floodplains in Kumasi as discussed below.

4.3 Changes in extent of rivers and floodplains in Kumasi

Satellite image analysis shows rivers and floodplains in Kumasi have changed substantially both in number and land area (see Figure 4.6 & Table 4.2). The number of rivers in Kumasi, which was about 63 in 1985, fell steadily to 52 in 2000 and to 34 in 2013. Overall, about twenty-nine rivers were lost, representing a 46% decline in the total number of rivers in the city over 28 years. That is, at least one river together with its floodplain disappeared per year over the period. This was supported by the MBID interviewee who said that:

“…..There are not many rivers in Kumasi now. Most of them have vanished. I can even sit in my office and count the number of rivers left in Kumasi now....” Metropolitan Building Inspectorate Division [MBID], June 2013.

The decline in the number of rivers and floodplains is accompanied by a drastic reduction in their land area, revealing the rapid process by which development is intruding into water areas. The total land area of rivers and floodplains decreased from approximately 38 km$^2$ in 1985, to 27 km$^2$ in 2000 and further to 6 km$^2$ in 2013. There was a large decline in the extent of the rivers and floodplains between 2000 and 2013, a period of rapid growth of the city and its environs (see Sections 5.2 & 6.2). The land area of rivers and floodplains decreased by 32 km$^2$ between 1985 and
2013, at an annual change rate of 1.2 km$^2$ y$^{-1}$. The area of the rivers and floodplains fell by about 83% over the 28 year period, with the extent in 2013 representing 17% of that of 1985.

Figure 4.6 Land use/cover maps of Kumasi for 1985, 2000 and 2013
Table 4.2 Changes in number and area of rivers and floodplains (1985-2013)

<table>
<thead>
<tr>
<th>Period</th>
<th>1985</th>
<th>2000</th>
<th>2013</th>
<th>Change Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Rivers</td>
<td>63</td>
<td>52</td>
<td>34</td>
<td>-17</td>
</tr>
<tr>
<td>Area of Rivers &amp; Floodplains (km²)</td>
<td>38</td>
<td>27</td>
<td>6</td>
<td>-30</td>
</tr>
</tbody>
</table>

In addition, spatial survey and results of satellite image analysis show that the mean water body size (MWBS) – width of rivers, floodplains and riparian zones – decreased from 23 m in 1985 to 20 m in 2000 and to 13 m in 2013. Likewise, the density of rivers fell from 0.25 rivers per square kilometre in 1985 to 0.20 and 0.13 rivers per square kilometre in 2000 and 2013 respectively.

Interviews with institutional and property owners highlighted the dramatic spatial change in the rivers and floodplains. The interviewees described the physical extent of the rivers using morphological features such as width and depth. The interviewees indicated that although many of the rivers in Kumasi had wide and deep channels, as well as large floodplains and riparian buffer zones in the past, these have substantially reduced in recent years. The FRWB interviewee explained that:

“...Yes, the spatial extent of the rivers and floodplains has reduced, and the reduction is very drastic. The rivers used to be very wide and deep but almost all of them have shrunk. So the status of the rivers ten or twenty years ago was not what we are seeing today and if we are not very careful in the next ten years we won’t see any viable river in the city......” Friends of Rivers and Water Bodies [FRWB], June 2013.

Many of the respondents expressed similar views and emphasised that many of the rivers had dried and vanished, leading to a drastic decline in the number of rivers that drain the city. The interviewees described the reduction in the spatial extent of the rivers and floodplains as rapid and obvious, and indicated that all such water areas are likely to disappear considering how they are being affected by urban development.

Thus, results from the satellite images and interview analysis demonstrate that an appreciable number of the rivers and floodplains in Kumasi have vanished, with the few existing ones subjected to morphological changes, which collectively reduce the
spatial extent of the aquatic areas. This reduction in the spatial extent manifests in different forms as discussed in the subsequent subsection.

4.3.1 Nature of rivers and floodplains spatial extent change

An overlay analysis of the historical land cover maps reveals that Kumasi’s rivers and floodplains are mainly changed into urban land uses, although there are a few cases of change into vegetated land. As illustrated in Table 4.3, between 1985 and 2013 an estimated 88% of the 32 km² reduction in the land area of rivers and floodplains was replaced by urban land cover. This conversion was more pronounced during 2000-2013, when about 18 km² (88%) of the entire 21 km² rivers and floodplains area converted went into urban land use development.

Table 4.3 Rivers and floodplains land area conversion matrix

<table>
<thead>
<tr>
<th>Period</th>
<th>Conversions from rivers and floodplains to other land uses</th>
<th>Remaining rivers and floodplains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conversion to urban</td>
<td>Conversion to vegetation</td>
</tr>
<tr>
<td>1985-2000</td>
<td>10</td>
<td>89</td>
</tr>
<tr>
<td>2000-2013</td>
<td>18</td>
<td>88</td>
</tr>
<tr>
<td>1985-2013</td>
<td>28</td>
<td>88</td>
</tr>
</tbody>
</table>

Discussions with the interviewees also highlighted the increasing intensity of urban functional land in and along the rivers and floodplains. The interview results indicate that the rivers and floodplains have been changed into urban land uses either through rezoning by the city authorities, direct purchase from the chiefs/landowners or self-occupancy by the developers. Some of the institutional interviewees (e.g., MBID and FRWB) explained that the structures that were constructed on rezoned lands were considered authorised developments, while the opposite is the case of those which were put up on illegitimately sold customary lands or self-occupied lands. The interviewee at FRWB explained that:

“….Nowadays people build any structure be it a house, shop or something along and in rivers and floodplains anyhow….You can find any type of activities along the rivers if you should walk along them…and they take over these lands by themselves; but some also manage to get support of corrupt officials within the KMA so that the
As illustrated in Table 4.3, change of rivers to vegetated land was very limited. It is therefore obvious that urban functional land is the main land use benefitting from the conversion of the rivers and floodplains. This illustrates the intensification of urban development in Kumasi and its associated increased conversion of rivers and floodplains (see Section 5.2). Given the intense transfer of rivers and floodplains to urban lands, the next subsection examines the types and nature of these land uses.

4.3.2 Land uses within river and floodplain areas

Various urban land uses, albeit largely illegal and unauthorised, have developed within 100 m from almost all the rivers and floodplains in Kumasi. The land use activities identified within these areas can be categorised as residential, commercial, industrial, civic and cultural, and nature reserve and recreational. Although the area of these urban land uses could not be determined due to the low spatial resolution of the satellite images used for this research, their prevalence, nature, and adverse effects on rivers and floodplains were made apparent through interviews and spatial survey.

4.3.2.1 Residential land use

Residential structures are the most common land use development within 100 m of the rivers and floodplains. The majority of the houses are temporary structures built from mainly wood and sometimes blocks, and also arranged haphazardly (see Figure 4.7a), which largely exhibit characteristics of informal settlements inhabited by the urban poor (Ahmed & Dinye, 2012; Campion & Venzke, 2013). The temporary wooden structures are mainly one-room single storey houses, and were mostly observed in suburbs such as Moshie-Zongo, Sepe and Aboabo along Aboabo River; Dakwadwom along Daban River; and Atonsu, Ahensan and Ahensan Estates along Sisa River. Nevertheless, there are some well-designed permanent structures built solely from blocks in and along the rivers and floodplains. The permanent structures comprise of traditional compound, detached and semi-detached houses, reflecting the general housing typology in Kumasi (Afrane & Asamoah, 2011). These permanent structures are prevalent in locations such as Adiembra and Kwadaso Estates along
Daban River; Ahodwo and Adiebeba along Subin River; and Kronum and Bremang along Owabi River, which are predominantly inhabited by medium to high income earners (Amoateng et al., 2013). The TCPD interviewee explained the pattern of the residential land use:

“...The residential developments comprise of temporary wooden and permanent concrete structures but they’re often illegal and unauthorised by us [TCPD]. The temporary structures are mostly single storey but the permanent buildings range from single to four storeys. And the pattern is such that most of the temporary structures are in a cluster form and with little or no housing facilities...” Town and Country Planning Department [TCPD], June 2013.

Additionally, the interviews revealed that the majority of structures are less than a decade old, although there are some which have existed for about two decades, especially those which are at the edges of the 100 m range from the rivers and floodplains. This suggests that intense conversion of rivers and floodplains to residential and other urban land uses is a recent phenomenon. It was also observed that many of the houses, especially the permanent structures, have been earmarked for demolition by the KMA due to unauthorised construction, yet the dates for the demolition have passed and no actions have been taken, with people still occupying the structures. This illustrates the low commitment of the city authorities to control of the conversion of the rivers and floodplains to different land uses.

4.3.2.2 Commercial land use

Several commercial activities are carried out in and along the rivers and floodplains in Kumasi. These include food vending, street trading, retail shops, car washing bays, petrol and gas filling stations, sewing and tie and dye making (see Figure 4.7b). Commercial operators typically erect temporary structures such as wooden kiosks or metal containers within the riparian areas, with the exception of vehicle washing bays and petrol and gas filling stations that often occupy large areas of land. The commercial activities are highly concentrated along Subin, Aboabo and Sisa Rivers, which flow through the city centre. Extensive commercial activities are common in locations like Kumasi Central Market Area and Kaase along Subin River, Airport Roundabou, Dichemso, Aboabo and Moshie-Zongo along Aboabo River, which are the purported hubs of informal economic activities in Kumasi (Afrane & Ahiable, 2011).
4.3.2.3 Industrial land use

Regardless of their adverse environmental impact, several large- and small-scale industrial activities have developed in and along rivers and floodplains in Kumasi. The industrial activities include wood processing, auto mechanic shops, abattoirs, breweries, metal processing and water packaging. They are prevalent along Subin, Aboabo, Sisa and Owabi Rivers, which run through places such as Kaase Industrial Area, Kumasi Central Market, Aboabo, Asokwa, Anloga Junction, Oforikrom and Suame among others, where the bulk of both large and small industries in Kumasi are located. The small-scale industries operate in temporary wooden kiosks and metal containers that are erected on banks of rivers and in floodplains (see Figure 4.7c).

4.3.2.4 Civic and cultural land uses

A number of civic and cultural land uses have developed in and along rivers and floodplains. Common civic and cultural land uses identified included churches, schools, mosques and shrines among others. The interviews results indicate that the development of religious buildings, especially churches, in the water areas has been on the rise in recent times, a phenomenon which can be attributed to the growing Pentecostalism in the country as a whole (Gifford, 2004). The “one man” churches, in particular, capture the available nature reserves along the rivers and develop either permanent or temporary structures as places of worship. The interviewee at WRC remarked that:

“Interestingly enough it is the religious buildings such as churches and mosques that are mostly developed in the waterways and buffer zones in Kumasi of late. Some of the developments are temporary wooden structures and others are permanent concrete structures” WRC, June 2013.

As expressed in the above quote, a number of churches and mosques are found in and along rivers and floodplains in locations like Ahensan, Aboabo, Moshie-Zongo, Sisanso and Dichemso (see Figure 4.7d). Regrettably, it was observed that most of the religious buildings and schools have channelled their toilet facilities into the nearby rivers.

Also, traditional belief in Ghana is that rivers are spirits and lesser gods (Opoku-Agyemang, 2005); therefore shrines are located along some of the rivers, including
Subin, Sisa and Owabi Rivers. Despite the traditional significance of the shrines, the interviewee at the FWRB, who doubles as a chief, indicated that activities such as libation and animal sacrifice that are performed in the shrines contaminated the rivers. He revealed that the blood of the slaughtered animals is poured into the rivers, and this contaminates the rivers and creates obnoxious odours several months after the traditional sacrifice. Thus, cultural land uses and practices if not well managed can negatively affect the spatial extent and water quality of rivers.

4.3.2.5 Nature reserve and recreational land use
This land use type is limited, despite being a requirement of the Buffer Zone Policy, based on its importance in controlling pollutants and runoff that cause water quality degradation, and also in preventing the drying up of rivers. This land use has virtually been lost, although green belts that coincided with the river channels were consciously designated in the "Garden City of West Africa" land use plan prepared for Kumasi in 1945 by the British Colonial Administrators (Abloh, 1972). This land use type is only prevalent along the course of Wiwi River, especially at KNUST, while patches of it are located along a few rivers such as Subin River at Kaase, Daban River at Dakwadwom, Aboabo River at Anloga Junction and Moshie Zongo and Owabi River at Afrancho. With the exception of the nature reserves along the Wiwi at KNUST and Daban River at Dakwadwom that have many trees, the reserves were dominated by grasses. Unfortunately, none of the nature reserves meet the acceptable riparian buffer zone width of 100 m for urban rivers (WRC, 2008). Also, it was apparent that only the nature reserve along Daban River at Dakwadwom is used for recreational purposes (see Figure 4.7e). The nature reserve at this location has been acquired and developed as a children’s park —Otumfuo Children’s Park— by FRWB, for use as a playground, as well as a public education and durbar ground.

It is clear from the above analysis that rivers and floodplains in Kumasi have been and/or are being utilised for different urban land uses. Also, the increasing development of these incompatible urban land uses has resulted in the implicit loss of useful and approved land uses like nature reserves along the rivers. The resultant urban functions do not only take up and reduce the rivers’ and floodplains’ extent,
but have also instigated increasing deterioration of water quality of the rivers, as discussed in the next section.

4.4 Changes in water quality of rivers in Kumasi

Analysis of water quality data in Kumasi between 1991 and 2012, obtained from the Environmental Protection Agency (EPA) in Kumasi, revealed water pollution that varied widely, and also deviated from the acceptable limits (EPA, 2009). The data indicated a general deterioration of the physico-chemical and bacteriological
characteristics of rivers in Kumasi. Statistics of water quality parameters of the rivers are presented in Tables 4.4 & 4.5 and Figures 4.8-4.9.

4.4.1 Temperature (T)

The yearly average temperature of all rivers in Kumasi increased from 25.7°C in 1991 to 28.7°C 2012 indicating a rise of about 3.0°C, with an overall annual average of 27°C (see Table 4.4 and Figure 4.8a). The average annual temperature of the individual rivers ranged from 25.5°C to 28.8°C over the period (see Table 4.5). Accordingly, the yearly average temperature of the majority of the rivers was above the acceptable limit of 25°C for freshwater habitats (EPA, 2009). The analysis of the temperature showed that Subin was the warmest river in Kumasi as it recorded the highest annual average temperature of 28.8°C, and the yearly average temperature also increased from 26.1°C in 1991 to 31.8°C in 2012, indicating a rise of about 5.7°C over the period (see Figure 4.9a). These high temperatures could promote concentration of ionic pollutants, as well as induce thermal stress that threaten species balance in, and productions of ecosystem services by the rivers (Sharma et al., 2010).

4.4.2 pH

With an annual average pH value of 7.3, the yearly average pH values of all rivers in Kumasi increased by approximately 1.7 from 6.5 in 1991 to 8.2 in 2012 (see Table 4.4 & Figure 4.8b). As presented in Table 4.5, the annual average pH values of the majority of the rivers were within the acceptable range (EPA, 2009). The pH values of the individual rivers were mostly acidic (6.62-6.78) and neutral to alkaline (7.06-10.60) in 1991 and 2012 respectively. However, the Sisa River recorded the highest annual average pH value of 8.3, with its yearly average pH value increasing by 3.8 from 6.8 in 1991 to 10.6 in 2012, to exceed the upper limit of the acceptable range (see Figure 4.9b). The increasing trends of the pH values suggests rivers are polluted by heavy metals mainly from small-scale industries, and these could hinder planktonic development, as well as render the river water unhealthy for domestic purposes (Sharma et al., 2010; Monney et al., 2013).
4.4.3 Biological Oxygen Demand (BOD)

BOD in all rivers was above the stipulated limit throughout the period. Annual average BOD of all rivers in Kumasi over the period was 197.8 mg L$^{-1}$, and the yearly average increased from 131.8 mg/L in 1991 to 269.5 mg L$^{-1}$ in 2012, reflecting a 104% increase over the 21 year period (see Table 4.4 & Figure 4.8c). For the various rivers, the annual average BOD concentration ranged from a minimum of 46.7 mg L$^{-1}$ in Wiwi River to a maximum of 460 mg L$^{-1}$ in Subin River, which are all above the allowable limit (EPA, 2009). The highest BOD was found in Subin River, which recorded an annual average of 449 mg L$^{-1}$ and also witnessed a change of about 46% in the yearly average BOD from 369 mg L$^{-1}$ in 1991 to 538 mg L$^{-1}$ in 2012 (see Table 4.5 & Figure 4.9c). The high BOD concentration indicates that the rivers are extremely polluted by organic pollutants that create anaerobic conditions in rivers, as well as lower the potential of the rivers to support aquatic life due to reduced dissolved oxygen (Akoto, Bruce & Darko, 2010; Monney et al., 2013; Owusu-Sekyere, Aasoglenang & Bonye, 2014).

4.4.4 Dissolved Oxygen (DO)

Concentration of DO in the rivers was largely below the desirable limit, and exhibited a significant decrease between 1991 and 2012. The overall annual average DO of the rivers over the period was 1.4 mg L$^{-1}$. The yearly average DO of all rivers in Kumasi decreased from 2.5 mg L$^{-1}$ in 1991 to 0.5 mg L$^{-1}$ in 2012, which is equivalent to a 78% reduction (see Table 4.4 & Figure 4.8d). The annual average DO of the individual rivers ranged from 0.9 mg L$^{-1}$ in Aboabo River to 3.0 mg L$^{-1}$ in Wiwi River, below the required level of 5 mg L$^{-1}$ set by the EPA (see Table 4.5). Throughout the period, only the DO concentration in the Wiwi River in 1991 met the stipulated limit of greater than 5 mg L$^{-1}$. DO concentration in all the rivers including Wiwi River had declined to unacceptable levels by 2012. The Aboabo River, which had an annual average DO of 0.9 mg L$^{-1}$, experienced the highest reduction in DO concentration, from 1.6mg L$^{-1}$ in 1991 to 0.2 mg L$^{-1}$ in 2012, indicating a 91% decrease over the period (see Figure 4.9d). The presence of DO below the optimum indicates pollution by high oxygen demanding organic matter, as well as increased
bacterial activity in the rivers, making them unsuitable to support aquatic life (Danquah et al., 2011; Monney et al., 2013; Owusu-Sekyere et al., 2014).

4.4.5 Total Suspended Solids (TSS)

TSS levels were generally beyond acceptable limits for natural waters (20-60 mg L\(^{-1}\)) (EPA, 2006), and underwent a substantial increase in all the rivers over the period. With an overall annual mean TSS of 221.2 mg L\(^{-1}\), the yearly average TSS of all rivers in Kumasi increased by 123% from 137.7 mg L\(^{-1}\) in 1991 to 306.6 mg L\(^{-1}\) in 2012 (see Table 4.4 & Figure 4.8e). In relation to the individual rivers, the annual average TSS was from 92 mg L\(^{-1}\) for Owabi River to as high as 396.3 mg L\(^{-1}\) for Subin River (see Table 4.5). The Subin River recorded the highest TSS concentration, with an annual average of 396.3 mg L\(^{-1}\), and an increase of 50% in the yearly average from 421 mg L\(^{-1}\) in 1991 to 631.8 mg L\(^{-1}\) in 2012 (see Figure 4.9e).

These high TSS levels increase turbidity of the water and make it appear murkier, thus reducing light penetration required for photosynthesis and phytoplankton formation to support aquatic organisms (Monney et al., 2013; Salih, Alkarkhi, Lalung & Ismail, 2013).

4.4.6 Total Dissolved Solids (TDS) and Electrical Conductivity (EC)

Although the TDS concentration and EC predominantly remained within acceptable limits over the period (EPA, 2009), both exhibited considerable increases by 2012. The similar pattern of TDS and EC levels could be explained by the fact that the latter is caused by the concentration of the former, as well as ionised species in the water (Akoto et al., 2010). The annual average TDS and EC levels of all rivers in Kumasi from 1991 to 2012 were 318.2 mg L\(^{-1}\) and 523.5 µS cm\(^{-1}\) respectively, and these are all within the acceptable ranges of 600-1000 mg L\(^{-1}\) and 700 µS cm\(^{-1}\) respectively (see Table 4.4). Although the yearly average TDS concentration of all rivers in Kumasi increased dramatically by about 168% from 199.8 mg L\(^{-1}\) in 1991 to 535.5 mg L\(^{-1}\) in 2012, it remained within the acceptable limits (see Figure 4.8f). For the various rivers, the annual average TDS levels ranged between 123.7-534 mg L\(^{-1}\) over the period (see Table 4.5). The highest concentration was found in Subin River, which had an annual average of 448.3 mg L\(^{-1}\) and also experienced approximately 440% change in yearly average TDS concentrations, from 189 mg L\(^{-1}\) in 1991 to
1020 mg L\(^{-1}\) in 2012, thereby slightly exceeding the permissible limit as shown in Figure 4.9f.

Likewise, yearly average EC levels of all rivers in Kumasi increased by 261% from 246.3 µS cm\(^{-1}\) in 1991, to 890 µS cm\(^{-1}\) in 2012, which is above the EPA (2009) acceptable prescribed limit (see Figure 4.8g). In relation to the individual rivers, the annual average EC levels were between 225.7 µS cm\(^{-1}\) in Owbai River, and 745.3 µS cm\(^{-1}\) in Sisa River (see Table 4.5). However, the Subin River recorded the highest EC level, with an annual average of 709 µS cm\(^{-1}\) over the time frame, and also witnessed a 365% increase in the yearly average EC concentration from 279 µS cm\(^{-1}\) in 1991 to 1296 µS cm\(^{-1}\) in 2012 (see Figure 4.9g). The high TDS and EC levels point to increased salinity and eutrophication, as well as the reduced palatability of water in the rivers, which threaten aquatic life, and also cause long-term health problems if utilised by humans (Kempster, Van Vliet, & Kuhn, 1997; Akoto et al., 2010; Monney et al., 2013).

4.4.7 Faecal Coliform (FC)

FC concentration grossly exceeded the acceptable limit of zero counts per 100 millilitres (0/100 mL\(^{-1}\)) throughout the period (EPA, 2009), indicating widespread faecal pollution of the rivers. With a general mean annual count of 3.65x10\(^{7}\) CFU/100 mL\(^{-1}\), the yearly average FC concentration in the rivers in Kumasi increased from 4.53x10\(^{6}\) CFU/100 mL\(^{-1}\) in 1991 to 8.00x10\(^{7}\) CFU/100 mL\(^{-1}\) in 2012, representing a rise of about 1665% over the period (see Table 4.4 & Figure 4.8h). In the case of the various rivers, the annual average FC counts ranged between 1.73x10\(^{6}\) CFU/100 mL\(^{-1}\) and 8.61x10\(^{7}\) CFU/100 mL\(^{-1}\) in Wiwi and Subin Rivers respectively, all far above the acceptable limit (see Table 4.5). The yearly average FC levels of Subin River increased substantially by about 2029% from 9.3 x10\(^{6}\) CFU/100 mL\(^{-1}\) in 1991 to 1.98x10\(^{8}\) CFU/100 mL\(^{-1}\) in 2012, as the most heavily contaminated river in Kumasi (see Figure 4.9h). The elevated faecal coliform concentrations in the rivers are signs of heavy pollution by disease causing pathogens, which makes the rivers unsuitable for any meaningful use (WHO, 2006; Akoto et al., 2010). The high levels of faecal coliform could have detrimental health effects on both humans and aquatic animals,
as the concentrations are within the infectious diseases region of $10^6$-$10^{10}$ (Akoto et al., 2010; Monney et al., 2013).

In summary, the trend analysis of water quality parameters between 1991 and 2012 demonstrated that the rivers are polluted beyond most acceptable limits. The water quality of many of the rivers exceeded the acceptable range of most of the physical, chemical and bacteriological parameters assessed. The pattern of pollution level of the rivers was such that the pollution is higher in rivers such as Subin, Aboabo and Sisa Rivers, which flow through the more urbanised and central parts of Kumasi (see Figure 4.4). The quality of water is deteriorating at an alarming rate, and this has rendered the rivers unfit for any useful purposes, as well as severely impaired the aquatic ecosystem dynamics of the rivers, including water flows and discharge.

Table 4.4 Descriptive statistics of average water quality parameters for all rivers in Kumasi from 1991 to 2012

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>EPA standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (ºC)</td>
<td>27</td>
<td>1.5</td>
<td>&lt;25</td>
</tr>
<tr>
<td>pH</td>
<td>7.3</td>
<td>0.9</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>BOD (mg L(^{-1}))</td>
<td>197.8</td>
<td>69</td>
<td>&lt;3</td>
</tr>
<tr>
<td>DO (mg L(^{-1}))</td>
<td>1.4</td>
<td>1</td>
<td>&gt;5</td>
</tr>
<tr>
<td>EC (µS cm(^{-1}))</td>
<td>523.5</td>
<td>331</td>
<td>&lt;700</td>
</tr>
<tr>
<td>TSS (mg L(^{-1}))</td>
<td>221.2</td>
<td>84.5</td>
<td>20-60</td>
</tr>
<tr>
<td>TDS (mg L(^{-1}))</td>
<td>318.2</td>
<td>188.4</td>
<td>600-1000</td>
</tr>
<tr>
<td>FC (CFU/100 mL(^{-1}))</td>
<td>3.65×10(^7)</td>
<td>3.91×10(^7)</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Adapted from EPA, (2001; 2009; 2012)
Figure 4.8 Yearly average water quality parameters for all rivers in Kumasi in 1991, 2001 and 2012
Source: Adapted from EPA, (2001; 2009; 2012)
Table 4.5 Descriptive statistics of water quality parameters for major rivers in Kumasi from 1991 to 2012

<table>
<thead>
<tr>
<th>River</th>
<th>Parameter</th>
<th>T (°C)</th>
<th>pH</th>
<th>TSS (mg L⁻¹)</th>
<th>TDS (mg L⁻¹)</th>
<th>EC (µS cm⁻¹)</th>
<th>DO (mg L⁻¹)</th>
<th>BOD (mg L⁻¹)</th>
<th>FC (FCU/100 mL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sisa (A)</td>
<td>Mean</td>
<td>28.0</td>
<td>8.3</td>
<td>198.3</td>
<td>339.7</td>
<td>745.3</td>
<td>1.3</td>
<td>267.7</td>
<td>5.27×10⁷</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>2.3</td>
<td>2.0</td>
<td>113.7</td>
<td>159.8</td>
<td>337.6</td>
<td>0.7</td>
<td>155.1</td>
<td>5.32×10⁷</td>
</tr>
<tr>
<td>Subin (B)</td>
<td>Mean</td>
<td>28.8</td>
<td>7.5</td>
<td>396.3</td>
<td>448.3</td>
<td>709</td>
<td>1.3</td>
<td>449</td>
<td>8.61×10⁷</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>2.8</td>
<td>0.9</td>
<td>248.8</td>
<td>495.8</td>
<td>526.4</td>
<td>1.5</td>
<td>84.9</td>
<td>9.91×10⁷</td>
</tr>
<tr>
<td>Aboabo (C)</td>
<td>Mean</td>
<td>27.6</td>
<td>7.3</td>
<td>367.7</td>
<td>534</td>
<td>718.7</td>
<td>0.9</td>
<td>299</td>
<td>7.14×10⁷</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>2.3</td>
<td>0.5</td>
<td>201.9</td>
<td>296</td>
<td>606.6</td>
<td>0.8</td>
<td>152.4</td>
<td>7.93×10⁷</td>
</tr>
<tr>
<td>Daban (D)</td>
<td>Mean</td>
<td>25.5</td>
<td>7.2</td>
<td>152</td>
<td>255</td>
<td>423</td>
<td>2.2</td>
<td>65.3</td>
<td>3.97×10⁶</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>1.4</td>
<td>0.7</td>
<td>103.1</td>
<td>48.8</td>
<td>156.4</td>
<td>1.5</td>
<td>7.5</td>
<td>1.16×10⁷</td>
</tr>
<tr>
<td>Owabi (E)</td>
<td>Mean</td>
<td>25.5</td>
<td>7.2</td>
<td>92</td>
<td>123.7</td>
<td>225.7</td>
<td>1.5</td>
<td>59.3</td>
<td>2.89×10⁶</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.7</td>
<td>0.8</td>
<td>39.2</td>
<td>103.8</td>
<td>225</td>
<td>0.5</td>
<td>8.5</td>
<td>1.56×10⁶</td>
</tr>
<tr>
<td>Wiwi (F)</td>
<td>Mean</td>
<td>25.8</td>
<td>6.6</td>
<td>121</td>
<td>208</td>
<td>319.3</td>
<td>3.0</td>
<td>46.7</td>
<td>1.73×10⁶</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>1.4</td>
<td>0.4</td>
<td>75.6</td>
<td>47.1</td>
<td>171.1</td>
<td>1.0</td>
<td>6.1</td>
<td>6.66×10⁵</td>
</tr>
</tbody>
</table>

Source: Adapted from EPA (2001; 2009; 2012)
Figure 4.9 Yearly average water quality parameters for major rivers in Kumasi
Source: Adapted from EPA, (2001; 2009; 2012)
4.5 Trends of water flow and discharge of rivers in Kumasi

Analysis of gauge height measurements in Kumasi between 1993 and 2012 obtained from the Hydrological Services Department (HSD) showed a mean annual discharge of 16.09 m$^3$ s$^{-1}$. The data revealed that the flow regime of rivers has a high flow season – from March to October – with annual average discharge of 11.62 m$^3$ s$^{-1}$, which represents about 72% of the overall mean annual flow. The low flow season – from November to February – has an annual average discharge of 4.47 m$^3$ s$^{-1}$, representing 28% of the general annual average flow (see Table 4.6). This means that a larger proportion of river flows occurs in the high flow period during the rainy seasons, indicating the potential of the rivers to overflow their banks and flood physical developments along them and in their floodplains (see Section 7.3).

The coefficient of variation of annual flows is 0.17, indicating low variability of the year to year mean flow of the rivers compared to the global standard of 0.27 (McMahon, Vogel, Peel, & Pegram, 2007). However, Mann-Kendall (Z) and Sen’s slope (Q) tests results demonstrated a significant decreasing trend (Z=-3.08 and Q=-0.33 at p=0.05) in the total annual discharge of the rivers as illustrated by Figure 4.10. The general downward trend reveals the decreasing volume of water available in rivers in Kumasi, a situation that has mainly resulted from conversion of the rivers and floodplains to physical developments.

Table 4.6 Descriptive statistics of discharge from rivers in Kumasi from 1993 to 2012

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean (m$^3$ s$^{-1}$)</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.95</td>
<td>0.30</td>
<td>0.32</td>
</tr>
<tr>
<td>February</td>
<td>1.03</td>
<td>0.32</td>
<td>0.31</td>
</tr>
<tr>
<td>March</td>
<td>1.26</td>
<td>0.35</td>
<td>0.28</td>
</tr>
<tr>
<td>April</td>
<td>1.36</td>
<td>0.34</td>
<td>0.25</td>
</tr>
<tr>
<td>May</td>
<td>1.48</td>
<td>0.31</td>
<td>0.21</td>
</tr>
<tr>
<td>Jun</td>
<td>1.54</td>
<td>0.32</td>
<td>0.21</td>
</tr>
<tr>
<td>July</td>
<td>1.50</td>
<td>0.22</td>
<td>0.15</td>
</tr>
<tr>
<td>August</td>
<td>1.48</td>
<td>0.30</td>
<td>0.20</td>
</tr>
<tr>
<td>September</td>
<td>1.51</td>
<td>0.25</td>
<td>0.17</td>
</tr>
<tr>
<td>October</td>
<td>1.48</td>
<td>0.23</td>
<td>0.16</td>
</tr>
<tr>
<td>November</td>
<td>1.34</td>
<td>0.25</td>
<td>0.19</td>
</tr>
<tr>
<td>December</td>
<td>1.16</td>
<td>0.35</td>
<td>0.30</td>
</tr>
<tr>
<td>Annual</td>
<td>16.09</td>
<td>2.74</td>
<td>0.17</td>
</tr>
</tbody>
</table>
The interviews and spatial survey emphasised the small and decreasing quantity of water available in and flowing through rivers in Kumasi, as reflected by the mean annual and seasonal discharges. It was apparent from the interviews that the generally low discharges of the rivers, especially in the low season, often make these water areas appear suitable for development, a situation which encourages the acquisition of such areas for physical development by desperate land seekers. Some of the interviewees explained the situation as follows:

“....The volumes of water in the rivers have drastically reduced now. For many of the river channels, you can’t even notice there is water flowing through them unless it rains or there is flooding. The water volumes are small and keep on decreasing over time which I think is due to the encroachment at the sources...” HSD, June 2013

“I didn’t notice a river here when I came to acquire my land. The place was very dry and there were no signs of surface water or marshy area here” POI 1, July 2013

Personal observations found that parts of many river channels were experiencing a small volume of water flowing through them while others were completely dry (see Figure 4.11). Some interviewees, including the HSD interviewee, revealed that the water that flows through many of the rivers is largely due to the wastewater that is discharged from the various homes. The HSD interviewee commented that:
“...People have directly connected wastewater channels into some of the rivers. So at least you can find dry water flow in them most of the time although it is mainly wastewater which is very little and dirty .......” *HSD, June 2013.*

The analysis has revealed a trend toward drying of rivers in Kumasi, as indicated by the decreasing discharge of the rivers. The decreasing discharge could have adverse impacts on the aquatic environment and ecological functioning of the rivers. The reducing flow indicates that the rivers have less capacity to dilute and degrade pollutants, leading to high levels of pollution (Marengo, Tomasella & Uvo, 1998). The limited discharge could undermine the ability of the rivers to process nutrients due to poor aeration, and thus result in low concentration of dissolved oxygen, a situation which could threaten the lives of aquatic organisms (Marengo et al., 1998; Baer, 2007). The slow-flowing nature of the rivers contributes to the high level of siltation and sedimentation that makes the river beds and floodplains apparently suitable for physical development.

### 4.6 Summary

This chapter has outlined changes in the rivers and floodplains in Kumasi based on the *State* component of the DPSIR framework. The results presented in the chapter addressed the research question: “how has the spatial extent of rivers and floodplains changed in Kumasi?” The data used in the chapter were obtained from multiple sources such as satellite images, spatial survey, semi-structured interviews, focus group discussions, and secondary data and documentary analysis. These different
data sources have proved useful in providing an understanding of the state of, and nature of changes in rivers and floodplains in Kumasi.

First, the analysis has revealed several important issues about the spatial changes in rivers and floodplains in Kumasi. It emerged that the pathways of the rivers through highly urbanised areas in Kumasi make them vulnerable to abuse by urban dwellers. Consequently, there has been a drastic reduction in the number and area of rivers and floodplains over the past three decades. This reduction in spatial extent has resulted in a decrease in width and depth of many rivers and floodplains in the city, with some disappearing altogether. The rivers and floodplains are largely converted to ecologically insensitive urban land functions such as residential, commercial and industrial, while acceptable land uses like nature reserves in the form of buffer zones are virtually lost along the rivers.

Second, the analysis indicates that the rivers in Kumasi are heavily polluted. The water quality parameters are either above acceptable limits or below desirable limits, and the level of deterioration had increased over the years. The interviews and spatial survey results attribute the increasing pollution to anthropogenic activities in and along the rivers.

Third, it was discovered that the discharge of the rivers is experiencing a significant decreasing trend. The average annual discharge is generally low and has the potential to negatively affect aquatic organisms, as well as further compound the problem of water pollution as the water volume is too small to dilute or carry away pollutants.

Thus, the rivers and floodplains in Kumasi have deteriorated in terms of spatial extent, water quality and discharge over the years. Having now covered these changes, the next chapter explores the processes through which the changes occurred, to address research questions one and two in part, as well as the Pressures element of the DPSIR framework. The examination of these factors is critical in order to understand and explain how the changes in rivers and floodplains occurred in Kumasi.
Chapter 5 - Pressures on rivers and floodplains in Kumasi

5.1 Introduction

Having examined the changes in rivers and floodplains in Kumasi, this chapter focuses on the pressures that account for these changes. Pressures are the processes and/or forces through which an environmental change occurs. According to UNEP (2007), environmental pressures are usually by-products of environmental change drivers, and have varying characteristics and importance from one place to another, but often act synergistically to degrade and/or change environmental elements like rivers and floodplains at various levels. As a result, an in-depth description of the environmental pressures does not only offer a measure of how driving forces acting at catchment levels affect rivers and floodplains, but also serves as a useful basis for policy frameworks for these inland water systems (MEA, 2005; UNEP, 2007). Unfortunately, these aquatic environment degradation pathways have not been systematically and holistically ascertained and examined in many urban contexts, especially in developing countries.

The results presented in this chapter lead to a discussion of how changes in rivers and floodplains in Kumasi have occurred. The analysis explains the processes of reduction in spatial extent of rivers and floodplains, the deterioration in water quality and the decrease in discharge or flow levels. The rivers and floodplains change pathways identified in the context of Kumasi and discussed in this chapter include encroachment, land filling, urban expansion, urban agriculture growth, poor waste management and eutrophication. Essentially, the analysis in this chapter answers parts of research questions one and two while addressing the Pressures component of the DPSIR framework.

The data used in this chapter were obtained from semi-structured interviews of institutions and property owners, focus group discussions, spatial surveys and satellite images. To triangulate these data sources, literature and official documents such as reports and policies, as well as local land use plans of Kumasi, were utilised. The data from the interviews and focus group discussions were coded and analysed using the NVivo software to identify predominant themes, while the spatial data was
analysed with ArcGIS software to derive historical land cover maps. Results are presented with different methods including narrative texts, descriptive statistics, charts and maps among others. These multiple methods were imperative in order to derive a holistic description and understanding of the pressures on the rivers and floodplains.

5.2 Unregulated expansion of urban land use/built-up area

Rapid and unregulated expansion, which is related to population growth, is one of the major pressures on rivers and floodplains in Kumasi. Analysis of the historical land use/cover maps and statistics indicates that the built-up areas of Kumasi have expanded considerably over the past 28 years (see Figure 4.6 and Table 5.1). The built-up area increased by approximately 73 km$^2$ from 1985 to 2000 and 90 km$^2$ from 2000 to 2013, which is an average of 4.9 km$^2$ y$^{-1}$ and 6.89 km$^2$ y$^{-1}$ between 1985 and 2000, and 2000 and 2013 respectively. The net increase in urban areas from 1985 to 2013 was about 162 km$^2$, with an annual average of 5.8 km$^2$ y$^{-1}$.

Consequently, there have been significant increases in the extent of urban land cover at the expense of natural land covers, such as vegetation and rivers and floodplains, over the study period (see Figures 4.6 and 5.1). Urban land occupied only 44 km$^2$ representing about 17% of the total land area in 1985, but increased steadily by 162% to 116 km$^2$ in 2000, and by a further 77% to 206 km$^2$ to become the largest land cover (that is, 81%) in 2013. Overall, the built-up areas expanded by about 372% during the period 1985 to 2013 (see Figure 5.1), indicating a rapid growth in the physical extent of the city.

An overlay analysis of the land use/cover maps and close examination of the change detection statistics reveals that the urban expansion has mainly involved the conversion of natural areas, comprising vegetation and rivers and floodplains, into built-up areas (see Table 5.2). Of the entire urban area in 2000, only 38% was unchanged urban land, while about 54% was converted from vegetation and 9% from rivers and floodplains. Again, of the overall urban area in 2013, only 57% was existing urban land while 34% of the total was converted from vegetation and 9% from rivers and floodplains. It is apparent that the rapidly but poorly regulated
expanding built-area of Kumasi has been invading and replacing water areas in the city.

**Table 5.1 Areas of land by land use/cover type (1985-2013)**

<table>
<thead>
<tr>
<th>Year</th>
<th>1985</th>
<th>2000</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use/Cover</td>
<td>Area (km²)</td>
<td>%</td>
<td>Area (km²)</td>
</tr>
<tr>
<td>Rivers and Floodplains</td>
<td>38.49</td>
<td>15.15</td>
<td>27.03</td>
</tr>
<tr>
<td>Vegetation</td>
<td>171.88</td>
<td>67.67</td>
<td>110.65</td>
</tr>
<tr>
<td>Urban</td>
<td>43.63</td>
<td>17.18</td>
<td>116.32</td>
</tr>
<tr>
<td>Total</td>
<td>254</td>
<td>100.00</td>
<td>254</td>
</tr>
</tbody>
</table>

**Figure 5.1 Changes in areas of land use/cover in Kumasi (1985-2013)**

**Table 5.2 Matrix of urban land use in Kumasi (1985-2013)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Existing Urban</th>
<th>Rivers and Floodplains</th>
<th>Vegetation</th>
<th>Total Urban Land</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (km²)</td>
<td>Percent</td>
<td>Area (km²)</td>
<td>Percent</td>
</tr>
<tr>
<td>2000</td>
<td>43.63</td>
<td>37.51</td>
<td>10.15</td>
<td>8.73</td>
</tr>
<tr>
<td>2013</td>
<td>116.32</td>
<td>56.48</td>
<td>18.04</td>
<td>8.76</td>
</tr>
</tbody>
</table>

The interviews provided insight into the nature of the physical expansion and the land cover changes. The interviewees explained that Kumasi has expanded to engulf what were originally different settlements, and that the current city has been an
amalgamation of hitherto independent villages into one urban landscape. An interviewee commented,

“....Kumasi is growing very fast. When I was in my twenties, Kumasi was just a small place and the development was only in the central part. But now the city has become very large and development has spread to every part of the city and even beyond the boundaries. For instance, now when you are driving along the Kumasi-Accra road, you realise that Kumasi is engulfing towns like Kwamo and Fumesua [peri-urban settlements] among others....” FRWD, June 2013.

This quote supports Figure 4.7 which shows the built-up areas, which were mainly concentrated in the central part in 1985, have expanded evenly in all directions through 2000 to 2013 to every part of the city. The institutional interviewees explained that the rapid expansion is primarily caused by the increasing population size and urbanisation level, but is largely unchecked by strategic planning considerations. Thus, the expansion of the built-up areas occurs mostly at the expense of the vegetation and rivers and floodplains in the city.

While the interview results largely attribute the expansion of the built-up areas into the rivers and floodplains to land shortages, increasing land prices and growing demand for housing, further investigation revealed that the phenomenon is also promoted by the desire of the people to live in and/or close to the city centre. Given that the course of most of the rivers is through the city centre, interviews with the property owners revealed that some preferred to occupy the “freely available” land along these rivers instead of developing on suitable lands at the outskirts, due to the proximity of such locations to the city centre as against the long distance and high transport fares to the city centre from the outskirts. Interviewees said that:

“.....The city centre location of the rivers is a contributory factor. Many people want to stay in the CBD and be closer to or find work yet the land in CBD is finished. So what happens at the CBD are redevelopments of old structures and/or encroachment upon the rivers flowing through the place. People try all possible means to reclaim the rivers and nature reserves in the CBD to erect all kinds of structures all in the name of proximity to work and high accessibility....” TCPD, June 2013.

“.....We prefer this location because it is close to the city centre where we work. Someone offered to sell to us a more suitable land at Kenyansi [a peri-urban settlement] at the time we were searching for land but we chose this location because of the short distance to the city centre. We are able to walk to work from here even when we don’t have money for bus/taxi fares.....” POI 10, July 2013.
5.2.1 Processes of urban land use expansion into rivers and floodplains

Discussions with the interviewees, as well as the researcher’s field observations revealed that the urban land uses expansion affects rivers and floodplains through two main processes namely: encroachment and land filling. The nature and prevalence of these processes are elaborated in the subsequent sections.

5.2.1.1 Encroachment

Encroachment, which changes rivers and floodplains to urban land uses, is the most widespread process affecting rivers and floodplains in Kumasi. Analysis of interviews results suggest that the encroachment is mainly done by squatters who occupy the riparian areas illegally, and sometimes by desperate land seekers who are deceitfully sold waterlogged areas in the dry season by landowners when those places appear suitable for development. The interview results indicate that encroachment occurs incrementally, and commences with the construction of structures along the banks of rivers or sometimes extending into the rivers. The owners of the structures then start to gradually reclaim the rivers and floodplains by dumping earthen material or refuse in these areas. It was apparent that the encroachers undertake these activities either to provide more land for development or forestall adverse effects such as flooding. An interviewee said that:

“*We had wanted to stay here temporary at first but now we wish to continue staying here and that is why we have started using blocks for our structures. We dump waste on the sides of the stream and then put up our structures when the place becomes dry. Also, you see how I have built these short walls? I will continue to build gradually, and extend the walls towards the river so that I can have enough land for another room and also prevent the floodwater from entering here*” POI 11, July, 2013.

Most encroachments are undertaken by low income earners who do not have adequate resources to finance outright land filling. These encroachers often put up temporary and substandard structures that may be replaced with permanent structures over time (see Figure 5.2a). One interviewee explained the category of people who encroach upon rivers and floodplains:

“...*We the poor live here and we don’t even have proper land documentations. As you can see, most of us living here have not been able to put up any better structures.*
Those with money to put up better structures do that on suitable lands...” POI, 21, August 2013.

Further probing revealed that many of the encroachers do not have all the requisite development permits, apart from the land allocation notes issued to some of them by the landowners. The interviewees argued that encroachment had become a common practice in Kumasi due to the city authorities’ failure to stop development of the structures at the outset or demolish completed ones, as well as the ability of encroachers to outmanoeuvre the city authorities. The FRWB interviewee remarked that:

“They [encroachers] put up the structures at night and on weekends to avoid being noticed by the city authorities. ....At times the officials [of KMA] overlook some of the developments that are undertaken at the full glare of everyone because of connivance” FRWB, June 2013.

Thus, the loss of rivers and floodplains through encroachment occurs gradually. The encroachment results in the diversion, siltation and shrinkage of the river channels that eventually lead to the disappearance of the rivers. The continuous shrinkage and disappearance of the rivers and floodplains through encroachment threaten inland water systems in the city.

5.2.1.2 Land filling

The land filling process involves piling up of earthen and other miscellaneous materials such as sand and logs in rivers and low-lying areas to raise the elevation (see Figure 5.2b). This practice creates new sites for putting up structures for several purposes including residential. One of the property owner interviewees who identified himself as a builder, and as such had been involved in a number of land filling activities explained the process:

“We fill the rivers/floodplains with sand to raise the lands so we can put up the structure on them. In filling, we pour the sand in the river channel and then use the bulldozer to compact and harden it. We use several tonnes of sand for the filling and it can take about two to three weeks to complete the size of a plot” POI 20, August 2013.

It can be inferred from the above quote that land filling is an expensive process and as such usually done by wealthy people who have the financial capacity to afford the high cost of the materials and earth moving machines used. Despite the high cost
involved, the interview results indicate that the practice has become widespread in recent times, and that it was undertaken either without the awareness of government agencies or in connivance with some officials within those agencies. The prevalent nature and processes of land filling activities in Kumasi was explained by the FRWB interviewee and an article in a national daily newspaper.

“The last ten years saw people filling rivers/floodplains with sand to reclaim the lands. The land filling has been happening at every corner of the city. But what is worrying is that people who are in positions to check these are always involved in the process so they see the filling but are unable to take any action” FRWB, June 2013.

“...At the moment, wetlands and streams in some suburbs of Kumasi are being reclaimed by some private land developers who have filled the wetlands with soil, purposely to claim lands to put up structures for business purposes.....The latest wetland in Kumasi to have come under serious threat is the former Mobil Depot at Asokwa where a new owner has heaped quantities of soil beyond the main depot stretching it into the wetland....and claiming portions of the wetland at the former Mobil Depot takes place only at night. Although the attention of the KMA has been drawn to the operations currently ongoing it is yet to act.....’Daily Graphic, 22nd February, 2012.

Land filling leads to the immediate disappearance of rivers and floodplains, and thus disrupts the hydrological system (Joshi & Suthar, 2002; Islam et al., 2010). Therefore, the rising incidence of the practice explains the rapid diminishing number and land area of rivers and floodplains in Kumasi.

![Figure 5.2 Processes of rivers and floodplains conversion to urban land uses](image)

In summary, the spatial data and interviews have demonstrated the fast and uncontrolled expansion of urban land uses and its adverse impacts on the rivers and floodplains through encroachment and land filling in Kumasi. The rapid but unregulated urban expansion process of Kumasi has caused widespread degradation and loss of rivers and floodplains by converting them to urban land uses. Although
the land area of the rivers and floodplains invaded by urban land uses (28 km²) is relatively small when compared to cases reported in cities in Asian countries (Prasad et al., 2009; Du et al., 2010; Islam et al., 2010; Zhang, Ke & Shang, 2014), it is very significant in the local context, considering that the process has resulted in a drastic reduction in the extent of these water areas in the city. In Kumasi, the built-up areas (e.g., residential, commercial and industrial) have expanded into the rivers and floodplains for various reasons, including cheap prices of river and floodplain land, proximity to the city centre, shortage of suitable land in the city, the perception of water areas as “no man’s land”, illegitimate sale by chiefs/land owners and unscrupulous rezoning of water areas by city officials.

5.3 Growth of unplanned urban agriculture

Another important pressure on rivers and floodplains in Kumasi is the growing urban agriculture, a key sub-sector of the informal economy in the city. Given the worsening poverty and economic conditions in Kumasi, analysis of data on employment distribution obtained from GSS and KMA reveals that an increasing number of the labour force is engaging in urban agriculture as a source of food supply, employment, income generation and livelihood (see Table 5.3). The urban agricultural activities comprise cropping and the production of livestock, poultry and ornamental plants (horticulture). Cropping was the most dominant urban farming activity and largely involved the cultivation of vegetables such as tomato, lettuce, cucumber, cabbage, cauliflower, carrot, capsicum, and spring onions, as well as staple food items like plantain, maize and cassava (see Figure 5.3). Consequently, it has been reported that about 90% of all lettuces and spring onions consumed in the city is produced internally by urban farmers, who earn about US$400-800 per annum, which is about twice the amount rural farmers earn (Danso, Drechsel, Wiafe-Antwi & Gyiele, 2002).
Table 5.3 Participation in urban agriculture and informal economy in Kumasi (1960-2010)

<table>
<thead>
<tr>
<th>Year</th>
<th>Informal Economy (IE)</th>
<th>Urban Agriculture (UA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Population</td>
</tr>
<tr>
<td>1960</td>
<td>41,015</td>
<td>9,027</td>
</tr>
<tr>
<td>1970</td>
<td>67,333</td>
<td>11,229</td>
</tr>
<tr>
<td>1984</td>
<td>122,465</td>
<td>22,888</td>
</tr>
<tr>
<td>2000</td>
<td>278,688</td>
<td>35,389</td>
</tr>
<tr>
<td>2010</td>
<td>465,918</td>
<td>46,468</td>
</tr>
</tbody>
</table>


Nonetheless, both the institutional and property owner interviewees argued that urban agriculture, as well as other informal economic activities, has not been well integrated into the urban space of Kumasi, and as a result their spatial locations and modus operandi are negatively affecting rivers and floodplains in the city. According to the interviewees, the situation occurs because of the lack of demarcated agricultural or farming lands on the city’s land use plans. The interview results indicate that much of the urban farming occurs on river banks and floodplains, as well as valleys, which are delineated as unsuitable for physical development on the city’s land use plans. Consequently, interviews and spatial survey found that vegetable farms, with an average individual farm size of 0.1-0.2 ha, are located in and along almost all the rivers and floodplains in the city (see Figures 5.3 & 5.4).

Figure 5.3 Urban agricultural activities in Kumasi
Given the “unauthorised” spatial location of urban agricultural activities, some of the cultural practices carried out by the urban farmers negatively impact the rivers. First, it was observed that the farmers either dig shallow wells in the rivers, or construct trenches to divert water from the rivers onto their farms to provide the needed water for irrigation to sustain all year round production. However, these actions often terminated the flow of the rivers downstream; due to the low discharge of many of the rivers (see Section 4.5).

Interviews with some urban farmers revealed that the production is input intensive, as they use significant amounts of organic and inorganic fertilisers, herbicides and pesticides to increase quantity and improve quality of produce. However, further investigations with the farmers and the KMA interviewee indicated that the quantities and types of the nutrients and pesticides applied are based on crude farming practices, as the farmers do not have the requisite knowledge for appropriate application of agrochemicals, and also do not receive support from extension officers. Accordingly, the EPA and WRC interviewees asserted that leachate and
runoff from the farmland pollute the rivers due to excessive application of fertilisers and pesticides. The interviewee at EPA for example explained that:

“...We have been recording high levels of chemicals such as Nitrogen (N) and Phosphorus (P) in the streams at places like Ahensan, Gyinyase and Atonsu [urban farming communities] in our [EPA] recent analyses. I think...the concentration of such toxics is caused by seepage and excesses of agricultural fertilisers from the farms around those areas. The trend is quite disturbing considering the threats the chemicals pose to aquatic habitat and human health...” Environmental Protection Agency, [EPA], June 2013.

In addition, personal observation of the effects of urban agricultural activities established that the indiscriminate dumping of farm wastes, such as stems of plantains and accumulation of sand from eroded beds in the rivers, lead to siltation and clogging of the rivers. Further, it was observed that the farmers use slash and burn methods to prepare their lands, and this leads to loss of riparian zones, and thus exposing the rivers to direct sunshine that increases the rate of evaporation and subsequent drying of the rivers (Ahmed & Dinye, 2012).

In summary, the quantitative and qualitative data analyses show that the rapidly growing but not well spatially integrated urban agricultural activities have negatively affected rivers in Kumasi. While the river courses and floodplains are encroached upon and used as farmlands, farming practices such as irrigation and agrochemical application also deteriorate water quality of the rivers, and these result in complete disappearance of the water areas in the long run.

5.4 Poor waste disposal and management practices

Poor waste management is another pressure affecting rivers and floodplains in Kumasi. Despite the increasing rate of daily waste generation that accompanied the rapid population growth of Kumasi (see Table 5.4), the waste management systems and facilities in the city remain highly inadequate and ineffective, leading to indiscriminate disposal of waste in rivers and floodplains. Available statistics indicate that average daily solid generation nearly tripled from 600 tonnes in 1995 to 1,626 tonnes in 2013, and it is further expected to more than triple to 5,004 tonnes in 2033 at an annual rate of 4% (KMA, 2013; Japan International Cooperation Agency (JICA), 2013). However, in 2013, only 1,200 tonnes of daily solid waste generated
was collected, leaving one-fifth uncollected on a daily basis (KMA, 2013). Thus, a sizeable proportion of the solid waste generated ends up being indiscriminately dumped or carried by runoffs into rivers and drains.

A similar situation occurs with the management of liquid waste comprising wastewater and human faecal matter. As presented in Table 5.4, the average daily wastewater generation in Kumasi was 29,120 m$^3$ in 2013, and this is expected to nearly quadruple by 2033 (JICA, 2013). However, less than 10% of the daily wastewater generated is collected through the simplified sewerage system and treated with waste stabilisation ponds (WSP’s) or trickling filters. As a result, about 90% of the wastewater generated in the city is disposed of into drains and open areas without any treatment, and eventually ends up in the rivers. In addition, it is estimated that about 6% of the population of Kumasi lacks access to toilet facilities, and as such indiscriminately defecate into rivers and nature reserves (KMA, 2010). This situation is compounded by the report that open defecation into rivers is also widespread among some of the estimated 38% of the city’s population that depend on public toilets, but try to escape the untidiness and/or costs of accessing the facilities (Dahlman, 2009).

<table>
<thead>
<tr>
<th>Year</th>
<th>Solid Waste</th>
<th>Liquid Waste (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount (tonnes)</td>
<td>Amount Increase (tonnes)</td>
</tr>
<tr>
<td>1995</td>
<td>600</td>
<td>-</td>
</tr>
<tr>
<td>2005</td>
<td>1,000</td>
<td>400</td>
</tr>
<tr>
<td>2010</td>
<td>1,500</td>
<td>500</td>
</tr>
<tr>
<td>2013</td>
<td>1,626</td>
<td>126</td>
</tr>
<tr>
<td>2018</td>
<td>2,166</td>
<td>540</td>
</tr>
<tr>
<td>2023</td>
<td>2,904</td>
<td>738</td>
</tr>
<tr>
<td>2028</td>
<td>3,833</td>
<td>929</td>
</tr>
<tr>
<td>2033</td>
<td>5,004</td>
<td>1,171</td>
</tr>
</tbody>
</table>

Source: JICA, (2013); KMA, (2013)

Results from interviews and spatial survey affirm the poor waste management practices, and emphasise the contributions to degradation and reduction in spatial extent of rivers and floodplains in the city. It was apparent that indiscriminate dumping of refuse into the rivers and floodplains was prevalent in Kumasi, especially
in the communities within the water areas, due to the absence of communal disposal sites within them, as well as dumping fees charged at disposal sites in nearby communities. As a result, the occupants of the houses and operators of the business and industries, as well as the farmers in and along the rivers and floodplains, have turned them into “free” waste disposal sites. Interview results further reveal that people who live afar also either carry their wastes to dump into the rivers or dispose of waste in nearby drains during rainfall events for the runoff to convey them into the rivers. Some of the interviewees said that:

“We throw our refuse into the river. There is no disposal site nearby and we cannot walk all the way to dump refuse at Atonsu Market [location of communal rubbish dump site]. So that’s why we dump our refuse into the river. But we sometimes pile up the refuse on the river bank and burn it after about a week” POI 27, August 2013.

“People from other communities also come to throw their rubbish into the river because no one charges them for dumping here. Such people usually come to dump at dawn when we’re asleep, to avoid being seen by us” POI 9, July 2013.

In accordance with the above quotes, not only were heaps of refuse such as plastics and plantain stems in the rivers and floodplains common scenes, but several people were also observed dumping garbage in these areas during the spatial survey (see Figure 5.5). Accordingly, piles of refuse were observed inside and along rivers such as Subin River at Kaase and Kumasi Central Market; Sisa River at Atonsu, Ahensan and Sisanso; and Aboabo River at Moshie-Zongo and Aboabo, while some rivers were found to be completely dry, with their channels filled with both biodegradable and non-biodegradable wastes that made them appear like refuse disposal sites.

Figure 5.5 Indiscriminate dumping of garbage along rivers and in floodplains
Given that many of the houses located along the rivers are substandard and as such without housing facilities like toilets, the occupants, especially children were observed openly defecating around and in the rivers and floodplains. The interviews and spatial surveys results indicate that domestic and industrial wastewater is thrown directly into open drains, which means it eventually ended up in the rivers. Interactions with the institutional interviewees and personal observations further revealed that the septic tanks of flush toilets and pit latrines of many houses, as well as effluent tanks of some industries and commercial activities, have been channelled straight to some of the rivers in the city. Some of the institutional interviewees said that:

"Yes, untreated wastewater is directly disposed into the rivers here [Kumasi]. Some houses and industries strategically build so that their liquid waste can go straight into the rivers.....Typical examples of these are the houses and industries located along the Aboabo and Subin Rivers at Oforikrom and Kaase [suburbs of Kumasi] respectively. I have also observed that wooden bathrooms have been constructed right across the Subin River at Asafo [suburbs Kumasi]..." Kumasi Metropolitan Assembly [KMA], June 2013.

“......Many people in this city indulge in unsanitary practices such as urinating, defecating and dumping of garbage into rivers. Some people intentionally channel waste from their homes directly into the rivers while others defecate and urinate directly in rivers, as well as into plastic bags which eventually find their way into the rivers.... Also leachates from many rubbish dump sites including the Oti landfill site at Dompoase enter into some of the rivers......These conditions have been increasing the biological load of the rivers, so when we [EPA] test water quality the faecal coliform count is always high...” EPA, June 2013.

“A lot of people come to this area to dump refuse and defecate into the stream...and many houses in this community have channelled their septic tanks directly into the river. I will blame the city authorities for all this because they don’t come around to do inspections....”POI, July, 2013.

Considering the magnitude of haphazard disposal of wastes, both property owners and institutional officials admitted that the practice immensely contributes to the extinction of the rivers and floodplains in Kumasi. According to the interviewees this occurs through: (i) pollution - deterioration of water quality of the rivers; (ii) eutrophication - excessive nutrient enrichment of water that leads to the growth of invasive weeds; and (iii) sedimentation/siltation- accumulation of non-biodegradable wastes within river courses and floodplains; which cumulatively lead to eventual disappearance of these inland water systems.
Underscoring the effects of unsanitary conditions, the EPA interviewee revealed that water quality analyses conducted by the EPA showed high levels of faecal coliform and heavy metals due to pollution by garbage waste, wastewater, night soil and industrial effluents. Personal observation also found that the water flowing through many of the rivers had a blackish colour (e.g., Akosua River at Suame near the Suame Auto-Mechanical Workshop), and the polluted water emitted a stench that could be smelled up to several kilometres away. In addition, many rivers were completely dry and the channels fully taken over by invasive weeds such as *Eichhornia crassipes*, *Egeria densa*, *Pennisetum purpureum* and *Tamaricaceae*, making them appear as vegetation when observed from satellite images, and ultimately reducing the number and land area of rivers in the city.

The statistical and interview data demonstrate that poor sanitation practice is a key environmental pressure that account for both spatial extent and water quality changes in rivers in Kumasi. The indiscriminate disposal of solid wastes and discharge of untreated and/or poorly treated liquid wastes into rivers have promoted pollution, eutrophication and sedimentation of rivers; with consequential loss of these rivers and their floodplains in the city.

### 5.5 Summary

The results in this chapter have described the factors and processes that directly account for changes in rivers and floodplains in Kumasi in line with the *Pressures* element of the DPSIR framework. The issues discussed answer aspects of key research questions: “how has the spatial extent of rivers and floodplains changed in Kumasi?” and “what anthropogenic factors account for the changes in the spatial extent of rivers and floodplains in Kumasi, and how do these interact?” The data utilised in the chapter were drawn from multiple sources including semi-structured interviews, focus groups discussions, satellite images, spatial surveys, and existing literature. These data aided better understanding of the dynamics of pressures on rivers and floodplains in Kumasi.

First, the analysis shows that the largely unregulated rapid expansion of urban land uses has resulted in encroachment and infilling of rivers and floodplains. It was
apparent that the urban extent of Kumasi more than quadrupled between 1985 and 2013, with about 9% of the built areas being converted from rivers and floodplains. The spatial analysis results show that about 73% of the land area of rivers and floodplains was lost to urban land uses over the period, leading to a reduction in the extent of these aquatic areas.

Second, it was determined that Kumasi is characterised by precarious waste management practices that have negatively affected rivers and floodplains in the city. About 300 tonnes of the daily solid waste generated is uncollected, and as such is indiscriminately dumped in waterways, while close to 90% of the liquid waste generated is directly discharged into rivers and open areas without any treatment. Also, an increasing number of the residents lack access to toilet facilities and openly defecates in and along the rivers and floodplains. Thus, a substantial proportion of waste generated in Kumasi ends up in the rivers, causing water pollution and blockage of flow.

Finally, the analysis reveals that a growing informal urban agricultural sector in Kumasi is mainly undertaken at unauthorised locations along rivers and in floodplains, with adverse impacts on these aquatic systems. This urban agriculture affects and contributes to loss of the rivers and floodplains through clearing of riparian areas for farmlands, and discharge of farm wastes and excess agro-chemicals into rivers.

It can be concluded that the changes in spatial extent and water quality of rivers, as well as floodplains in Kumasi occur through pressures exerted by or connected with anthropogenic processes. The next chapter therefore explores the drivers that account for these pressures, as well as the changes in rivers and floodplains with emphasis on the anthropogenic changes, in response to research question two and the Drivers component of the DPSIR framework. The analysis of these drivers is essential to understanding and explaining why the changes in rivers and floodplains have occurred in Kumasi.
Chapter 6 - Drivers of change in rivers and floodplains in Kumasi

6.1 Introduction

It was established in Chapter 5 that rivers and floodplains in Kumasi have degraded due to pressures exerted by change drivers. The MEA (2005) defines a driver as any factor that changes an aspect of an ecosystem or environmental resource such as rivers and floodplains. Drivers – anthropogenic or natural – often interact and operate synergistically to alter environmental elements, as well as the ecosystem services they provide. Consequently, knowing and understanding these drivers of change in the various environmental elements are critical to designing interventions that capture positive impacts and minimise negative ones (MEA, 2005; UNEP, 2007). Regrettably, not only are the drivers of change in rivers and floodplains not clearly identified in many urban situations in developing countries, but their levels of influence and interactions that complicate the adverse consequences are also not well understood.

The results presented in this chapter explore the change drivers to provide insight into why the changes in rivers and floodplains in Kumasi occurred. The drivers affecting rivers and floodplains identified and described in this chapter represent those most commonly discussed by the research participants. The drivers discussed in the chapter include anthropogenic factors such as population growth, land ownership and administration, policy, legislative and institutional framework, as well as natural factors like rainfall and temperature patterns in Kumasi. Ultimately, the analysis addresses the question “what anthropogenic factors account for the changes in the spatial extent of rivers and floodplains in Kumasi, and how do these interact?”. This represents the Drivers component of the DPSIR framework.

The chapter draws on data gathered through semi-structured interviews and focus group discussions in which participants were directly asked to identify drivers that they thought accounted for the changes in the rivers and floodplains in Kumasi. Spatial survey data that physically identified and ascertained some of the drivers
reported by the respondents are also used. Data from literature and official documents such as reports and policies, as well as satellite images are utilised to provide rigour to the primary data. The research findings in this chapter are presented with an array of methods including narrative texts, descriptive statistics and charts among others.

6.2 Rapid population growth

Rapid population growth is a key driver of the changes in rivers and floodplains in Kumasi. The available demographic data show that Kumasi has witnessed a dramatic increase in population size in recent times after a slow growth prior to the 1960s (see Table 6.1 & Figure 6.1). The population of Kumasi grew rapidly from 218,175 in 1960 to 1,170,270 in 2000, to become one of the mushrooming "million plus" cities in developing countries. The 2010 National Population and Housing Census reported the population of Kumasi as 2,035,064, which represents about 16% of the national urban population, with an annual population growth rate of 5.5% far above the national growth rate of 2.5%, making Kumasi the fastest growing city in the country (GSS, 2013). Thus, Kumasi’s population witnessed an eleven fold increase between 1960 and 2010, underscoring the fast pace of urbanisation that has characterised cities in developing countries since the mid-20th century (UNDESA/PD, 2012, Cobbinah et al., 2015b).

The in-migration rate for Kumasi was about 62% and 49% in 1984 and 2000 respectively, making migration a major cause of population growth in the city (GSS, 2005). Based on past growth, it is expected that Kumasi’s population will continue to increase, with the effects on environmental elements, particularly rivers and floodplains in the city likely to be compounded.
Table 6.1 Population growth for Kumasi (1921-2030)

<table>
<thead>
<tr>
<th>Year</th>
<th>Kumasi's population</th>
<th>Kumasi’s population as percentage of urban population of Ghana (%)</th>
<th>Kumasi's annual population growth rate (%)</th>
<th>Kumasi’s immigration rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921</td>
<td>23,694</td>
<td>13.2</td>
<td>2.2</td>
<td>N/A</td>
</tr>
<tr>
<td>1931</td>
<td>35,829</td>
<td>12.1</td>
<td>4.1</td>
<td>N/A</td>
</tr>
<tr>
<td>1948</td>
<td>71,436</td>
<td>13.4</td>
<td>4.1</td>
<td>26.5</td>
</tr>
<tr>
<td>1960</td>
<td>218,175</td>
<td>14.1</td>
<td>9.3</td>
<td>60.8</td>
</tr>
<tr>
<td>1970</td>
<td>346,336</td>
<td>14.0</td>
<td>4.6</td>
<td>53.1</td>
</tr>
<tr>
<td>1984</td>
<td>469,628</td>
<td>11.9</td>
<td>2.2</td>
<td>62.2</td>
</tr>
<tr>
<td>2000</td>
<td>1,170,270</td>
<td>14.1</td>
<td>5.7</td>
<td>48.6</td>
</tr>
<tr>
<td>2010</td>
<td>2,035,064</td>
<td>16.2</td>
<td>5.5</td>
<td>N/A</td>
</tr>
<tr>
<td>2020*</td>
<td>3,180,000</td>
<td>18.7</td>
<td>4.5</td>
<td>NA</td>
</tr>
<tr>
<td>2030*</td>
<td>4,215,000</td>
<td>19.1</td>
<td>2.8</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: Tipple (1997); GSS, (2005; 2013); UNDESA-PD, (2014)
* UNDESA/PD (2014) Projections
N/A- Data are not available.

Figure 6.1 Population growth trend of Kumasi (1921-2030)

The interviews provided more depth and explanation as to why rapid population growth is a major driver effecting changes in the rivers and floodplains. The interview results suggest that the sharp increase in population was the outcome of migration of people from different parts of the country to Kumasi. The socio-
economic and political importance of the city, the social services and facilities, and its strategic central location are the attraction for immigrants. The interviews also revealed that rapid population growth has resulted in a shortage of suitable land for development in the city, and this compels people to encroach upon the rivers and floodplains. The institutional interviewees in particular indicated that the city dwellers and/or in-migrants who are unable to access suitable lands in the city cluster on the land around the rivers to develop unauthorised structures that end up as informal settlements. Many of the property owners also confirmed that they were compelled to put up their structures in and along the rivers and floodplains due to their inability to access suitable land in the city. Some of the interviewees commented,

“.....Everyone wants to live in Kumasi now, and that has resulted in shortage of land. People move in from several places and when they come they want land to put up structures meanwhile all the developable lands are finished, so they squeeze themselves on the lands and nature reserves along the rivers...” TCPD, June 2013.

"...There are no developable lands in Kumasi... The only available lands are the nature reserves and waterways, and that is why you see developers who still want to put up structures within the city encroach upon those water areas now and then....” MBID, June, 2013.

“....We didn't want to acquire this land initially after inspecting it because it was waterlogged, but we couldn't find an alternative land anywhere within the city. So we came back to acquire this land after fruitless search....” POI 17, July 2013

Related to the unavailability of suitable land is the issue of housing shortages. The rapidly growing population has not been matched by housing supply, leading to a rising housing demand deficit. Housing statistics from GSS (2005) and KMA (2010) reveal that the housing demand deficit of Kumasi increased by about 71% from 124,159 in 2000 to 280,509 in 2010, and it is further anticipated to rise by about 36% to reach 381,909 in 2020 (GSS, 2005; Afrane & Asamoah, 2011) (see Figure 6.2). As a result, it is estimated that about 2.4% of households in Kumasi live in temporary structures, such as containers and kiosks that are mainly located in and along rivers and floodplains, as ways of satisfying their housing needs (GSS, 2005; KMA, 2010). Thus, Kumasi has a huge and an increasing housing deficit, a phenomenon that pushes many of the city’s residents, especially the poor and low income earners, out
of the normal housing market due to the high rents charged for the few available houses, as widely reported by the interviewees.

The interviews provided further explanation of how housing shortages compel desperate home-seekers to erect structures along rivers and floodplains to satisfy their shelter needs. The institutional interviewees (e.g., MBID & FWB) said that the encroachers end up erecting houses on available lands along rivers and in floodplains when they fail to secure access to accommodation due to the acute housing shortage. In addition, interactions with the property owners revealed that some erected their own houses in the water areas to avoid persistent pressure from landlords, who abruptly increased rents and/or frequently threatened them with ejection knowing that they would have difficulty securing new accommodation due to the housing situation. Some of the interviewees said that:

“....Population is exploding in the city and definitely people will need places to lay their heads and so on. But there is inadequate housing supply and the rent charges are so prohibitive in this city that not many people are able to cope with it especially the poor with large family sizes... So with the smallest piece of land that anybody secures, and usually it's these waterlogged areas that are available and cheaper to acquire; they prefer to put up two or three bedrooms houses that can cater for their families. They feel better off staying in their own houses irrespective of the location than thinking of renting expensive apartments....”*KMA, June 2013.*

“...We were living in a rented room in Ashtown [suburb of Kumasi] but the landlord was always disturbing us with rent increments and threats of ejection because he knows it's difficult to have a room to rent here [Kumasi]. So after sometime we decided to put up our own house to have our peace of mind. Although I know this
area is not very good for habitation, at least we live in our own house, which is better than renting expensive room...” POI 11, July 2013.

Thus, the rapidly growing population with its shortage of developable land and housing has driven encroachment and infilling of rivers and floodplains in Kumasi. The rapid population growth has promoted loss of, and reduction in the spatial extent of the rivers and floodplains through development of these water areas for various urban land uses, especially residential (see Section 4.3).

6.3 Poverty and growth of informal economy

The worsening economic condition coupled with the growth of unplanned informal economic activities was identified as an important driver of changes in rivers and floodplains in Kumasi. A key phenomenon that has accompanied Kumasi’s growing population is the increasing incidence of poverty among the city's residents, especially in-migrants. Data from GSS (2008) showed that the percentage of Kumasi’s population living below the national poverty line of GH¢370 ($200) per annum increased by about 16% from 156798 in 1991/92 to 181214 in 2005/06, and this figure has undoubtedly further increased proportionally with population growth since then. Analysis of interview results indicates that the incidence of poverty is generally high in Kumasi, and particularly pervasive among poor in-migrants and/or slum dwellers in the city. The interviewees identified the manifestations of poverty in the city as increasing homelessness, high room occupancy rates and increasing occupation of abandoned/dilapidated and temporary structures in waterways among others. The institutional interviewees explained that the urban poor who are neither able to afford suitable land nor rent decent accommodation end up erecting temporary structures on the apparently “free” land along and within the rivers and floodplains in the city. Some institutional interviewees said that:

“The people who put up temporary structures along the rivers and floodplains are low income earners who migrate into the city to do menial jobs and finally decide to stay yet cannot raise an amount of GH¢1,500 per annum to rent decent accommodation. So these poor migrants in their bid to overcome their problem of homelessness erect temporary structures usually in cluster form in the waterways....” MBID, June 2013.
“…..The poor in-migrants build any structures such as kiosks and containers on the available lands within the floodplains just to get a place to lay their heads…..” TCPD, June 2013.

Thus, poverty conditions deprive the urban poor of the economic capacity to afford suitable developable land in the city. This situation leaves them with the only option of capturing the available free but less desirable lands in and along rivers and floodplains to erect predominantly temporary structures to shelter themselves. Accordingly, some of the property owners revealed that they settled along and in the rivers and floodplains because they could not afford suitable land or rooms elsewhere, while the land within the water areas was described as “no man’s land”, “free” and/or relatively cheap, which they could easily secure. One of the property owners said that:

“...We live here because we didn’t have the financial resources to buy expensive land elsewhere when we migrated to Kumasi. But we needed a place to lay our heads so we came to put up these temporary structures on this land [waterway] when we noticed it was available...We would have bought a suitable land at a better location if we had money ....” POI 11, July 2013.

Consequently, the areas of the rivers and floodplains that are eventually taken over by informal settlements are also used for informal economic activities that the urban poor are often engaged in for survival and livelihood. Informal economic activities, which comprise petty commerce/service e.g., merchandising and retail; petty production e.g. craft, artisan; and urban and peri-urban agriculture have witnessed substantial growth as the mainstay of Kumasi's economy in recent times. As presented in Table 6.2, the informal economy employs the majority of the city's active labour force, making it a key contributor to local economic development in terms of employment creation and revenue generation for the city authorities. For example, the KMA official interviewed revealed that the informal economy contributes more than half of the internally generated revenue of the KMA.
Table 6.2 Informal economy employment levels in Kumasi (1960-2010)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total employed population (TEP)</th>
<th>Informal Economy Population</th>
<th>As percentage of TEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>87265</td>
<td>41015</td>
<td>47.00</td>
</tr>
<tr>
<td>1970</td>
<td>124691</td>
<td>67333</td>
<td>54.00</td>
</tr>
<tr>
<td>1984</td>
<td>207568</td>
<td>122465</td>
<td>59.00</td>
</tr>
<tr>
<td>2000</td>
<td>442362</td>
<td>278688</td>
<td>63.00</td>
</tr>
<tr>
<td>2010</td>
<td>709845</td>
<td>465918</td>
<td>65.64</td>
</tr>
</tbody>
</table>


However, interview results emphasise that the informal economic activities appear forgotten in the land use planning process of Kumasi, as land for such purposes is not allocated on land use plans. As a result, it was observed that while informal economic activities like urban agriculture mainly involves clearing of the rivers and floodplains for farmlands, others such as petty trading and small-scale industrial activities are undertaken in temporary wooden and metal structures like kiosks and metal containers are illegitimately erected within these water areas in the city. The adverse effects of these poorly located informal economic activities on the rivers and floodplains were summed up by the EPA interviewee as:

“...If we take the informal economic activities, we can talk of the auto mechanic workshops, wood processors, car washing bays, petty trading and farming among others mostly locate along rivers and in floodplains. And operators/owners of these activities directly discharge garbage, oils and effluents into the rivers, which increase chemical and heavy metal concentrations in the water, as well as fill up the river courses...At the moment many rivers are silted with plastics and/or record high concentrations of grease and as a result of waste disposals by these activities that are scattered along them.....” EPA, June 2013.

Thus, while the pervasive poverty situation has compelled the urban poor to invade and develop substandard structures in the rivers and floodplains, the growing unplanned informal economy has also promoted the encroachment and degradation of these water areas by various economic activities, particularly urban agriculture (see Section 5.3).

6.4 Land ownership and delivery practices

Another key driver of the spatial changes in rivers and floodplains in Kumasi is the land ownership and delivery system. Two main land ownership systems are practised
in Kumasi: state land, and customary or stool land ownerships. The customary lands constitute 60% of the entire land area of Kumasi, indicating that a large proportion of the city's land is claimed by lineage and administered by the traditional leaders as the custodians (KMA, 2010; Hammond, 2011). Consequently, rivers and floodplains that are deemed part of customary land in Ghana and Kumasi in particular, are also subject to the control of the traditional leaders (Opoku-Agyemang, 2005).

Given the size of the customary lands in Kumasi, the majority of physical developments in the city are undertaken on such lands. However, analysis of interview results reveals that the administration and delivery of these customary owned lands to prospective developers by the traditional leaders is complicated by a high level of informality, and lack of collaboration and co-ordination with appropriate government institutions. The interviewees indicated that the shortfalls in the administration of the customary lands greatly contribute to the encroachment upon rivers and floodplains in Kumasi. A focus group participant said that:

“…..I think the chiefs [traditional leaders] are the major cause of the problem. We couldn’t have put up structures there [in the water areas] if the chiefs had not sold the lands to us. Nobody can build a house or any structure on a land which has not been sold to him/her by the owners, so the chiefs are the ones to blame for the encroachment on the rivers...” Focus Group Discussions [FGD] 2 Participant, September 2013.

The traditional leaders now sell waterlogged areas to developers on a commercial basis for their self-aggrandisement due to the increasing demand for land in Kumasi. Discussions with selected traditional leaders revealed that some of them have “sold” lands in and along rivers to private developers to undertake various physical developments. One of the traditional leaders said that:

“...Yes, I allocated some of the lands along the rivers in this community to private developers to raise funds to settle my personal debts and also finance the activities of the traditional council....”Traditional Leader 1, August 2013.

The actions of the traditional leaders as depicted in the above quote have led to the degradation and loss of several rivers and floodplains in Kumasi. The traditional leaders often indulge in these commercial and unwarranted sales of water areas without any regard to the approved land use plans of Kumasi, which usually demarcate rivers and floodplains as ecological zones and nature reserves. Again, it
was observed that the traditional leaders were able to allocate the water areas to private individuals because the city authorities had not followed the necessary legal procedures to acquire the areas for public interests, as stipulated in the land use plans. This suggests that protection and conservation of natural areas such as rivers and floodplains are often not among the top priorities of the city authorities, but left to the mercy of the traditional leaders who sell such areas to private developers without considering public interest.

Given the apparent absence of developable lands in the city, it was realised that the traditional leaders usually sell the lands in the water areas to desperate prospective developers in the dry season when such locations appear suitable for development (see Section 4.5). As a result, some of the property owners did not have prior knowledge of the fact that the lands which they acquired were within floodplains. An interviewee said that:

“....I didn’t know the land was waterlogged. I didn’t like a waterlogged area....I even walked around the plot to check if I could see a stream when I came to inspect the land with the chief but I didn’t see any stream. The land was very dry....I got to know this land is located in a waterway when we started experiencing frequent floods after we have completed the house and moved in....” POI 1, July 2013.

In summary, the dominance of customary land ownership has significantly accounted for the loss of rivers and floodplains through the unscrupulous activities of traditional leaders, who sell these water areas to desperate land seekers. This is underscored by the indication by the majority of the property owners interviewed that they acquired their lands directly from the chiefs, with a few indicating they are squatters.

6.5 Management framework for urban growth, rivers and floodplains

The need for orderly urban physical development and protection of environmental resources such as rivers and floodplains is enshrined in the 1992 Constitution of Ghana. Specifically, Articles 36(9), 41(k) and 85 of the constitution direct the government to formulate policies, enact laws and establish institutions, as well as enjoin the citizens to take and adhere to measures for protecting and safeguarding both the built and natural environments of the country. The country has also ratified
several international conventions and treaties to ensure orderly urban development and create safe urban environments (see Appendix 9). However, a poor management framework, which comprises legislation, policies and institutions/stakeholders, remains an important driver affecting the spatial extent of rivers and floodplains in Kumasi.

6.5.1 Legislative and policy frameworks

Urban growth, river and floodplain management in Kumasi is based on national legislation and policies as there are no specific local laws and policies for that purpose. The relevant laws and policies that apply include Town and Country Planning Ordinance, 1945 (CAP 84), Local Government Act, 1993 (Act 462), National Building Regulations, 1996 (LI 1630), Land Use Planning and Management Project, Environmental Sanitation Policy, National Urban Policy Framework/Ghana National Urban Policy Action Plan, Environmental Protection Agency Act of 1994 (Act 490), Wetlands Management Regulations of 1999, Water Resources Commission Act of 1996 (Act 522), Riparian Buffer Zone Policy, National Water Policy and National Environmental Policy/National Environmental Action Plan. These national urban, environmental and water resource legislations and policies form the broad framework within which efforts to regulate physical development and protect rivers and floodplains are pursued in Kumasi and other parts of Ghana. The focus and limitations of policies and legislation gathered from interviews and documentary analysis are presented in Table 6.3.

As presented in Table 6.3, there exist a plethora of policies and laws in the statute books of Ghana for managing physical development, rivers and floodplains in Kumasi. Both the institutional representatives and property owners interviewed indicated the policies and legislation designed to regulate physical development and prevent the degradation of rivers and floodplains in Kumasi are relatively adequate. Also, analysis of the interview results reveal that the legislations and policies have established new and reformed existing urban and water resource management institutions in the city, and in the country as a whole. For example, the TCPD, WRC, EPA and KMA were all established in Kumasi following the formulation of CAP 84, Act 522, Act 490 and Act 462 respectively. According to the interviewees, the
creation of these institutions has helped consolidate water resource management functions, as well as enhanced responsiveness to physical development challenges in the city to some extent. The WRC and TCPD interviewees said that:

"I don't think our outfit [WRC] will be here by now if the National Environmental Policy/National Environmental Action Plan and WRC Act had not proposed its establishment. So if for nothing at all, I think the policy and law have helped create our institution [WRC] that now deals with all issues relating the water resources management in the city. And I think the same applies to many of the urban and water resources related institutions in the city; they [institutions] came into existence through passage of one particular policy/legislation or a combination of them” WRC, June, 2013.

We [TCPD] used to take most of our instructions from the national office and the ministries because of the provisions of CAP 84. But following the enactment of Act 462, which made us [TCPD] a decentralised institution, we [TCPD] now work more closely with the Assembly [KMA] and that has improved our efforts at managing physical development in the city because we hold meetings together and discuss issues in-depth”. TCPD, June 2013.

It was also apparent that these national laws and policies have formed the basis of many actions that have attempted to control physical development and protect rivers and floodplains in Kumasi. Some institutional interviewees (e.g., MBID, TCPD and LC) revealed that the CAP 84 constituted the legal basis for preparing Kumasi’s Garden City of West Africa Planning Scheme (1945) that established green belts along the rivers to protect them from pollution and encroachment. The TCPD interviewee explained that:

".....There was no land use plan for Kumasi until 1945 when CAP 84 was passed and the city was declared a planning area. It was after this that the colonial masters were able to develop a planning scheme that had a lot of greenery for the city. So before the law, there was no formal land use planning here [Kumasi].....“TCPD, June 2013.

Analysis of institutional interview data indicates that, based on the provisions of subsequent legislation and policies such as the National Wetlands Conservation Strategy and Action Plan, the Riparian Buffer Zone Policy, and the National Environmental Policy/National Environmental Action Plan, rivers, floodplains and marshy areas are demarcated as unbuildable areas on the city’s revised and/or new land use plans. In addition, their protection is incorporated into the environmental management sections of the four year Medium Term Development Plans (MTDPs)
that guide day-to-day development activities in the city. Some interviewees (e.g., FRWB, EPA, and WRC) emphasised that the National Wetlands Conservation Strategy and Action Plan in particular has promoted the development of wise use activities such as recreational centres on floodplains in the city. The FRWB said that:

"When we [FWRB] first attempted to develop a children's playground on the marshy areas along the Daban River in Dakwadwom, our proposal was rejected....but following the National Wetlands Conservation Strategy and Action Plan, the KMA realised the need to promote such wise use activities on the wetlands in the city so they [KMA] approached us again and offered the approval to develop the park. So I think the wetland policy has increased awareness of the need to protect wetlands and rivers, at least among the local authorities, as evidenced by their support for our creation of the park" FRWB, June 2013.

"These days, environmental issues and management are considered in our [KMA] development plans as required by the EPA Act and National Environmental Policy/National Environmental Action Plan. A whole section of the plans is usually dedicated to identifying and addressing environmental problems in the city.....And we have also brought on board private waste management companies such as Zoomlion Company Limited, Aryeetey Brothers Company Limited and SAK-M Company Limited, which collect waste in the city to help improve environmental sanitation in line with the provisions of ESP” KMA, June 2013.

Despite the accomplishments outlined above, the interview results strongly emphasise that the realisation of the objectives of the policy and legislative frameworks in Kumasi have not been far reaching, due to shortfalls in the policies and laws, as well as implementation challenges. According to the interviewees, this situation has contributed to the degradation and loss of rivers and floodplains in Kumasi. The interviewees indicated that although the various policies and legislations represent numerous attempts to manage physical development, rivers and floodplains in a more scientific and effective manner, they have resulted in a general lack of a comprehensive framework for such purposes. In analysing the policy and legislative frameworks objectives, it was observed that initiatives either directly or indirectly regulate just one aspect of urban growth and water resource management, and in many cases fail to complement one another (see Table 5.6). As a result, the interviewees indicated that the multiplicity of urban and water management related legislation and policies results in overlaps and contradictions when attempting to protect and conserve rivers and floodplains. The EPA interviewee said that:
“...There are several national water-related policies and legislations used for protecting the environment and river bodies in Kumasi. But the problem is that most of the policies and laws are overlapping and conflicting...the laws are often formulated without due consideration to existing ones and this hinders effective water resources management. So there is a need for a more comprehensive law/policy that harmonises the existing ones...” EPA, June 2013.

Typical cases of contradictions with pre-existing laws are found in Acts 490 and 522. For example, although Act 522 appears to make the WRC the sole water resources regulatory and management body with powers to issue water use rights, it does not address issues in the area of competence of pre-existing regulatory institutions. Again, the Minister for Mines and Energy and the Irrigation Development Authority (IDA) are mandated by the Minerals and Mining Law, 1986, and the Supreme Military Council Degree (SMCD) 89, 1977 respectively, to grant permission to individuals and organisations to undertake activities (e.g., mining and dam construction) that can divert, obstruct or alter courses of rivers. Furthermore, while Act 490 requires all individuals and organisations to acquire environmental permits from the EPA before undertaking any potential environmentally hazardous activities, the Volta River Development Act, 1961 (Act 46), entitles the Volta River Authority (VRA) to clear all trees, including in buffer zones, in the path of power mains, without the acquisition of an environmental permit from the EPA. According to the interview results, such situations lead to conflicting environmental functions and this impedes effective and well-coordinated urban and water resource management in the city.

Moreover, analysis of the interview results suggests that some legislative and policy frameworks are irrelevant because they contain obsolete, broad and vague objectives, and involve bureaucratic processes. Examples of such legislation/policies included CAP 84, National Water Policy, National Urban Policy Framework/Ghana National Urban Policy Action Plan and Act 462 among others. The interviewees cited the lack of amendments or revisions, and low public involvement in the formulation of legislation and policies as the reasons that have rendered them less relevant. The CAP 84 for example, has not undergone any extensive amendment since its enactment in 1945, despite being the main basis of land use planning in Kumasi, making it difficult for the legislation to comprehensively address most current
physical development challenges. The institutional interviewees (e.g., MBID, TCPD, and WRC) further explained that the bureaucratic nature of the permit acquisition process outlined in CAP 84 and Act 462 encouraged developers to evade the planning procedures, resulting in development at unauthorised locations. The MBID interviewee said that:

"...It takes unusually long time to obtain development permit here [Kumasi] but most developers are impatient so they go ahead to develop their lands without acquiring permit and advice of the city authorities, especially if they are building in unauthorised locations like waterways and don't want to be noticed. But the fact is most of them submit application for the permit just that they don't wait for the process to complete before they develop” MBID, June 2013.

This situation is further compounded by the long gestation period that some of the legislations and policies underwent. Institutional interviewees (e.g., FRWB, KMA, MBID, TCPD and WRC) lamented that despite the creation of a green belt along rivers in the Garden City Plan of Kumasi in 1945, the RBZP was not formulated to guide the protection of the zones until 2011, a time when all the nature reserves had virtually being lost. Thus, according to results of the interviews, the timing of the RBZP has made it less useful, with its aim of promoting appropriate demarcation and protection of riparian buffer zones along rivers seemingly unrealistic, given the current state of the rivers and their buffer zones in the city (see Section 4.3).

Analysis of the interview results also reveals widespread poor implementation of legislation and policies in Kumasi. Interviews with the institutions (e.g., WRC, TCPD, MBID, EPA and FRWB) indicated that the majority of legislation/policies have not and/or did not achieve even five percent of their objectives because of institutional weaknesses such as limited resources, lack of co-ordination, bribery and corruption, as well as social and political interferences and non-compliance by the public. In addition, the property owners interviewed identified inadequate community involvement in the formulation and implementation of policies and legislation, as well as low commitment by local authorities as factors that have hindered realisation of the policy/legislative objectives. Some of the interviewees commented that:

“..... We have many Acts of parliament and policies for managing urban development and water resources but the implementation is often a challenge....There is general lack of personnel, equipment and legal backing for
enforcement...And of course non-compliance is a problem, because the public are usually not adequately involved in the process...” WRC, June 2013.

“... The institutions lack resources and will power to enforce the laws...So people build on floodplains and go scourge-free and; that has become the order of the day here [Kumasi]” FRWB, June 2013.

“The plans are there; it's just that the landowners and developers are overlooking those plans with the ‘help’ of the city officials. The developments [building in waterways] are done by the so called influential people in society so they wittingly secure the support of the authorities who are supposed to enforce the laws ....” POI 35, September 2013.

Given that, urban and water resource management regulations and policies are not effectively enforced and/or adhered to the interview results indicate that urban, river and floodplain management in Kumasi relies on reactionary approaches. The institutional interviewees (e.g., HSD, KMA, TCPD and NADMO) revealed that the city authorities embark on structural/engineering interventions such as concreting and straightening river channels, dredging rivers and demolishing structures along rivers and floodplains usually after flood disasters, to protect the rivers and floodplains, as well as improve flow of runoff and forestall future flood occurrences. Other interviewees, (e.g., FRWB, EPA) however, argued that the physical modifications, especially the concreting of river channels, have adversely affected the capacity of the rivers to recharge and clean themselves, resulting in eventual loss of the rivers. Some institutional interviewees said that:

“Our main approach for protecting rivers here [Kumasi] is concreting the channels to prevent channel erosion and also promote smooth flow of runoff. At the moment we have concreted sections of Aboabo, Subin, Sisa Rivers, and there are plans to concrete most of the rivers here [Kumasi]. Also, we usually go to the communities to desilt/dredge the rivers channels when floods start occurring, but we have not been able to do that for the sometime now due to lack of funds” HSD, June 2013.

“....We collaborate with institutions like HSD, MBID, and KMA to demolish structures in waterways in flood affected communities” NADMO, June 2013.

“These days the KMA has started channelising rivers in the name of protecting them and controlling floods, but this approach turns to ‘kill’ the rivers because it disrupts the resurgence of the rivers.....” FRWB, June 2013.
<table>
<thead>
<tr>
<th>Policy/Legislation</th>
<th>Aim</th>
<th>Scope</th>
<th>Strengths</th>
<th>Weaknesses/Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Town and Country Planning Ordinance, (CAP 84), 1945</td>
<td>To promote orderly and progressive land development and preserve or improve amenities.</td>
<td>Process of declaring statutory planning areas, preparing and approving planning schemes.</td>
<td>Supports preparation of planning schemes for key settlements e.g., Kumasi &amp; Accra.</td>
<td>Obsolete provisions. Neglects several settlements/parts of settlements leading to haphazard development.</td>
</tr>
<tr>
<td>Local Government Act, (Act 462), 1993</td>
<td>To transfer overall responsibility for development and environmental management to local authorities (MMDAs).</td>
<td>Planning and development control. Powers of local government authorities (MMDAs).</td>
<td>Deepens decentralisation. Supports preparation of planning schemes for every settlement.</td>
<td>No clear provision on need to prioritise protection of nature reserves in land use and development plans.</td>
</tr>
<tr>
<td>Environmental Sanitation Policy, 2009</td>
<td>To ensure acceptable levels of environmental sanitation to improve health and quality of life.</td>
<td>Sanitation sector stakeholders and capacity. Environmental sanitation awareness creation. Cost recovery.</td>
<td>Supports private sector involvement and popular participation in waste management.</td>
<td>Lacks concrete strategies for waste disposal and development of flood control infrastructure e.g., storm drains.</td>
</tr>
<tr>
<td>National Urban Policy (NUP)/ Ghana National Urban Policy Action Plan (GNUPAP), 2012</td>
<td>To create sound and sustainable urban settlements for all people.</td>
<td>Urban population re-distribution. Environmental quality improvement. Urban infrastructure development. Climate change adaptation and mitigation</td>
<td>Extensive stakeholder involvement in formulation process. Well defined policy actions in GNUPAP.</td>
<td>Contains broad and vague global goals e.g. climate change adaptation. No clear measure(s) to address uncoordinated and conflicting functions of urban management institutions. Lacks legal basis as its legislative instrument, Land Use and Planning Bill, is not yet enacted.</td>
</tr>
<tr>
<td>National Environmental Policy (NEP)</td>
<td>To ensure sound environmental management and avoid environmental resources overexploitation.</td>
<td>Integration of environmental considerations in development activities. Maintenance of ecosystem and ecological processes.</td>
<td>NEAP spells out specific interventions for safeguarding the environment and ensuring sustainable utilisation of natural resources.</td>
<td>Lacks provisions to: control waste discharge in rivers, establish and protect watershed and prevent encroachment on water areas.</td>
</tr>
<tr>
<td>-------------------------------------</td>
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<td>------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Water Resources Commission Act, (Act 522), 1996</td>
<td>To establish WRC and ensure effective regulation and management of the utilisation of water resources.</td>
<td>Mandates and functioning of WRC. Process for acquiring water usage permits.</td>
<td>Creates an institution (WRC) that deals solely with water resources management.</td>
<td>Unclear about area of competence of, and WRC’s relationship with other water related institutions that existed prior to its enactment.</td>
</tr>
<tr>
<td>National Water Policy, 2007</td>
<td>To provide a framework for the sustainable management of water resources.</td>
<td>Integrated Water Resources Management (IWRM), Urban water supply. Community water and sanitation</td>
<td>Acknowledges the principle of universal access to water.</td>
<td>Emphasises on broad and vague global objectives e.g., sustainable environmental and biodiversity management. Lacks clear policy actions to mitigate human-induced water pollution.</td>
</tr>
<tr>
<td>Riparian Buffer Zone Policy, 2011</td>
<td>To promote the creation, regeneration, maintenance and protection of riparian buffer zones/nature reserves around rivers.</td>
<td>Process for creating buffer zone. Maintenance and sustainability of ecosystem functions of buffer zone.</td>
<td>Unifies the previously varied and unclear buffer zone dimensions that were used by the various water related agencies (100 m).</td>
<td>Lacks Legislative Instrument to give it a legal backing. Fails to address customary landownership concerns. Suffered a long gestation period.</td>
</tr>
</tbody>
</table>
6.5.2 Institutional and stakeholder arrangement

The management of physical development, rivers and floodplains in Kumasi is a multi-faceted activity that involves many actors representing different interests. The stakeholders comprise state agencies/departments, local government authorities, traditional authorities, non-governmental organisations, and local communities. Although these numerous stakeholders have undertaken actions that are aimed at directly and indirectly promoting orderly physical development, and protecting rivers and floodplains in Kumasi (see Table 6.4), the interviews and documentary reviews show that their effectiveness leaves much to be desired in terms of regulating urban growth and conserving these water systems in the city. The interview data also reveal that most of the institutions perform overlapping and conflicting functions, leading to constant stalemates among institutions, which hamper effective urban growth, and river and floodplain management in Kumasi.

“A major challenge to protecting the rivers and floodplains is the overlapping and conflicting functions. For example, the EPA Act was enacted without due consideration of the VRA Act. So while the EPA Act requires everyone to acquire permit from the EPA before cutting down any tree, the VRA Act gives it (VRA) mandate to clear any trees even in riparian buffer areas, within the path of power mains without any recourse to EPA. So there is always a sort of power struggle between us [EPA] and them [VRA] because we feel their actions degrade rivers and buffer zones” EPA, June 2013.

The interview results further reveal that most of the institutions have been weakened by a lack of resources and the unprofessional attitude of staff. The institutions generally lack adequate skilled personnel, funds and logistics to undertake their activities. This is because most of the institutions rely on the central government and donor agencies for funding and logistics for their operations. Also, analysis of the interview results indicates that high levels of corruption among staff, as well as political interference results in connivance, which leads to issuance of land titles and development permits to illegal developers. It was also apparent that due to the corruption, some staff have difficulty demolishing physical developments undertaken in the water areas by property owners or developers who they have accepted bribes from. The cumulative result of these has been poor functioning institutions, as remarked by some of the interviewees:
“Our institutions are weak. They lack resources to work with and there are a lot of corrupt officials in some of the institutions so they manipulate the processes for people to gain approvals to develop in waterways. An official who is charged to execute demolition of structure may turn around to accept bribe from the developer and then cover up for the developer. And those of us [NGOs) who want to ensure order do not have the support of the laws” FRWB, June 2013.

“......and most of us [institutions] don’t have adequate resources to effectively undertake activities like monitoring and public education” TCPD, June 2013.

Additionally, the interview results suggest that the situation is worsened by the poor collaboration between the institutions, as well as the uncooperative attitudes of traditional leaders and the general public, which result in actions and inactions that degrade the rivers and floodplains. The interviewees stated that the institutions do not collaborate in their activities, which leads to the pursuit of water related projects with diverse/conflicting focuses. In addition, the traditional leaders often unscrupulously allocate and sell rivers and floodplains to developers without any regard to the city’s land use plan (see Section 6.4), and there is also apathy among the public towards protecting the rivers and floodplains. The interviewees indicated that the public regard rivers and floodplains as “no man’s land”, where they dispose of waste and erect unauthorised structures, resulting in the loss of these water areas. Some interviewees said that:

“People are unconcerned about the protection of rivers in Kumasi. They see the protection of the rivers as the responsibility of only the government agencies. They don’t help in protecting these rivers and floodplains but rather erect structures or dump waste in the rivers and floodplains……” WRC, June 2013.

“People do whatever they like around the rivers. The chiefs sell the lands along rivers and floodplains to developers to build houses, and the public have turned the rivers into refuse dump sites and developable lands” POI 20, August 2013.
### Table 6.4 Institutional/stakeholder arrangements for rivers, floodplains and urban management in Kumasi

<table>
<thead>
<tr>
<th>Institution/Stakeholder</th>
<th>Functions/Activities</th>
<th>Weaknesses/Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Resources Commission (WRC)</td>
<td>Develops and harmonises water resources plans and policies e.g., Pra River Basin Integrated Water Resources Management Plan. Assesses water resources and grants water use rights.</td>
<td>Low coordination, conflicting functions and stalemate with other water aligned institutions like Irrigation Development Authority (IDA). Inadequate political support and finance to implement plans and decentralise operations.</td>
</tr>
<tr>
<td>Environmental Protection Agency (EPA)</td>
<td>Grants environmental permits and develops Environmental Impact Assessment procedures e.g., Environmental Assessment Regulations (LI 1652), 1999. Monitors water quality of rivers and sets effluent standards.</td>
<td>Overlapping environmental functions and constant stalemate with other related institutions e.g., Volta River Authority (VRA). Inadequate human resources and lack of standards to regulate non-point source water pollution.</td>
</tr>
<tr>
<td>Town and Country Planning Department (TCPD)</td>
<td>Prepares land use plans that demarcate rivers and floodplains as unbuildable areas e.g., 1945 Garden City Plan of Kumasi. Grants development permits and educates the public to support orderly physical development initiatives and desist from developing in ecologically fragile lands.</td>
<td>Acute shortage of logistics and qualified personnel. Widespread corruption and connivance among some staff. Legislative constraints e.g., lack specific legal authority under Act 462, &amp; CAP 84 is largely outmoded. Low coordination with other institutions.</td>
</tr>
<tr>
<td>Lands Commission (LC)</td>
<td>Manages public and vested lands based on land use plans and advises on land policies e.g., National Land Policy (NLP). Issues lease and land titles and refuses prospective developers with lands acquired in waterways.</td>
<td>High incidence of corruption and connivance among staff. Political interference and prevalence of land litigations. Ineffective collaboration and inadequate personnel and logistics.</td>
</tr>
<tr>
<td>National Disaster Management Organisation</td>
<td>Spearheads and coordinates flood emergency responses e.g., searching, rescuing and evacuating</td>
<td>Lack of qualified and experienced technical personnel due to highly politicised staff recruitment</td>
</tr>
<tr>
<td><strong>(NADMO)</strong></td>
<td>Flood victims, distributing relief items (e.g., food, clothes) and providing humanitarian aid to flood victims.</td>
<td>Process with staff changing along with changes in political regimes. Relies on ineffective and ad hoc measures because of financial constraints.</td>
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</tr>
<tr>
<td><strong>Hydrological Services Department (HSD)</strong></td>
<td>Modifies river channels to improve runoff flow e.g., concreted and straightened sections of Aboabo, Subin &amp; Sisa Rivers. Designs, constructs and maintains artificial storm drains. Collects hydrological and hydrometric data e.g., stream discharge.</td>
<td>Inadequate skilled personnel. Low financial capacity due to over reliance on central government and donor agencies’ funding. Inadequate and dysfunctional equipment because of lack of maintenance.</td>
</tr>
<tr>
<td><strong>Kumasi Metropolitan Assembly (KMA)</strong></td>
<td>Prepares plans to direct overall development e.g., Medium Term Development Plans 2006-2009 &amp; 2013-2015. Enforces building regulations (e.g., LI 1630) and demolishes unauthorised structures through Metropolitan Building Inspectorate Division (MBID). Funds development activities e.g., river modifications, storm drain construction, flood emergency relief items.</td>
<td>Low financial capacity. Inadequate personnel and logistics to monitor and track down unauthorised physical development. Staff find it morally difficult to demolish unauthorised structures along rivers and floodplains due to corruption and connivance among them. Weak decentralisation system and co-ordination among departments.</td>
</tr>
<tr>
<td><strong>Friends of Rivers and Water Bodies (FRWB)-(Non-Governmental Organisation [NGO])</strong></td>
<td>Plants trees along rivers. Educates public through forums and newspaper features. Undertakes ‘wise’ use activities along rivers and floodplains e.g., Otumfu Children’s Park around Daban River at Dakwardwom, Kumasi</td>
<td>Legal constraints because of absence of environmental association laws to promote mainstreaming of its activities into government’s policies/activities. Insufficient funds. Low support and cooperation of government and government agencies.</td>
</tr>
<tr>
<td>Traditional Leaders/Chieftaincy</td>
<td>Allocates (‘sells’) customary lands to developers. Demarcates nature reserves along rivers as sacred groves and institutes traditional norms and values that prohibit urban land use development in such areas. Mobilises community members to undertake development activities e.g., dredging rivers.</td>
<td>Non-compliance with land use plans in allocation (‘sale’) of land to developers. Low collaboration with government institutions in land allocation process. Corruption, multiple land allocations and land litigations</td>
</tr>
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<td>--------------------------------</td>
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</tr>
<tr>
<td>Community</td>
<td>Undertakes individual and communal activities to protect rivers and floodplains and reduce floods e.g., constructing drains and clearing waterweeds. Develops traditional knowledge systems and practices to guide physical development, and protect rivers and floodplains.</td>
<td>Some community members lack environmental consciousness and perceive the rivers and floodplains as wastelands and “no man’s land”. Lack of coordination in implementing flood adaptation measures e.g., constructing drains and sandbag embankments.</td>
</tr>
</tbody>
</table>
Therefore, policy, legislative and institutional failures have greatly contributed to the extensive reduction in the spatial extent and the deterioration of water quality of rivers and floodplains in Kumasi. The policy and legislative failures which result from inherent limitations and poor implementation, coupled with the weak and ineffective institutional arrangements, often lead to reliance on reactionary measures that have not only failed to address the underlying multiple causes of loss of rivers and floodplains, but have also contributed to the degradation of these water areas. These findings agree with previous claims that urban development practices, and river and floodplain management in Ghana and other developing countries, are ad hoc, unscientific and uncoordinated (Rain, Engstrom, Ludlow & Antos, 2011; Okyere et al., 2012). These shortfalls have the potential to worsen the reducing extent of rivers and floodplains and its adverse effects in Kumasi.

6.6 Climate pattern and trends

Climatic elements, particularly, rainfall and temperature are regarded as key factors that affect inland water systems (Carpenter et al., 2011; IPCC, 2013). This section analyses the patterns and trends of rainfall and temperature in Kumasi, and their effects or otherwise on rivers and floodplains in the city.

The analysis of rainfall data over the period 1961-2013 obtained from GMA shows that Kumasi has a mean annual rainfall of 1382 mm, although the mean annual rainfall of wet and dry years with an eighteen year return period was 2117 mm and 927 mm respectively. On the other hand, mean annual temperature in Kumasi over the period 1961-2013 was 26 °C based on temperature records obtained from GMA. Graphical analysis indicates a slightly bimodal rainfall regime of major and minor rainy seasons, concentrated within seven months, which records about 82% of the annual rainfall (see Figure 6.3). The major rainfall season is between March and July while the minor season is in September and October, with June experiencing the highest mean monthly rainfall of 214 mm for the year. The graph further reveals that the temperatures in Kumasi are moderate and uniform all year round, with minimum and maximum temperatures of 26 °C and 28 °C being recorded in August and February respectively (see Figure 6.3).
Furthermore, the inter-annual rainfall variability in Kumasi is relatively high, with a coefficient of variation of 0.20 compared to the global mean coefficient of variation of 0.27 (Peel, 2013 as cited in Chen et al., 2014). Nevertheless, inter-annual mean temperature is characterised by a very low coefficient of variation of 0.02.

![Graph showing average monthly rainfall and temperature for Kumasi (1961-2013)](image)

**Figure 6.3 Average monthly rainfall and temperature for Kumasi (1961-2013)**

Additionally, a Mann-Kendall test reveals a decreasing trend for the total annual rainfall of Kumasi as illustrated in Figure 6.4, albeit not statistically significant (Z=-0.41). As a result, a Sen’s slope estimator shows a decrease of 0.81 mm y⁻¹ for the total annual rainfall, culminating in an overall decrease of 42 mm between 1961 and 2013, which is about 68% higher than the national decrease of about 25 mm during 1951-2010 (IPCC, 2013). On the contrary, a Mann-Kendall test shows a significant positive trend for the mean annual temperature of Kumasi (Z=7.25) as shown in Figure 6.5. The Sen’s slope estimator further reveals that the mean annual temperature increases at 0.03 °C y⁻¹, indicating an overall increase of 1.56°C between 1961 and 2013, which is more than double the global average increase of 0.72 °C over the period 1951-2012 (IPCC, 2013).
Consequently, the interview results suggest changing rainfall and temperature trends. The interviewees at GMA, WRC and EPA, as well as some of the property owners interviewed, indicated that the precipitation level in Kumasi has decreased over the years albeit not conspicuously, partly because of the variability of the rainfall pattern. Similarly, the interview data analysis reveals a gradual perception of rising temperatures in Kumasi, with many interviewees asserting that the city is relatively
warmer now. According to the interviewees, the trend of the rainfall and temperature is explained by the rapid loss of the vegetation and other environmental resources to urban land use development, with its associated disruption of the hydrological cycle and increased emission of greenhouse gases. Nonetheless, the interview results largely emphasise that the patterns and trends of rainfall and temperature have not contributed in any significant way to the degradation and loss of the rivers and floodplains in Kumasi. The interviewees vehemently argued that the loss of rivers and floodplains is mainly driven by human activities such as erecting of structures and disposal of wastes in the water areas, and not by natural factors like rainfall changes. Some interviewees explained that:

“There has been variability in the climate of Kumasi. In the 1960s, we had heavy rains in Kumasi, the period was extremely wet. The 1980s was characterised by severe drought, and that was the driest period and the worst period in the whole country [Ghana]. Then after the period, there have been slight ups and downs in the rainfall in Kumasi. But the temperature has been generally moderate except some marginal rises in times largely because of urbanisation and increased human activities. But in all I will say, these changes haven't affected aquatic habitat in any major way here [Kumasi]...” Ghana Meteorological Agency [GMA], June 2013.

“Yes, Kumasi is getting warmer but that is not the cause of the low flow and loss of the rivers. The destruction of the rivers is due to human activities within the catchments and not rising temperatures...” HSD, June 2013.

“.....The loss of rivers in Kumasi is not because of decreases in rainfall but encroachment and pollution although there are times when one might expect much water in the rivers but find less due to extended dry period .....” POI 18, July 2013.

Thus, the analysis of the interviews indicated that Kumasi’s climate pattern and trend, especially the decreasing rainfall and increasing temperature, have not had any considerable impact on the spatial extent and water quality of the rivers in the city. Nevertheless, insignificant effects such as low seasonal river volume occur sometimes due to reduced runoff inflows and/or discharge and increased evaporation that often accompany relatively dry and/or hot periods or months. This suggests that the spatial changes in, and contamination of the rivers are largely driven by the human and urban development processes discussed earlier.
6.7 Summary

The results presented in this chapter have examined the reasons for the degradation and loss of rivers and floodplains in Kumasi, which addressed the Drivers component of the DSPIR framework. The findings answered the second key research question: “what anthropogenic factors account for the changes in the spatial extent of rivers and floodplains in Kumasi, and how do these interact?” The data were gathered from satellite images, spatial survey, semi-structured interviews and focus groups, and were complemented with secondary data and documentary analysis. The multiple data sources enhanced the explanation and understanding of the broad array of factors that affect rivers and floodplains in Kumasi, and the salient issues that emerged are summarised below.

First, the data analysis shows that Kumasi has experienced rapid population growth, recording an increase of more than eleven fold from 218,175 in 1960 to 2,035,064 in 2010, largely because of high in-migration into the city. The largely unregulated rapid population growth has resulted in a shortage of developable land and housing, a situation that encourages the city’s dwellers to encroach and infill rivers and floodplains in order to satisfy land and housing needs. This is further compounded by an increasing poor population who are priced out of the formal land and housing markets, and as such resort to erecting substandard structures that eventually develop into informal settlements in the water areas.

Second, it was found that the dominance of the customary landowner and delivery system, which is plagued with informal and uncoordinated land delivery and transactions, has resulted in the commercial sale of lands water areas for development, contrary to the provisions of existing land use plans. Third, the analysis indicates that although the economy of Kumasi is dominated by growing numbers of informal activities, these are not well planned and therefore encroach on the rivers and floodplains. The waste generated from these activities is disposed of in these water areas, contributing to the degradation of the rivers in particular.

Fourth, it is apparent that there are several urban and water related policies, legislations and institutions that should be able to ensure orderly and sustainable
physical development. Unfortunately, the analysis demonstrates that these are unable to holistically address the problem of encroachment and degradation of rivers and floodplains in Kumasi. Thus, management shortfalls in the form of ineffective policy and legislation frameworks, low institutional implementation and enforcement capacity, as well as non-compliance and uncooperative attitude of land owners and the general public are deemed key contributory factors to the changes in rivers and floodplains in Kumasi.

Finally, the analysis indicates that the decrease in the rainfall, and increase in the temperature, as well as the variability of both have not significantly contributed to the changes in the extent and water quality of the rivers, although some of the rivers have become seasonal due to the rainfall and temperature dynamics.

In summary, the chapter has provided an understanding that the changes in rivers and floodplains in Kumasi are largely driven by human-induced factors, which are interconnected and interact in various ways to complicate the change process. The next chapter discusses flood incidence and intensity in Kumasi in order to address research question three, as well as represent the Impacts component of DPSIR framework used in this research. The findings presented in the chapter assist in better understanding the flooding implications of the changes in extent of rivers and floodplains, as well as the impacts of floods generally in Kumasi.
Chapter 7 - Flooding and the impact on ‘human wellbeing’ in Kumasi

7.1 Introduction

The frequency and intensity of flooding and the associated devastating impacts on the wellbeing of exposed and vulnerable populations have been on the rise in urban areas across the world, particularly in developing countries (Douglas & Alam, 2006; IPCC, 2007; 2013). Flooding is reported to cause more casualties and economic losses than any other natural catastrophe (Jha et al., 2011). Recent studies have associated the increasing frequency and intensity of flooding in urban areas in developing countries with rapid urbanisation, coupled with the increasing development of human settlements along rivers and in floodplains (MEA, 2005; IPCC, 2007; 2013; Islam et al., 2010; Campion & Venzke, 2013). These studies present flooding as a socio-environmental consequence of changes in the spatial extent of rivers and floodplains in urban areas, yet these views have not been adequately substantiated by systematic research in developing countries (Islam et al., 2010; Campion & Venzke, 2013).

The results outlined in this chapter seek to establish and explain the connections between flooding and changes in the spatial extent of rivers and floodplains in Kumasi. In essence, the results address both the research question: “how have the spatial changes in the rivers and floodplains contributed to the frequency and intensity of urban flooding in Kumasi?”, as well as the Impacts component of the DPSIR framework. The analyses in this chapter posit flood incidence and intensity as outcomes of the changes in spatial extent of the rivers and floodplains in Kumasi (see Chapter 4). The chapter contains analyses of the frequency and nature of flooding in Kumasi, an examination of how flooding is influenced by the reduction in spatial extent of the rivers and floodplains, as well as discussion of the effects of flooding, and coping and adaptation strategies.

The data used in this chapter are drawn from semi-structured interviews, focus group discussions and spatial survey. Literature and secondary data such as reports, policy documents, newsletters and publications on urban growth, flooding and water resource management on Kumasi and Ghana are also used to provide rigour to the
primary data. The triangulation of these multiple sources of data was to ensure in-depth understanding of the flooding dynamics, links to loss of rivers and floodplains and impacts in Kumasi. Data analysis involved open and axial coding using NVivo to identify key themes, narrative descriptions of key issues, descriptive statistics and mapping to crystallise important concepts.

7.2 Nature of flooding in Kumasi

7.2.1 Frequency and intensity of flooding

Analysis of flood occurrence records from 2009 to 2013 documented by NADMO indicates that flooding has become a perennial phenomenon in Kumasi with at least five incidences per year. As presented in Figure 7.1, there were 28 flood events in the city over the five year period, and these mainly occurred at the onset and peak of the rainy seasons (see Figure 7.2 & Section 6.6). June has the highest monthly rainfall and the highest reported floods, although an increasing number of flood events are being recorded in March at the onset of the rainy season (see Figure 7.2).

Figure 7.1 Recorded floods in Kumasi (2009-2013)
Source: NADMO, Kumasi (2013)
Nevertheless, the interviews and spatial survey found that the flood occurrences were predominantly confined to the numerous informal settlements along rivers and in floodplains in Kumasi (see Figure 7.3). The interviewees indicated that floods occur in most of these areas whenever there is moderate to heavy rainfall or a storm. Some of the interviewees said that:

"In fact there are a lot of flood prone areas in Kumasi but they are mainly the slum communities where developments have encroached on rivers and floodplains. I can mention communities like Aboabo, Dichemso, Atonsu, Ahinsan and Moshie-Zongo among others which are characterised by encroachment on rivers and floodplains and as such experience flooding every rainy season...In these communities, flooding is an annual disaster...." HSD, June 2013.

"Floods are very pronounced in certain parts of the city and they [floods] occur many times in the year during the rainy season” National Disaster Management Oragnisation [NADMO], June 2013.

“We experience flooding in this community with the least rainfall. It occurs several times in a year” POI 1, July 2013.

The property owners, who have all had their homes flooded, described the floods experienced in the city as severe and disastrous. They indicated that floodwaters usually rise as high as the rafters of their houses, with some houses being completely submerged (see Figure 7.4a).
It was also apparent from the interviews and spatial survey that the time taken for the floodwater to recede depends on the location of the houses. Property owners who reside far from the river channels claimed the floodwaters last for only 1-5 hour(s) while those whose houses are very close to the river channels reported that the floodwaters remain for days. Further investigations and personal observations established that the floodwaters can take as long as seven days to completely recede and for the houses to dry (see Figure 7.4b), suggesting that the flood victims live under flood conditions for approximately a month in a year. Some of the interviewees explained the flood conditions as follows:

"The floodwater occupies the whole house and enters the rooms so we are unable to come here until it recedes...It can take more than a week before this place becomes completely dry " **POI 24, August 2013.**

"Whenever the floods occur we visit the communities and we see that the water level is up to the windows or roofs of some houses....When it happens like that it takes
almost a week before the water recedes but it can take shorter period to recede in some places” HSD, June 2013.

Thus, Kumasi is experiencing a rising incidence of floods with prolonged floodwater inundation in the rainy seasons. The flood affected areas or communities are characterised by development of structures along and in rivers and floodplains where water overflows are expected during rainy seasons. The next subsection examines the rainfall intensities that trigger these floods in Kumasi.

7.2.2 Flood incidences and associated rainfall events

The floods experienced in Kumasi between 2009 and 2013 were preceded by rainfall of varying magnitudes. Table 7.1 reveals that the floods occur during moderate to heavy rainfall events, with at least 27 mm of rainfall needed to trigger a flood in Kumasi. Based on this, analysis of the daily rainfall data for Kumasi from 2009 to 2013 obtained from GMA indicates that 81 out of the 610 rainfall events that occurred during the period were potential flooding rainfalls (>=27 mm). This suggests that 81 rainfall events should have resulted in floods in Kumasi between 2009 and 2013 if rainfall was the key cause of flooding in the city.
Table 7.1 Rainfall and flood events in Kumasi (2009-2013)

<table>
<thead>
<tr>
<th>Flood day</th>
<th>Rainfall on flood day (mm)</th>
<th>Rainfall on day before flood day (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09-Jun-09</td>
<td>27.8</td>
<td>3.1</td>
</tr>
<tr>
<td>11-Jun-09</td>
<td>60.4</td>
<td>0.1</td>
</tr>
<tr>
<td>15 Jun 09</td>
<td>43.3</td>
<td>0.0</td>
</tr>
<tr>
<td>26-Jun-09</td>
<td>90.3</td>
<td>17.3</td>
</tr>
<tr>
<td>04-Jul-09</td>
<td>51.4</td>
<td>12.8</td>
</tr>
<tr>
<td>09-Jul-09</td>
<td>72.7</td>
<td>27.6</td>
</tr>
<tr>
<td>15-Jun-10</td>
<td>83.6</td>
<td>0.0</td>
</tr>
<tr>
<td>06-Jun-10</td>
<td>48.4</td>
<td>0.0</td>
</tr>
<tr>
<td>12-Sept-10</td>
<td>28.3</td>
<td>9.9</td>
</tr>
<tr>
<td>22-Sept-10</td>
<td>46.6</td>
<td>0.0</td>
</tr>
<tr>
<td>23-Jan-11</td>
<td>33.6</td>
<td>2.0</td>
</tr>
<tr>
<td>03-Mar-11</td>
<td>75.5</td>
<td>0.0</td>
</tr>
<tr>
<td>07-Mar-11</td>
<td>45.0</td>
<td>0.0</td>
</tr>
<tr>
<td>19-Mar-11</td>
<td>40.2</td>
<td>0.0</td>
</tr>
<tr>
<td>03-Jun-11</td>
<td>30.9</td>
<td>0.0</td>
</tr>
<tr>
<td>25-Mar-12</td>
<td>42.9</td>
<td>0.0</td>
</tr>
<tr>
<td>19-Apr-12</td>
<td>38.4</td>
<td>0.0</td>
</tr>
<tr>
<td>08-May-12</td>
<td>31.1</td>
<td>5.6</td>
</tr>
<tr>
<td>02-Jun-12</td>
<td>57.6</td>
<td>0.8</td>
</tr>
<tr>
<td>20-Jun-12</td>
<td>76.1</td>
<td>0.0</td>
</tr>
<tr>
<td>28-Jun-12</td>
<td>35.6</td>
<td>0.0</td>
</tr>
<tr>
<td>15-Mar-13</td>
<td><strong>27.0</strong></td>
<td>0.0</td>
</tr>
<tr>
<td>13-Apr-13</td>
<td>27.6</td>
<td>0.0</td>
</tr>
<tr>
<td>17-Apr-13</td>
<td>30.4</td>
<td>0.2</td>
</tr>
<tr>
<td>17-May-13</td>
<td>43.7</td>
<td>0.0</td>
</tr>
<tr>
<td>27-May-13</td>
<td>33.5</td>
<td>0.0</td>
</tr>
<tr>
<td>04-Jul-13</td>
<td>36.8</td>
<td>0.0</td>
</tr>
<tr>
<td>08-Sept-13</td>
<td>28.0</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Source: Adapted from NADMO, Kumasi, (2013); GMA, Accra, (2013)

However, as presented in Table 7.1, only twenty-four instead of eighty-one flood events occurred in the city over the 5 year period. This smaller than expected number of flood incidences suggests a diminishing and/or less significant role of rainfall intensity in the occurrence of flooding in Kumasi in recent times. For example, the flood that was triggered by a 27 mm rainfall, the least rainfall to have triggered flooding in the city, occurred in 2013 (see Table 7.1). Nevertheless, this situation indicates the crucial roles of other factors (e.g., development in water areas) in causing flooding in the city, as was echoed by some of the interviewees as follows:
"The least rainfall and we hear reports of flooding in the communities along the rivers...and these occur several times in the year, especially at the start and middle of the rainy season. The duration of the downpour influences the floods, but I think there are other factors that are more critical because in many cases the floods occur/affect communities where it has not even rained there” GMA, June 2013.

"There are times we don’t expect floods because it has not rained heavily and yet we experience floods in this area. Sometimes the rainfall is upstream, yet we suffer from floods, so the real causes of our problem is something else than rainfall” POI 31, September 2013.

Thus, the frequent flood occurrences in Kumasi in recent times are not the result of unusual rainfall events. In view of this, the next section discusses the role of the loss and/or degradation of the rivers and floodplains in flood incidences in Kumasi.

7.3 Understanding how the reducing spatial extent of rivers and floodplains contributes to flood incidences in Kumasi

As discussed in Chapters 4, 5 and 6, the spatial extent of rivers and floodplains in Kumasi has drastically reduced due to unregulated rapid population growth, uncontrolled urban expansion, inappropriate land ownership and delivery practices, poor waste management practices, and uncontrolled urban agricultural activities. The interview results emphasise that this extensive degradation and disappearance of rivers and floodplains has resulted in the almost complete loss of their flood mitigation functions, like conveying and holding runoff. As a result, the institutional officials and property owners interviewed largely attributed the increased incidence and intensity of floods in Kumasi to the reducing spatial extent of these water areas.

According to the interviewees, flood disasters were rare in Kumasi in the past because the numerous rivers and floodplains facilitated safe conveyance and infiltration of runoff after rainfall, by serving as natural drains and reservoirs. However, following the loss of many of the rivers and floodplains, flooding has become an annual disaster in the city. Some of the interviewees explained that:

“…..There were many rivers here [Kumasi]……and served as natural drainage channels that collected the rainwater/runoff for proper disposal. But many of the rivers have been and still being used for physical development, and as garbage disposal sites. Because of these, many of the rivers and floodplains have disappeared while the channels of existing rivers have become narrow, so a little rain just overflows the banks to enter the houses around them…I can say that about 90% of
floods in Kumasi are due to the encroachment and loss of the rivers and floodplains” HSD, June 2013.

“I joined NADMO in 1998, and during that time Kumasi was not experiencing much flooding. Flooding was not one of the disasters we were battling with. But for the past five years, flooding has become one of the major disasters we experience here because of the encroachment and loss of rivers and floodplains that served as natural drainage channels...” NADMO, June 2013.

“I have lived here for over 30 years but we never experienced any floods until recently. The runoff flowed freely and no floodwater ever entered my house until people started building in the waterways. At the moment almost all the river channels and floodplains have been utilised to put up structures, and we are suffering from floods.....” POI 12, July 2013.

The interviewees further explained that the development of physical structures and dumping of garbage in and along the rivers and floodplains, coupled with the eventual disappearance of these water areas, causes the obstruction and/or loss of pathways of the runoff. Also, due to encroachment, it was observed that the few existing rivers have small and disjointed channels which cannot support the smooth flow of runoff. In such situations, any excessive water or runoff on rainy days overflows the river banks, and flows through any available land, as well as inundating houses. Thus, flooding in Kumasi is mainly a consequence of development being located in waterways and/or blocking the flow of rivers and/or runoff as indicated by the MBID interviewee:

“We usually experience floods at the peak of the rainy season because a lot of buildings occupy waterways that have low infiltration rate, and also get saturated at that period. So the large quantities of runoff generated during rainfall spreads into homes and other structures that block its flow” MBID, June 2013.

Nevertheless, some of the property owners interviewed described the floods as punishments from the “river gods” because of the degradation of the rivers. This perception is based on the belief in Ghana that rivers are “gods” with “spirits and powers”, which can be helpful if appeased, or harmful if degraded by human activities like farming, physical development and dumping of refuse (Sarpong, 2005; Opoku-Agyemang, 2005). Based on this traditional belief, the interviewees observed that the recent widespread encroachment and associated pollution of the rivers and floodplains has incurred the wrath of the river gods, who punish them with frequent destructive floods. An interviewee said that:
“...I think the floods we experience here [Kumasi] are because the [river] gods are angry with us for contaminating the rivers. You know these rivers are spirits and as such do not like filth but now we dump waste into them.... So I think the rivers are angry and punishing us for the pollution because we didn't have any flood problems when the rivers were clean...” POI 15, July 2013

Many of the interviewees shared similar views, with an emphasis on the fact that the floods are expressions of the wrath of the river deities due to the degradation of the rivers and floodplains by human activities. Thus in a traditional sense, the spatially altered rivers in Kumasi now cause harmful flood disasters, instead of being sources of blessings like water supply or carrying runoff. Botchie et al. (2007) trace this problem to the apparent downgrading of traditional beliefs and norms like the prohibition of human activities in sacred groves, which were used to protect the rivers to stimulate and/or guarantee the purported spiritual blessings and protections from the river gods.

The interview results have demonstrated that the flood control functions of rivers and floodplains in Kumasi have been undermined by the massive reduction in their spatial extent, and as such they are unable to cope with the increasing quantity of runoff (see Section 4.2.2). Given the reduction of channel capacity of the rivers by physical structures, the rivers overflow their channels and/or spread over any open area with the water intruding into developments on the river banks and floodplains following any minimal rainfall. Therefore, the interview results strongly suggest that the floods experienced in Kumasi are mainly connected to the loss of rivers and floodplains, that hitherto helped mitigate such disasters in the city. This finding indicates that the flood disasters might be further exacerbated if effective measures are not adopted to arrest the reducing extent of the water areas, as underscored by the traditional belief that degradation of the rivers will bring disastrous occurrences including floods. The effects these of floods in the city are discussed in the subsequent section.

7.4 Effects of flooding in Kumasi

The interview, focus group and physical survey results indicate that flooding affect almost every facet of the existence of residents of flood prone areas in Kumasi. It was apparent that flooding has had human, social, physical, economic, environmental and
emotional effects, and the gravity of these effects has been increasing over the years, according to the interview results. The specific effects of flooding in the city are discussed below.

7.4.1 Human effects

Data on flood victims obtained from the NADMO office in Kumasi show that flooding poses an increasing threat to human lives in Kumasi, especially the urban poor, who occupy structures and undertake business activities in and along rivers and floodplains in the city. Flood victims in the city from 2009 to 2013 totalled 2,718 people, with an average of ninety-seven persons per incidence. A closer look at the data reveals that the number of people affected by floods in a year is increasing (see Figure 7.5). For example, the number of people affected by floods increased by approximately 40% from 583 persons in 2009, to 812 persons in 2013. The flood victims are affected in many ways including life loss, displacement, property destruction and disease.

![Figure 7.5 Flood incidence and victims in Kumasi (2009-2013)](image)

Despite unavailability of statistics on flood casualties, both the institutions and property owners interviewed vehemently emphasised that the floods have led to loss of human lives in the city. The NADMO interviewee for example, indicated that at least 3 people, particularly children and aged, are killed by flooding every year. This
was underscored by a focus group participant and the HSD interviewee who lamented that:

“We have over ten tribes in this community [Moshie-Zongo], and at least a member of each of the tribes has been drowned by flooding in the last five years. My own uncle was drowned some years back. Two lives were lost last year and one person was killed by the flood that occurred three days ago” FGD 1 Participant, September 2013.

“Yes, the floods cause deaths here [Kumasi]… children and older persons are often drowned. In this year for instance, two boys were killed in the flood that occurred in Asuoyeboah [suburb of Kumasi]…” HSD, June 2013.

Thus, there is an increasing trend in the numbers of flood victims in Kumasi, which gives an indication of the rising severity or intensity of flood disasters in the city. Although the number of people affected by floods, as well as the death toll, is generally low compared to international flood disasters, there are still high human costs over the long run. Given the rapid loss of rivers and floodplains (because of encroachment and land filling), more people are likely to be exposed to flood disasters, and this could cause panic and grief in the city (Karley, 2009; Institute of Local Government Studies/International Water Management Institute [ILGS/IWMI], 2012).

7.4.2 Loss of property

Property destruction is another key effect of flooding in Kumasi. Both institutional representatives and property owners interviewed widely reported that the floodwater damages foodstuffs (e.g., rice, maize and garri) clothes, household furnishings and electric appliances (e.g., television sets and fridges), furniture (e.g. beds, chairs and woollen carpets), personal property (e.g., cars and cash) and valuable documents (e.g., certificates and books) among others. The interviewees indicated that the items are either destroyed beyond retrieval or carried away by the floodwater. Some of the interviewees said that:

“The floods damage our properties like food, clothes, electrical appliances and books among others. In fact any item that we leave on the ground/floor is destroyed or carried away by the floodwater…” POI 10, July 2013.

“Yes, the floods cause a lot of damage to properties in this community. We are unable to use most household items again after the floods” FGD 2 Participant, September 2013.
The above quotes highlight that flooding causes extensive loss of, and damage to personal property that the already poor inhabitants of the flood prone areas have toiled to acquire over years. This exacerbates the precarious living conditions of the affected people as many take a long time to replace the lost property or never recover.

7.4.3 Physical damage

The spatial survey and interview results indicate that floods cause considerable damage to the built environment by destroying houses and infrastructure in affected communities. The interviewees explained that the strong current of the floodwater causes complete collapse of many houses and render the inhabitants homeless (see Figure 7.6). Some of the interviewees said that:

“The floods cause collapse of our houses/walls. The runoff flows from that direction so it first collapses the walls of my neighbour and then mine follows. My fence wall for example has collapsed more than five times in the last three years....” POI 5, July 2013.

“The whole of my building collapsed about four years ago as a result of floodwater...... but I think it was also partly because the house was a wooden structure......As you can see a lot people have even abandoned their houses and plots in the bush over there because of the floods...” POI 13, July 2013.

Further, it was observed that the floods and the associated waterlogging results in structural damage to many houses, including cracked walls, exposed and weakened foundations, leaking roofs and gradual submergence. The interview revealed that
many of the affected houses often eventually collapse from these structural defects, with the occupants being compelled to live in cramped conditions with limited space.

In addition, the interviewees reported that the floods damage physical public infrastructure and facilities such as roads, bridges, school buildings and office buildings. In particular, the interviewees emphasised that the destruction of the transport facilities obstruct free movement of people and vehicles. Given the slum conditions of most of the communities affected by floods, the property owners interviewed reported that the floodwaters often destroy the already poor roads and carry away makeshift bridges (see Figure 7.7), thus cutting off the communities from the rest of the city. Some of the interviewees commented that:

“Whenever the floods occur all the roads are damaged and our bridge is also carried away so we can’t even cross to the other part of the community to buy stuff from the market” POI 6, July 2013.

“No vehicle comes to this community whenever flooding occurs because the roads are submerged by water. If you are in town and the flood occurs, then it means you have to find a place to sleep that night because you can’t get transport to return home” FGD 1 Participant, September 2013.

The destruction of public infrastructure was underscored by the KMA interviewee who revealed that many of the roads, especially the earth roads in Kumasi, are submerged and rendered impassable by vehicles and pedestrians after floods. According to the KMA interviewee, this brings difficult living conditions because residents of the affected communities are unable to access essential facilities like markets and hospitals, as well as attend work in other parts of the city.
Analysis of the interview results indicates that the destruction of school buildings and/or the submerging of school compounds by floodwater interfere with educational activities. The interviewees reported that the affected schools are sometimes closed for weeks to clean up the classrooms/compounds, fix/replace damaged learning facilities and reconstruct collapsed walls before the students could return to school. The effects of flooding on education were summarised by a focus group participant as follows:

“Many children in this community don't attend school after the floods because their school buildings are affected and, are closed down by the headmasters, as they clean the compounds, fix damaged items or rebuild collapsed walls. These repair works sometimes take several weeks and the children have to stay at home until all is done.....” FGD 2 Participant, September 2013.

7.4.4 Disruption of business activities

It was apparent from the interviews that the floodwaters often inundate facilities and buildings in the Central Business District (CBD) of Kumasi, and thus halt business activities for hours, and sometimes days (see Figure 7.8). Since Kumasi has mainly open markets with unpaved surfaces, it was observed that the grounds become muddy and are rendered unusable for several days after the floods, affecting economic activities like petty trading. For example, the NADMO interviewee revealed that a flood incident in 2009 submerged the Kumasi Central Market and resulted in closure of stores and warehouses, as well as damaged goods on sale and stored in warehouses.
Additionally, the interview results show that the effects of floods on businesses is compounded by the fact that many of the informal economic activities (the city’s main economic activities) are located close to waterways, and as such are easily inundated with floodwater (see Section 6.3). Consequently, some of the property owners interviewed, who either work at the CBD or have business activities along rivers and in floodplains, indicated that they do not open their shops for several days after the floods because of an inability to access the shops and/or find dry ground to display their products. According to them, even if they are able to operate, customers often stay away. Some interviewees said that:

“I don’t go to shop after the floods because no one will even come to the shop to purchase the goods. The grounds become muddy so I can’t find a place to display the goods. I can stay in the house for about a week after the floods before I return to work and that affect my income” POI 36, September 2013.

“I am unable to come to here and work when flooding occurs...sometimes I just stand afar to watch my items floating on the floodwater because I would be drowned if I attempt to come closer. So most of items are damaged by floodwater....” POI 20, August 201

The results presented above clearly indicate that floods adversely affect business activities in Kumasi. This effect occurs through destruction and/or inundation of business facilities, damage of goods and products and loss of productive hours. This is in agreement with earlier findings that flooding slow down business activity and/or leads to complete collapse of certain businesses in extreme cases (Okyere et al., 2012). These disruptions inhibit the ability of the people to earn sufficient income, which can affect long term saving or investment for improving their living conditions (ILGS/IWMI, 2012; Okyere et al., 2012).

7.4.5 Destruction of urban farmlands and produce

Given the prevalence of agricultural activities along rivers and in floodplains in Kumasi, floods are associated with extensive damage of crops and farm animals. According to the farmers interviewed, the inundation of their farmlands by floodwaters causes considerable crop failure and/or poor yield, especially among crops like maize, cassava and vegetables. Some of the interviewees said that:

“Yes, flooding destroy our crops, especially those of us nearer to the river [Wiwi River]. The floodwater inundates the farmland and damages the beds, which make us
to temporary halt farming activities. For example, flooding destroyed all the spring onion and cabbage we planted here two years ago” POI 39, September 2013.

“I have witnessed several urban farming activities being damaged by flooding in this community [Asuoyeboah]. For example, there was one year when all the chicken in a poultry farm along the Asuoyeboah River were carried away by floodwater” FGD 2 Participant, September 2013.

This extensive destruction of urban agricultural activities indicates that flooding does not only destroy acquired properties, but also poses serious challenges to means of survival and livelihood. As a consequent, further probing revealed that many urban farmers in the city have been rendered impoverished through the destruction of their crops and animals by floods. The flood damage to the farmlands could also affect food supply, especially vegetables from urban farming, which most of the city’s residents heavily rely on (see Section 5.3).

7.4.6 Insanitary conditions, water contamination and health threats

Flooding exacerbates the already poor sanitation and often increase water pollution, which poses public health threats in Kumasi. The interviewees reported that the floodwaters carry garbage, plastic wastes and faecal matter that are left behind in homes and on the streets after floods. According to the interviewees these accumulated wastes create unsightly scenes and emit an abhorrent stench. An interviewee said that:

“The floodwater brings a lot of filth to our house. Every part of the house is always filled with wastes like polythene bags, faeces, garbage, tree etc. after the floods. The house becomes very dirty and unhealthy after the floods” POI 28, August 2013.

Further, the interviews and spatial survey found that the floods leave large areas of mud and pools of polluted stagnant water in some houses (see Figure 7.9), that serve as breeding grounds for disease transmitting vectors like mosquitoes. This situation is compounded by the contamination of open hand dugout wells, which are sources of domestic water for many households in communities along and within the rivers and floodplains (Owusu-Sekyere et al., 2014). Some of the interviewees disclosed that the water quality of their wells is undermined after the floods, as the water turn brownish with unpleasant taste and odour, and this exposes the residents to gastric problems. For example, an interviewee disclosed that:
“Most people in this community depend on wells because only few houses have pipe-born water. We use the well water for almost all our domestic activities like cooking, bathing, washing etc. but we patronise sachet water and sometimes purchase pipe-born water from a nearby house for drinking. But we are unable to use the our well for anything after the floods because the floodwater contaminates the water, and it becomes dirty and smells badly” POI 13, July 2013.

Figure 7.9 Pools of polluted water containing algae

Accordingly, some property owners revealed that the filthy conditions and contamination of domestic water often trigger sanitation related and water borne diseases in the communities. Although the institutional interviewees indicated that there has not been any reported major outbreak of diseases following floods, the property owners and focus group participants stressed that there are widespread cases of malaria, typhoid, diarrhoea, dysentery, cholera and other diseases in their communities during and after floods. Some interviewees remarked that:

“...A lot people fall sick whenever flooding occurs in this community. People suffer from all kinds of illness like malaria, typhoid and cholera etc. after the floods...” FGD 1 Participant, September 2013.

“..Our house is invaded by mosquitoes at nights whenever flood occurs because of the stagnation of the floodwater. We suffer a lot of mosquito bites which make us fall ill. This place is not good for healthy living whenever there is flooding” POI 10, July 2013.

Also, analysis of interview results shows that flood victims who come into direct contact with floodwater often suffer injuries, and sicknesses such as skin rashes. The interviewees revealed that floodwaters carry sharp objects such as trees and roofing sheets, as well as dangerous reptiles that caused cuts and bites. The interviewees further explained that the adults who stand in the inundated floodwater to create
trenches to divert and hasten flow of the floodwater from their houses usually suffer the skin rashes. An interviewee said that:

“I stand in floodwater to divert its course from our house so I often suffer cuts by sharp objects and insect bites, and I can easily be bitten by snakes if am not very careful. Also, I usually, and sometimes my children suffer from skin rashes after the floods...”  POI 38, September 2013.

In summary, flooding in Kumasi is accompanied by insanitary conditions and water contamination that have serious health consequences with adverse effects on the lives of flood victims. The flood incidents increase people’s vulnerability to contracting diseases and/or suffering injuries that could hinder them from undertaking daily activities. The people who fall ill as a result of the floods incur health bills, cannot work to earn a living and may become burdens to their households and their communities at large (ILGS/IWMI, 2012).

7.4.7 Emotional and psychological trauma

The various destructions and losses that accompany the floods cause emotional and psychological stress among flood victims and the general populace in Kumasi. The property owners interviewed indicated that they panic any time clouds gather, especially at night, and also become worried about the safety of their children and property when it starts raining at a time they are not at home. Some interviewees revealed that they often rush home from work to safeguard their children and valuables. The property owners stated that even the packing and unpacking of property involved in relocating to safe locations is traumatic. An interviewee said:

“We always live in fear and panic during rainy season because we don’t know when the flooding will occur. I get very disturbed about the safety of children whenever it begins to rain and I am not in at home. Sometimes I run from work to pack my valuable properties and take my children to safe place. Everything about the flooding is stressful, even packing items to safety...”  POI 11, July 2013.

Analysis of the interview results indicates that the emotional trauma is even more intense for those who have their property damaged but lacked the means to recover, as well as those whose relatives are drowned by the floodwater. The interview results show that these categories of flood victims grieve for long periods, which in many cases adversely affect their social wellbeing. A focus group participant said that:
“People cry as they helplessly watch their properties being carried away by the floodwater. The flood brings sorrow and grief in this community as people lose their property and relatives. Everything is affected in this community; floods times are times of mourning here and the grief can go on for several months” FGD 1 Participant, September 2013.

Thus, flooding leads to emotional and psychological distress that continues for at least the whole of the rainy season, and sometimes years. The prolonged period of stress and discomfort associated with the floods can affect the living conditions of the people, productivity of businesses, as well as functioning of the communities (Karley, 2009; Okyere et al., 2012).

The above analysis has shown the multidimensional effects of flooding in Kumasi. As highlighted in the analysis, the numerous effects poses several challenges to the general wellbeing of flood victims and to the general populace in the city. Based on this, the next section discusses the measures that have been adopted by the residents to contain and/or mitigate the impacts of the floods.

7.5 Coping and adaptation strategies to flooding in Kumasi

The interview and spatial survey results show that the residents have adopted several coping and adaptation mechanisms to survive and minimise the adverse impacts of the flooding as individuals and communities. As a result, both structural and non-structural measures for coping and adapting are undertaken before, during and after floods. The nature and purposes of the coping and adaptation strategies employed at the various phases of flood incidences are explained below.

7.5.1 Pre-flooding

Analysis of interview results reveals that the residents of flood prone areas undertake several actions prior to the onset of the rainy and/or flood season to curtail flood hazards. Many residents construct drains, build protective walls or build embankments with sandbags around their houses to prevent floodwater from entering their homes. Some residents also make structural changes to their houses by building protective fences or walls, raising the foundation of buildings, converting single storey houses to multiple storey houses and raising staircases of the houses to accommodate the rising inundation level (see Figure 7.10). An interviewee said that:
“My building was a single storey structure but I converted it to two storeys because of the frequent flooding... It is rare for the floodwater to reach the top here. I have also been constructing short walls in front of the rooms downstairs to prevent the floodwater from entering them....” POI 11, July 2013.

Property owners interviewed indicated that they have constructed shelves and raised the height of furniture such as wardrobes in their rooms to safeguard valuable property such as clothes, jewels, certificates and electronic appliances among others from being destroyed by floodwater. Others pack and send most of their valuable items to friends and relatives in other suburbs of the city that are not flood prone for safekeeping, prior to the onset of the rainy season. One interviewee explained that:

“We always prepare ahead because we know the situation here. We pack some of our valuable properties to our relatives/friends in other areas for safekeeping before the start of the rainy season....We have also constructed shelves on the walls and ceilings where we store some of the items when the floodwater inundate our house” POI 19, August 2013.

7.5.2 During flooding

A number of strategies are employed by the flood victims during flooding. Some interviewees revealed that they move their valuable property to higher ground or to neighbours when the clouds start forming and/or the runoff begin to overflow nearby drains. Nevertheless, further investigation revealed that many residents only begin to act when flooding is apparent because of the absence of early warnings about impending rainfalls and flooding. In the rare cases that such announcements are made on local radio stations, they are often delayed. Consequently, flood victims whose houses are suddenly inundated with floodwaters resort to climbing onto rooftops, packing children onto roofs or carrying them on their backs, standing on high objects, packing valuables up high and/or relocating to friends or families till the floodwaters recede. An interviewee said that:

“We start to pack our items onto the ceilings and shelves when the water starts coming here and then leave the house to stay with relatives in other parts of the city. But sometimes we are unable to go out because the floodwater inundates the house unexpectedly, so when that happens we carry our children to the ceilings while we stand on tall objects like tables or climb to the ceilings” POI 17, August 2013.

However, the interview results indicate that the most common strategies used during flood emergencies are sealing and/or opening vents in houses at appropriate times to
regulate the flow of floodwater in the houses, creating trenches to divert or facilitate the flow of the floodwater, as well as fetching floodwater out of rooms/houses with buckets. Some interviewees narrated their strategies as follows:

*We have installed a valve at the opening of our drain so we close it when it starts raining to prevent water from coming outside into the house and then open after the rain has subsided for the water accumulated in the house to flow out*” POI 6, July 2013.

*“I stand in the floodwater to clear the drains and construct new ones to make sure that the floodwater can flow out. Sometimes I use bucket to fetch the floodwater out of the house and rooms.”* POI 34, September 2014.

7.5.3 Post-flooding

The interviews and observations found that the flood victims engage in several activities to restore their lives to normalcy after the flooding. Post flooding activities in the flood affected communities include constructing trenches to drain stagnated floodwater, cleaning and drying of houses and rooms, searching for lost items, replacing of lost items, filling house floors with sand or sawdust and placing stepping stones and/or constructing raised wooden walkways within and/or between houses (see Figure 7.10). The interviewees explained that these actions are the first steps taken to return to normal life immediately after the floods. Consequently, these are followed by repairing and rebuilding of structures such as reconstructing collapsed buildings or protective walls, fixing ripped off roofs, raising building heights, and replacing wooden structures with permanent structures to prevent or accommodate future floods. Some of the interviewees explained the post flooding measures:

*“We undertake a lot of activities after the floods. We clean our rooms with detergents, drain the remaining floodwater in the houses and then dry our wet clothes and properties...”* POI 1, July 2013.

*“In this community, you see a lot people reconstructing their buildings or protective walls reroofing their houses after flooding....In last year, I reconstructed drains around my house and raised the height of the fence walls after the floods to prevent the floodwater from coming here again....”* POI 23, August 2013.

Besides the above individual actions, the residents mobilise as a community to (re)construct drains, (re)desilt drains and/or streams and (re)construct sandbag embankments within the communities (see Figure 7.10). In addition, communal meetings are organised to discuss the flood problems and proper waste disposal
practices, as well as to disseminate information on planned communal dredging or cleaning up exercises. A focus group participant said that:

“We organise communal labour to desilt gutters and construct new ones in the community. We also meet to discuss the problem among ourselves to find lasting solutions. The men in the community even went to construct sandbag embankments along one of the rivers this morning because of the floods that happened yesterday”

FGD 1 Participant, September 2013.

Although the community members contribute in various ways such as providing labour, technical expertise and finance, these communal efforts sometimes degenerate into conflicts due to non-participation by some individuals and lack of consensus among others. These problems result in individuals undertaking their adaptations and coping measures (e.g., construction of trenches around houses) independently without any coordination, hence sometimes worsening the flood problems for others.

Given the various adaptation and coping mechanisms employed at individual and community levels, the interview results show that very few of the interviewees had intentions to completely relocate from the flood prone communities to better communities. Further investigations however revealed that the relocation decisions of the few rarely become reality, due to an inability to afford land or housing at the safer locations, the strong social ties established in communities, as well as the emotional attachment to their homes and neighbourhoods.

“I have already invested my money in this house and that’s all I have. I can’t relocate to live somewhere else because I don’t have the money for that” POI 15, July 2013.

Nevertheless, some residents do nothing to either pre-empt the floods or reduce their impacts. These residents have accepted the floods as inevitable occurrences, and indicated that they put their faith in God to rescue them and/or reduce the floods. A property owner who has lived in one of the communities for over 40 years said that:

“The floods have become part of us; I just pray and hope that the situation will improve one day…” POI 23, August 2013.
In summary, the analysis demonstrates that both structural and non-structural coping and adaptation strategies have been developed for the pre, emergency and post incidence phases of flooding by residents of flood prone communities in Kumasi. Most of the measures suit the type of flood experienced, but their rudimentary nature...
and uncoordinated implementation have reduced their effectiveness. Nevertheless, many of the residents, including those with and without adaptation and coping strategies, are resolved to remain living in the communities irrespective of the adverse impacts of floods. This resolve underscores the intense drive of humans to inhabit risky ecological zones to meet land and housing needs (see Sections 5.2, 6.2 & 6.3). The next section examines the measures pursued by the city authorities to mitigate the floods, and their associated impacts on the flood victims.

7.6 Analysis of official efforts to manage flooding and its impact in Kumasi

The commitment of city authorities in Kumasi to mitigate the incidence and impacts of floods in the city is evident in the formulation of the Kumasi Disaster Management Plan (KDMP), which is modelled on the National Disaster Management Plan (NDMP). The KDMP was developed in 2011 and, consistent with the NDMP, has the central objective of promoting a more scientific and effective management of disasters such as flooding in Kumasi. The KDMP recognised the application of integrated disaster management approaches, as well as identifying measures for managing the pre, emergency and post disaster phases of flood incidences. The policy actions of the plans include flood hazard mapping (identifying hazard situations, identifying safe havens, vulnerability and risk assessment); education and training (creating public awareness of hazards, skills acquisition by emergency response workers); emergency response and relief management (distributing relief items, evacuating and sheltering victims); as well as rehabilitation and resettlement (reconstructing infrastructure and utility services, promoting self-reliance and income generating activities). However, this plan has yielded little success due to implementation challenges like poor institutional collaboration, lack of integration of flood disaster management issues into sectoral plans and inadequate funds.

As a result, the interviews and spatial survey results show that flood management in Kumasi mainly involves structural engineering measures like storm drain construction and river channel modifications, as well as reactionary flood emergency phase interventions. Storm drains – primary, secondary and tertiary – have been constructed to receive and carry storm water, runoff and sullage water in various
parts of the city. Also, sections of some of the rivers including Aboabo, Subin and Sisa Rivers, totalling about 23 km, have been concreted to strengthen the channel walls and increase flow capacity, for the purposes of controlling floods.

Unfortunately, the interview and spatial survey results reveal that these structural measures have not only been ineffective in reducing floods but have also contributed in many cases to the occurrence of floods in Kumasi. The interview results emphasise that inadequate provision of drains, lack of proper maintenance and low capacities of the existing drains are key contributors to the floods. For example, it was observed that storm drains are non-existent in many of the suburbs, and as such storm water and runoff have to find their own flow paths within the communities. As a result, the storm water or runoff eventually spread to inundate nearby houses, as was noted by one interviewee:

“The flooding we suffer in here [Moshie-Zongo] is a result of lack of drains...The floodwaters wouldn’t have entered our homes if there were drains for them to flow through. But because there are no drains, the runoff passes and enters anywhere it finds a way” POI 27, August 2013.

Also, the interviews, focus group discussions and observations revealed that many of the drains have construction defects that inhibit their functioning. It was observed that the majority of the drains in the city are either undersized or connected at almost 90°, which hinders flow of runoff. The interviewees explained that these engineering limitations have undermined the flow and discharge capacities of the drains, resulting in a backwater effect that causes flooding with even small rainfall events. The HSD interviewee and focus group participant said that:

“Yes, many of the drains in Kumasi are undersized and have engineering deficiencies especially at the confluences and these result in overflows and backwater effect that contributes to flooding” HSD, June 2013.

“The flood that occurred in this community this year was caused by the small size of the drain they [city authorities] came to construct across the river...The drain is very narrow so the storm water was not able to flow through it and that made the water to spread and enter into the houses around the area ....” FGD 2 Participant, September 2013.

Additionally, the interviews results indicate that the problems are compounded by the deplorable conditions of drainage systems. According to the interviewees, the poor
state of the drains has resulted from the lack of proper routine maintenance, development of unauthorised structures on and along the drains, dumping of refuse and human excreta in the drains, as well as laying of service and utility lines within some of the drains. Interviews with the institutional officials and property owners revealed that no routine dredging and desilting is undertaken due to financial constraints, while the residents have turned the drains into garbage dumping sites leading to accumulation of sediment and refuse in and along the storm drains. For example, field inspection reports and hydraulic calculations obtained from HSD indicated that the Aboabo storm drain, which was originally 2.5 m deep, had reduced to 0.7 m in 2013, indicating that more than three quarters of the drain is filled with sediment. Personal observations also found that some of the drains are choked with solid wastes such as plastic bags, cans and bottles, especially at the entrances, which are sometimes completely blocked (see Figure 7.11).

![Figure 7.11 Choked and silted storm drains in Kumasi](image)

Given these conditions, the drains are unable to carry the storm water during downpours due to blockage of flow and reduced capacity, therefore causing floods; as was narrated by some of the interviewees as follows:

“...People have turned the drains into refuse dump sites. They throw garbage, especially plastic bags into the drains and these heavily choke the drains so when it rains the storm water that enters them [drains] is unable to flow and as such spreads to destroy properties. This is one reason for the numerous flood incidences at the onset of the rainy season because the wastes dumped into the drains severely obstruct free flow of runoff generated by the initial rains” NADMO, June 2013.

“If you go to places like Adum and Kejetia [the city centre] among others, we have small drains that are supposed to flow into primary drains but these open drains are almost always choked with garbage, while people have also built on them. So the
slightest rain results in flood because it’s either there are no ways for runoff to pass or the drains have been blocked at the entrance.....Besides, we don’t have funds to maintain these drains. For example, at the moment we need to desilt the Aboabo storm drain and many others but we are still waiting for funds from the Ministry of Water Resources, Works and Housing, which we don’t know when we will receive it” HSD, June, 2013.

“The city authorities don’t manage the drains well while people dump all forms of waste into them [drains]...Most of the drains in this community have not been dredged for more than five years and because of that the gutters are highly silted, so with the little rain, then the whole of this area get flooded” POI 32, September 2013.

Given the failure of engineering approaches, interviews results show that the cities authorities resort to reactionary emergency and post flood phases mitigation measures such as distributing relief items (that is, food and non-food items), evacuating victims and salvaging belongings, as well as demolishing structures within waterways; when the floods eventually occur. The NADMO interviewee explained that:

“We normally give them [flood victims] food, clothes, plastic utensils, roofing sheets, mattresses and blankets among others. Sometimes call on the Fire Service to pump out water from the houses and do some kind of rescue sometimes.....We also collaborate with institutions like HSD, MBID, and KMA to demolish structures in waterways in the communities affected by the floods” NADMO, June 2013.

Nevertheless, many interventions such as demolition of structures within the rivers and floodplains hardly become a reality due to fierce opposition from the occupants, lack of political will on the part of the KMA, as well as corruption and connivance among staff of institutions tasked to undertake such activities. Also, the institutional interviewees explained that, emergency responses like providing relief items are often limited due to lack of human and financial resources. This was underscored by many of the property owners, who indicated that they have never received any assistance from the city authorities before, during or after flood disasters. A property owner and the NADMO interviewee remarked that:

“I don’t receive any help from the KMA or NADMO; I have been dealing with the problem myself. Sometimes they come here to write names of those affected by the floods, but I have never received anything from them [KMA/NADMO] ” POI 9, July 2013.
“We are unable to provide relief items to everyone [flood victims] because we usually do not have enough funds to purchase large quantities. But we have been doing our best to help them [flood victims]” NADMO, June 2013.

Thus, despite the increasing flood disasters in Kumasi, interventions tend to be reactionary, and sometimes aggravate the incidence and impacts of floods. While the well-structured disaster management plan has not been duly implemented due to several challenges; the reliance on storm drains has been largely ineffective, with emergency responses being mostly inadequate. As a result, the underlying causes of floods – development in flood prone areas – as well as impacts have not been well addressed by authorities. These revelations support earlier observations that flood disaster management practices in Ghana and other developing countries are ad hoc, one dimensional, unscientific, uncoordinated and not largely integrated in land use plans (Rain et al., 2011; Okyere et al., 2012). These practices could exacerbate the damage and inconvenience that are caused by flooding in Kumasi.

7.7 Summary

The results in this chapter have explicated the nature and impacts of floods in Kumasi, addressing the Impacts component of the DPSIR framework. The issues analysed essentially answered the research question: “how have the spatial changes in the rivers and floodplains contributed to the frequency and intensity of floods in Kumasi?” The data analysed in the chapter were obtained through spatial survey, semi-structured interviews, focus groups and secondary data analysis. The multiple sourced data have been useful in ascertaining and understanding flooding as a sequel to the reducing spatial extent of rivers and floodplains in Kumasi. The chapter highlighted salient findings that are summarised below.

First, the analysis demonstrates that floods have become recurrent disasters in Kumasi, but are mainly concentrated in communities with extensive developments within rivers and floodplains. The frequency of floods has been increasing and at least five floods are recorded annually during the rainy season, with the effects of inundation remaining for about a month.

Second, the analysis reveals that the flooding in Kumasi could be described as the outcome of human actions and inactions, as it is largely fuelled by the loss of rivers
and floodplains that has resulted from the various anthropogenic pressures and drivers discussed in Chapters Five and Six respectively. The situation is compounded by the poor state and inadequacy of storm drains, despite this being the main approach for mitigating and controlling floods in the city.

Third, the analysis indicates that floods have had a broad range of consequences including human, physical, social, economic, environmental and emotional, which undermine the quality of lives of those affected. The effects identified include loss of lives, loss of personal property, damage of houses and physical infrastructure, disruption of economic activities, poor sanitary conditions and increased incidence of sanitation-related and waterborne diseases, destruction of farmlands and crops, as well as emotional and psychological trauma. It was apparent that the magnitude of the effects of the floods is increasing, with immediate impacts becoming permanent, as the victims who are undoubtedly poor take a long time to recover, or never recover.

Finally, the analysis shows that the residents have adopted both structural and non-structural coping and adaptation strategies at individual and community levels to prevent the flood, or at least reduce its effects. Some of the measures include constructing and desilting drains, constructing sandbag embankments and raised wooden walkways, erecting protective walls, raising the height of furniture, packing and sending valuable property to friends and relatives for safekeeping and temporarily relocating to stay with friends and relatives; and these are employed differently before, during or after the flood incidences. Nevertheless, the analysis emphasise that not only have some measures, especially structural approaches like construction of protective walls and drains been ineffective, but also they aggravate the flood problems due to their uncoordinated nature.

The chapter has highlighted the increasing intensity and impacts of flooding in Kumasi in the face of the reduction in spatial extent of rivers and floodplains in the city. Unfortunately, the chapter revealed that coping and adaption strategies of flood victims, as well as official management approaches by city authorities, continue to fail to prevent and/or minimise the floods and their impacts due to the reactionary nature of the measures. The next chapter presents a discussion of all the key findings.
of this research, as well as recommendations for improving the urban, river and floodplain management, in keeping with the *Response* component of the DPSIR framework. The findings and the literature provide the basis for developing plausible scenarios of river and floodplains in Kumasi, making recommendations and concluding the whole thesis.
Chapter 8 - Discussions, plausible scenarios and conclusions

8.1 Introduction

The changing spatial extent of inland water systems, particularly rivers and floodplains, in urban areas is widely acknowledged in the literature on natural resources management and urban planning. Unfortunately, our knowledge of how and why the extent of rivers and floodplains is changing is limited, especially in developing countries where the phenomenon is increasingly observable and pervasive. This thesis is contributing to that knowledge by explaining the trends, nature, drivers and implications of the changes in spatial extent of rivers and floodplains in Kumasi, a rapidly growing city in Ghana. Therefore findings from this research contribute to understanding and managing the loss of rivers and floodplains in cities in developing countries. The key research findings are highlighted in terms of the research questions and the DPSIR conceptual framework, and discussed in the context of the broader literature. Based on the findings and conceptual framework, recommendations for informing urban, water resource and flood management in developing countries, as well as plausible futures of rivers and floodplains in Kumasi and possible directions for further research are discussed. Finally, the conclusions of the research are provided in the light of the evidence discussed.

8.2 Key findings of the research

8.2.1 Key finding 1: Rapid reduction in spatial extent of rivers and floodplains

This research found that the spatial extent of rivers and floodplains in Kumasi is rapidly declining through conversion to urban land uses. According to the literature, cities often originate near natural water courses (Lerner & Holt, 2012). However, these inland waters now lie in highly urbanised corridors of many modern and rapidly expanding cities, making the inland water systems, especially rivers and floodplains, vulnerable to replacement and degradation by intensive anthropogenic activities in the catchments (Lerner & Holt, 2012; Everard & Moggridge, 2012).

The results of satellite image analysis for this research reveal that many rivers and floodplains in Kumasi have disappeared, while others have undergone significant
morphological changes. The results indicate a 46% and 83% reduction in the number and area of rivers/floodplains respectively, at rates of one river and 1.2 km² lost per year over the last 28 years. The area of rivers and floodplains decreased from 38 km² in 1985, to 6 km² in 2013, which represents only 2.5% of the 254 km² total land area of Kumasi. Results from interviews and focus group discussions suggest that the observed reduction in rivers and floodplains has resulted in drastic and obvious changes in the spatial extent of these water areas in the city; given that Kumasi was once well-known for its dense network of rivers that earned the city the accolade “Garden City of West Africa”.

This finding is consistent with the literature regarding the loss and reduction of inland water systems globally, particularly in cities in developing countries (Prasad et al., 2009; Akumu et al., 2010; Du et al., 2010; Davidson, 2014). Also, the decreasing trend in spatial extent of the rivers and floodplains demonstrates the existence of and/or trend towards fragmentation of the surface water network which has undermined the ecological and hydrological vitality and functionality in Kumasi (Du et al., 2010; Islam et al., 2010; Deka et al., 2011) (see Chapters 4 & 7). Nevertheless, this finding on the rate and extent of loss of rivers and floodplains is significant for informing spatial planning locally, as well as in other cities of developing countries, considering that such information remains poorly documented or unavailable (Finlayson et al., 1999; 2005; Davidson, 2014).

Additionally, the research findings show that almost all the reduction in the area of the rivers and floodplains went into urban development. This research found that between 1985 and 2013 about 88% of the land area of rivers and floodplains was utilised for various forms of urban development. This finding was not completely unexpected considering the urban context, and agrees with the literature on extensive reclamation of inland water systems for urban land use activities in cities. Several researchers (e.g., Dewan & Yamaguchi, 2009; Akumu et al., 2010; Du et al, 2010) have reported widespread replacement of inland waters, particularly lakes and wetlands, by physical development in rapidly growing metropolitan areas like Kumasi. This corroboration highlights the importance of urbanisation and its associated processes in the loss of inland water systems. Alternatively, this research
finding suggests that the type of land use that invades or replaces water areas is dependent on the context; so rivers and floodplains that are located in cities are likely to be converted into mainly urban land uses.

The different urban land uses identified in and along the rivers and floodplains are residential, commercial, industrial, civic and cultural. Residential land use, which is the commonest, comprises mainly temporary wooden and concrete structures, indicating the unplanned and unapproved nature of the development in the water areas. While at least some form of urban land use is found within 100 m from every river or floodplain, nature reserves and buffer zones are virtually non-existent. This finding indicates that while ‘unauthorised’ land uses are growing, acceptable land uses, particularly nature reserves/buffers, are becoming less common along rivers and floodplains (Ahmed & Dinye, 2012). Previous literature has also noted the progressive growth of similar human activities leading to spatial loss and pollution of inland waters in urban areas in developing countries (Braimoh & Onishi, 2007; Prasad et al., 2009; Du et al., 2010). Thus, this present research, together with the previous studies, provides an understanding of potential urban land uses along rivers and on floodplains, and hence offers a useful basis for enhanced water resource and flood risk management.

8.2.2 Key finding 2: Pressures reducing spatial extent of rivers and floodplains

The research findings indicate that the reduction in spatial extent of the rivers and floodplains occurs through three main processes, namely: unregulated urban expansion, growth of unplanned urban agriculture and poor waste disposal practices. The research found that these pressures operate synergistically to directly account for the loss of rivers and floodplains and/or their replacement by other land uses/covers. The dynamics of the pressures that reduce the spatial extent of the rivers and floodplains are highlighted in the subsequent sections.

The fast and uncontrolled expansion of built-up areas into the rivers and floodplains is as a major pressure that reduces the spatial extent of the water areas in Kumasi. The satellite image analysis shows that about 9% (18 km$^2$) of the total 206 km$^2$ of built-up areas in Kumasi in 2013 was reclaimed from rivers and floodplains. This finding supports earlier studies which indicated that rapid but unregulated urban
expansion encourages draining of rivers and floodplains for physical development, as well as promotes water quality degradation by polluted urban runoff and high evapotranspiration rates, which eventually affect the extent of the rivers and floodplains (Finlayson et al., 2005; Vörösmarty et al., 2005). In addition, the significant loss of rivers and floodplains in Kumasi to the rapidly expanding urban land uses has resulted in a land use/cover pattern that ultimately does not conform to the city's land use plans, which envisaged the interspersing of built-up areas with natural environments, such as rivers and floodplains (see Chapter 6).

The research findings show that the main processes that reduce the spatial extent of the rivers and floodplains in Kumasi are encroachment and land filling. The interviews explained that although these two processes convert the rivers and floodplains to mainly urban land uses, the pace of disappearance of the rivers and floodplains varied under each process. The reclamation and loss of the rivers and floodplains occur gradually under encroachment, while they happen instantaneously under land filling. Despite the high cost involved, the research participants frequently stated that land filling has become very common (among the wealthy) in recent times, posing a severe threat to the few remaining rivers and floodplains in the city. The findings appear to confirm previous research that suggests the loss of rivers and floodplains may occur through processes that aim at creating more space to satisfy the increasing demand for land, especially in urban areas (Prasad et al., 2009; Islam et al., 2010). For example, it is the earnest need for space for human activities that has accounted for the widespread practice of land filling, which causes instant and outright disappearance of rivers and floodplains (see Chapter 6).

Another important pressure on rivers and floodplains is the growing informal economy and the urban agriculture subsector in particular. Data analysis reveals that the informal economy has experienced tremendous growth, and employs about 66% of the labour force in Kumasi (KMA, 2010). Regarding urban agriculture, it emerged that the sector has now become a key employment and survival choice in the city, with urban farmers increasing more than fourfold between 1960 and 2010 (see Chapter 5). However, this research found that urban agriculture is not duly recognised in urban land use plans of Kumasi, and as such the majority of the urban
farmers operated in the riverbanks, wetlands, floodplains and valleys in the city. This finding is consistent with claims in the literature that the informal economy, particularly urban farming is often forgotten in the urban land use planning processes of many cities in developing countries (Chen, 2005; Obuobie et al., 2006). As a result, this research found that the majority of agricultural activities in Kumasi are illegally undertaken within rivers and floodplains. In addition to converting the riverbanks and riparian areas into farmlands, it was observed that farming operations, such as diverting and damming stream channels for irrigation, excessive application of pesticides and herbicides and disposal of farm wastes, have negatively affected the rivers and floodplains. The data analysis indicates that these adverse impacts gradually degrade water quality and aquatic organisms of rivers, as well as leading to the eventual disappearance of rivers and floodplains in the city. This finding agrees with the often held assertion that unregulated agricultural activities result in the degradation of inland water systems; albeit the loss rivers and floodplains to urban agriculture in Kumasi has not been immense as often claimed in literature (Eppink et al., 2004; Finlayson et al., 2005; Ramsar Convention Secretariat, 2007).

Finally, findings of this research show that poor waste disposal practices remain a major pressure on rivers and floodplains in Kumasi (see Chapter 5). Poor waste management has been widely reported in the literature as a major cause of water pollution and eutrophication (Finlayson et al., 2005; Vörösmarty et al., 2005, MEA, 2005). This research found that the waste management systems in Kumasi are insufficient to ensure clean human surroundings, and protection of the environment. The analysis reveals that the quantity of solid and liquid wastes generated in the city has outpaced the available collection, disposal and treatment facilities and services. With 20% of daily solid waste uncollected, as well as about 90% and 44% of households without sewerage and internal toilet facilities respectively, interviews results indicate that large quantities of untreated domestic and industrial wastes generated in the city are disposed of in any available “free” space, mostly rivers and floodplains.

The research found that this widespread indiscriminate disposal leads to the release of organic and inorganic water pollutants into the rivers, and also siltation and
blockage of rivers channels by large waste materials like plastics. This has resulted in reduced water quality and stream flow, as well as increased sedimentation and disappearance of the rivers (see Chapter 4). This finding relates to earlier demonstrations of the negative effects of poor waste management on inland water systems (Ito, 2005; Prasad et al., 2009; Islam, 2010). However, the interview results indicate that the adverse consequences of poor waste management systems on rivers and floodplains in Kumasi are known by both the local people and institution officials. Thus, it seems that the discharge of untreated effluent and solid wastes into aquatic environments could be addressed through better public education and concerted enforcement of punitive measures by all stakeholders.

8.2.3 Key finding 3: Multiple anthropogenic drivers of loss of rivers and floodplains

Overall, the research found that multiple anthropogenic drivers are largely responsible for reducing the spatial extent of rivers and floodplains in Kumasi. The drivers comprise of demographic, economic, cultural, social, political and institutional factors. The interactions of these multiple forces shape the trends, processes and nature of spatial changes in rivers and floodplains in Kumasi. Environmental factors such as climatic conditions and physical hydrologic modifications to a lesser degree accounted for temporary spatial changes in the water areas. This understanding of the importance of the multiple interacting drivers is relevant for urban environmental change management not only in the local context, but also in the wider developing world.

The research findings indicate that unregulated population growth and the associated increases in urban poverty significantly contribute to the reduction in extent of rivers and floodplains in Kumasi. The research found that Kumasi has experienced rapid population growth because of a high influx of (poor) migrants in recent times. The population of the city nearly doubled in a decade to exceed 2 million by 2010 (see Chapter 6). This large unregulated population increase led to land and housing shortages that meant rivers and floodplains were converted to urban land uses. The research findings further show that urban poverty, which is mainly manifested in homelessness and high room occupancy rates, has been increasing and is pervasive,
especially in the growing population of in-migrants. As a result, many residents, particularly the low income migrants who could not access and/or afford the few available houses and land, have resorted to erecting predominantly temporary structures that often degenerate into sub-standard informal settlements in the readily available less desirable water areas. The interview results emphasise that the rivers and floodplains are mostly freely encroached upon and land filled for physical developments, particularly residential and commercial land uses, due to the increasing unmet housing and land needs of the city’s dwellers.

This finding is supported by previous research that indicates that urban population growth is instrumental in urban environmental change (Alcamo et al., 2005; Cobbinah et al., 2015b). These researchers explain that population determines which environmental elements are utilised appropriately and inappropriately for provisioning services such as housing and food among others, and also influences factors that drive changes in the ecosystem (e.g., magnitude of waste generation and proportion of the waste disposed into the rivers and floodplains). This present research emphasises that population growth when rapid but unguided, as well as accompanied by pervasive poverty conditions as in the case of Kumasi, drives more dramatic reduction in the extent of inland waters. This is because the pressures from land and housing shortages result in the invasion of rivers and floodplains for developments such as residential, commercial and industrial land uses among others.

Furthermore, a number of interrelated socio-cultural, institutional and political factors, including land ownership practices, legislative and policy frameworks, and institutional arrangements also contribute to river and floodplain degradation in Kumasi. First, in accordance with prevailing socio-cultural practice, the research found that a greater proportion of developable land in Kumasi is customarily owned with highly informal land allocation practices, and little or no government control. As a result, the traditional leaders who are the custodians of the customary lands allocate land, irrespective of the location, to private developers in the city. Given the shortage of developable lands in Kumasi, the research results reveal that waterways and floodplains are sold to prospective developers by traditional leaders for their self-interest, without any recourse to planning layouts and legislation and without public
or government approval. Thus, the customary land ownership system which has entrusted land administration and delivery to traditional leaders contribute to the destruction of rivers and floodplains in Kumasi. Nevertheless, findings of this research suggest that the situation could be minimised if due diligence is exercised by the city authorities and/or institutions to acquire and preserve the water areas as unbuildable lands as proposed in land use plans of the city for public interest and safety.

Although a multiplicity of broad national policies and legislations are used to manage water resources and physical developments in Kumasi, their effectiveness leaves much to be desired. Analysis of the policies and legislations reveals that they generally aim to ensure that physical developments conform to minimum acceptable standard of environmental health, and also improve the quality of life in Kumasi and the nation as whole. However, it emerged that the contribution of these laws and plans to orderly development and protection of rivers and floodplains in Kumasi has been limited. This situation has resulted from inherent weaknesses of the majority of the policies and legislations, as well as poor implementation of their objectives. Findings of this research demonstrate that some of the key policies and legislations are obsolete (e.g., CAP 84), while the majority of the new ones are vague and incomprehensive, and hence unable to counter the challenges posed by the rapid population and physical growth in Kumasi. In addition, the findings indicate that the impacts of the legislation and policies on river and floodplain management have been hampered by poor implementation due to low capacity of enforcing institutions, undue political and social interference and a general public disregard of the laws and policies. These challenges are compounded by the limited public participation in the formulation and implementation of policies and legislation, although most of these policies and legislation advocate for bottom-up approaches to water resource management. Thus, the ineffectiveness and poor implementation of urban and water resources management legislative and policy frameworks significantly account for the degradation and loss of rivers and floodplains.

The analysis further indicates that the poor functioning of the various urban and water resource management institutions, negatively affect the spatial extent of rivers
and floodplains in Kumasi. In addition to their low institutional capacity, such as a lack of human, financial and logistical resources, the institutions also operate without any effective collaboration, and sometimes pursue programmes with focuses other than water resources conservation (see Chapter 6). This is partly due to the existing institutional arrangements where the agencies operate under diverse sector ministries including Ministry of Education, Ministry of Agriculture, Ministry of Environment, Science, and Technology, Ministry of Communication and Ministry of Works, Water Resources and Housing among others, which all have different policy directions (Fuest, Haffner, Ampomah & Tweneboah, 2005; Amoateng et al., 2013). The end result of this institutional setup is overlapping functions, conflict and stalemate between and among the institutions, as well as poor institutional performance. This is compounded by the poor environmental attitude of the public and traditional leaders, who are also key stakeholders in water resource and urban growth management (see Section 5.7). Thus, this research highlights that the actions and inactions of all the stakeholders, including government institutions, NGOs, traditional leaders and local residents, contribute to the degradation and loss of rivers and floodplains in Kumasi.

The preceding findings on the adverse impacts of socio-cultural and institutional factors are in congruence with previous claims that a lack of effective policies, legislations and institutions thwarts effective management of physical development and water resources in cities in developing countries (Joshi, 1993; Hens & Boon, 1999; Fuest et al., 2005). These legislative, policy and institutional issues are ubiquitous internationally, and point to the wider issues of providing sufficient capacity for water resource management. In Ghana, the situation is closely linked to the country’s low level of economic development and political maturity, which culminates in poor quality policies and legislation, low resource capacity of institutions, poor law enforcement and lack of public participation (Hens & Boon, 1999, Afeku, 2005). This underscores the findings of Mensah (2014), who argues that the protection of green spaces and nature reserves including rivers and floodplains has been accorded a low priority by city authorities and governments in Africa. The findings of this research further suggest the need for a high degree of stakeholder collaboration, coordination and monitoring, taking note of the strengths and weakness of each of these interest groups in order to effectively implement
policies and laws to ensure orderly urban development, and thus conserve rivers and floodplains to protect their range of ecosystem services including flood mitigation.

Conversely, the widespread reporting of the transformative effects of dam development on the hydrologic cycle in terms of stream fragmentation and flow regime modification, aquatic habitat destruction, runoff changes and increased water logging duration (Maheshwari et al., 1995; Carpenter et al., 2011) is not relevant to the situation in Kumasi. This is because stream flows and runoff in Kumasi are not interrupted by dams/reservoirs along their pathway downstream in the city. Thus, the rivers in Kumasi receive all the necessary hydrologic inputs through rainfalls. This finding affirms an earlier finding by Chen et al. (2014) that despite extensive dam development within the catchment of Yangtze River in China, water input to the river has not witnessed any significant change over the years. This present research finding also implies that the degree of impact of dam developments on stream flow, hydrologic regime and connectivity of rivers is significantly influenced by the location of the dams in relation to the source and course of the rivers.

Finally, the analysis of rainfall and temperature changes and variability shows that their effects on the rivers and floodplains in terms of the reducing spatial extent have been insignificant. While the annual rainfall is decreasing and has relatively high variability, the temperature showed an increasing trend with low variability, emphasising the tropical climatic conditions of Kumasi. According to the literature, this prevailing climatic condition is the result of the movement of the Inter-Tropical Convergence Zone (ITCZ) and oscillating Atlantic Sea-Surface Temperatures (SST), which cause temporal variations in weather conditions in the West African region (Barbé, Lebel & Tapsoba, 2002; Sultan & Janicot 2003; Shanahan, Overpeck, Sharp, Scholz & Arko, 2007; Weldeab, Lea, Schneider & Andersen, 2007). The decreasing rainfall and rising temperature are also attributed to the rapid growth of Kumasi, which has resulted in the replacement of practically all the vegetation cover with urban land covers, with their associated reduced soil moisture, as well as evapotranspiration, high heat retention and greenhouse gases emission (Carpenter et al., 2011; IPCC, 2013).
Previous research indicates that low and variable rainfall, and high temperatures cause reduced hydrologic input in rivers and high evaporation, as well as high pollutants concentration and reduced oxygen concentration in rivers. These consequently undermine the stream flows, aquatic habitat quality and extent of inland waters (Carpenter et al., 2011). In contrast, interview results for this research reveal that the decreasing rainfall and rising temperature, as well as their respective variability has not had any significant influence on reducing the spatial extent of the rivers and floodplains, apart from making some of the once perennial rivers seasonal due to increased variability of hydrologic inputs into rivers. This finding supports reports that changes in climate variables have not had much noticeable effect on the spatial extent of water bodies located within the moist semi-deciduous tropical lowland forest zone of southern Ghana (Turner, Gardner & Sharp, 1996; Shanahan et al., 2007). For example, two separate studies have reported that the level and extent of Lake Bosumtwe, a hydrological closed-basin lake which is located about 30 km south-east of Kumasi, have remained nearly steady despite the extreme sensitivity of its water budget to changes in precipitation and evapotranspiration, which have undergone significant changes in recent times (Turner et al., 1996; Shanahan et al., 2007). This suggests that there is no strong evidence that the degradation and loss of rivers and floodplains in Kumasi are due to changing natural conditions like climate; rather they are strongly linked to anthropogenic drivers such as urban development and water management challenges.

8.2.4 Key finding 4: Incidence and impacts of flooding

This research found that the conversion of rivers and floodplains to urban land uses has resulted in widespread flood incidences in Kumasi, because of fragmented hydrological networks and loss of ecosystem services such as runoff conveyance and retention offered by aquatic areas (Dhar & Nandargi, 2003; Anil et al., 2010). The findings reveal that flooding has become a frequent disaster in the largely informal communities where there is extensive physical development along rivers and on floodplains. The characteristics, perceived underlying causes, as well as responses to the floods, indicate that Kumasi experiences a greater frequency of riverine floods compared to flash or urban floods (see Chapter 7).
Analysis of flood records shows that flood disasters mostly occur at the onset and peak of the rainy seasons, with an average of five events per year. The interview results and available statistics suggest that the flooding, which is a relatively recent phenomenon in the city, is increasing in incidence and intensity. Often, many houses are completely submerged in floodwaters that last for several days before receding, due to the high water holding capacity soil type at the affected communities/locations. The long floodwater retention renders many houses uninhabitable, providing the city with the increased problem of homelessness and its associated vulnerabilities (Aboagye, 2010).

Consequently, findings of this research demonstrate that floods in Kumasi have had multiple direct and indirect consequences that impacted almost every facet of society. The effects included loss of lives, loss of personal property, destruction of houses and physical infrastructure (e.g., roads, school buildings), farmland damage, insanitary conditions and health threats, and emotional and psychological trauma, among others. Although the effects in Kumasi may not be as extensive when compared with floods in other Asian and North American countries (Anil et al., 2010; Hammond, Chen, Djordjević, Butler & Mark, 2013), these are very significant in the local context. This is because the findings of this research appear to suggest that the urban poor who have encroached upon the rivers and floodplains are the ones heavily burdened by the floods, as they already have high exposure to the floods but lack the resources to counter their occurrence or impacts (Karley, 2009; Aboagye, 2010; Okyere et al., 2012). In such situations, Okyere et al., (2012) explain that the multifaceted nature of the immediate effects of the flood disasters (e.g., human, physical, economic, social and environmental) leads to long term severe adverse impacts, with the potential to delay and slow recovery. For example, many researchers have indicated that flood victims often use their limited income or contract loans annually to replace or repair damaged properties, restock damaged goods and products, pay health bills, replant or clear destroyed crops and reconstruct collapsed walls or houses, resulting in low economic capacity that can perpetuate their occupation of undesirable highly flood prone areas (Karley, 2009; Aboagye, 2010; ILGS/IWMI, 2012; Okyere et al., 2012; Campion & Venzke, 2013).
Findings from this research strongly suggest that the increased incidence of floods in Kumasi has mainly resulted from the reduction in the spatial extent of rivers and floodplains, although the floods are usually preceded by heavy rainfall events. The research found that the rivers have been rendered incapable of conveying and absorbing the high volume of runoff generated during storms, due to reduced channel capacity and land area of the rivers. In addition, it was observed that the physical developments often affected by flooding are located in areas that naturally have high water table and slow absorption capacity, and as such reach saturation points quickly and generate excessive discharge that overflows the riverbanks to inundate these developments. This finding confirms earlier assertions in the literature that the development of urban land uses and/or loss of inland waters increases flood problems (Dhar & Nandargi, 2003; Prasad et al., 2009; Islam et al., 2010). In Kumasi, the enormous influences of the encroachment and development in rivers and floodplains on flood incidences is further underscored by the extended retention of floodwater in affected houses, as this indicates that the houses are located in low-lying areas where water logging is expected in rainy seasons because of high clay content of soils and high water tables (Kesse, 1985; Adjei-Gyapong & Asiamah, 2002; Campion & Venzke, 2013).

Furthermore, the research found that despite the significant increase in runoff yield in Kumasi in recent times, storm drains, the main official approach for controlling flooding in the city, have been largely ineffective due to inherent construction defects and lack of maintenance. It was discovered that while annual runoff has dramatically increased by about 538 mm in the last 52 years due to the massive expansion of urban land cover, drainage networks remain inadequate and inefficient because of the general low level of economic development, negligence by authorities, ignorance and non-compliance of maintenance requirements by the public (Afeku, 2005; Okyere et al., 2012; JICA, 2013). The situation has resulted in an insufficient capacity and under-functioning of the drainage system that leads to overflow of runoff and hence severe flood conditions at critical locations during rainstorms. This finding underscores the claims in the literature that traditional structural flood control measures, which usually aim to prevent floods rather than minimise the effects of their occurrences, tend to worsen these natural disasters if they are not well
implemented and maintained (Aboagye, 2010; Afuku, 2005; Ikeda et al., 2005; Petroski, 2006; Kounsana & Takahashi, 2012). The magnitude of this seeming urban flooding in Kumasi is aggravated by the fact that the developments are located within the flow paths of storm drains and rivers, as well as on floodplains.

Over time, flood victims develop coping and adaptation mechanisms to accommodate and moderate damage from flood disasters. These anticipatory adjustments help to protect people’s lives, livelihoods and development thereby reducing the socio-economic vulnerability of individuals and communities. The actions and strategies used are often developed through experience, learning, resource availability, technology, external support and networks among others. However, recent studies have asserted that the adaption measures are significantly informed by the flood types and conditions which are linked to the underlying cause(s) of the floods (IPCC, 2007; ILGS/IWMI, 2012; Campion & Venzke, 2013).

This research found that flood victims have developed both structural and non-structural coping and adaptation strategies to prevent the floods, reduce losses and ensure resilience. Particular actions have been developed, and implemented before, during and after flood disasters, largely individually and sometimes collectively. Some of the key measures used are raised wooden or block walkways, building on stilts, filling of house floors with sand or sawdust and raising of entrances/staircases of houses/rooms, which are known to be the commonest adaption strategies for riverine floods (Campion & Venzke, 2013). According to Campion and Venzke (2013), such adaptation measures are associated with inhabitants of areas where heavy rainfall events trigger flow of effluent streams and eventual inundation. Thus, the adaptation and coping strategies used by flood victims in Kumasi further indicate that flood disasters in the city are the result of encroachment, occupation and loss of rivers and floodplains.

The findings also indicate that most of the coping and adaptation measures are rudimentary and largely undertaken individually, with few communal initiatives, and as such persistently fail to achieve the objective of minimising flood disasters in the city. Given that the flood prone communities are arguably inhabited by the urban poor in Kumasi (Campion & Venzke, 2013), this finding confirms earlier claims that
a lack of economic and social resources, as well as absence of coordinated effort, undermines people’s ability to adopt effective measures to cope with, and adapt to flood disasters (Aboagye, 2010; ILGS/IWMI, 2012). However, the ineffectiveness of the adaptation strategies could be better explained by the fact that the communities are located on land previously considered as waterways and floodplains, which are highly susceptible to intense floods that can overpower any flood control measures.

8.3 Plausible futures for rivers and floodplains in Kumasi

Following the above discussion about the trends, nature and drivers of the loss and degradation of rivers and floodplains in Kumasi, it was imperative to develop scenarios that explore plausible future spatial changes that might occur in these inland water systems in the city, with and without changes in the current water resource management practices (see Section 3.6 for a detailed description of the scenarios development process). The scenarios developed are Reactive Scenario and Proactive Scenario, and they are used to outline and interpret how the current pressures and driving forces may unfold, and what that means for rivers and floodplains in Kumasi, based on the prevailing water resources management practices. Thus, the scenarios represent two distinct possibilities for the future of rivers and floodplains in Kumasi, with an emphasis on strategies for achieving a sustainable environmental future for the city.

Given the argument by many of the research participants that a change to proactive management could help protect the rivers and floodplains in Kumasi, the two scenarios were developed to ascertain the possible future of the rivers and floodplains with and without such a change. The two scenarios therefore provided an opportunity to investigate further river and floodplain degradation that may occur under the current reactive management practices as discussed in Chapter 6 on the one hand, and the degree to which the rivers and floodplains could be protected with a change to a proactive management approach on the other hand. Consequently, the Reactive Scenario assumed continuity of the present urban, river and floodplain management practices in Kumasi (see Chapter 6). The Proactive Scenario, however, assumed a changed urban, river and floodplain management framework, and this was based on
the emphasis by the research participants that such was the change needed to fix the river and floodplain degradation problems in Kumasi.

These assumed conditions informed the ways in which each pressure/driver develops/changes towards 2050, with the pattern of change in the drivers/pressures differing under each scenario. As a result, the drivers/pressures undergo a high magnitude of changes with much detrimental effect under the Reactive Scenario, because few or no new policies are introduced to regulate them, while the opposite is the case under the Proactive Scenario, due to the introduction of new proactive urban and environmental policies to control them (see Table 8.1).

**Table 8.1 Trends of the drivers/pressures under the scenarios**

<table>
<thead>
<tr>
<th>Pressures/Drivers</th>
<th>Reactive Scenario (RS)</th>
<th>Proactive Scenario (PS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Population more than triples because of high in-migration and fertility rate.</td>
<td>Population more than doubles due to an influx of skilled in-migrants and natural growth.</td>
</tr>
<tr>
<td>Urban extent (land use/cover change)</td>
<td>Urbanised land doubles, but with substantial unauthorised developments.</td>
<td>Built-up areas increase by 70% and have mainly authorised developments.</td>
</tr>
<tr>
<td>Waste generation &amp; disposal</td>
<td>Quantity of waste generated quadruples but without matching expansion of waste collection services and treatment facilities.</td>
<td>Quantity of waste generated more than doubles but is accompanied by appreciable increase in waste collection services and treatment facilities.</td>
</tr>
<tr>
<td>Urban agriculture expansion (Pollution, eutrophication, withdrawal, diversion, draining)</td>
<td>Urban farmers increase by 60% due to unemployment but access to land remains a problem.</td>
<td>Urban farmers increase by 48% because of profitability of urban farming and availability of farmlands.</td>
</tr>
<tr>
<td>Institutional and socio-political environment (institutions, policies and land ownership)</td>
<td>Reactive and fragmented policies executed through ad hoc interventions by poor-functioning institutions. Apathy towards environmental conservation and emphasis on individual</td>
<td>Proactive and comprehensive policies implemented by well-functioning institutions that utilise planned and tested interventions. High environmental consciousness e.g.,</td>
</tr>
</tbody>
</table>

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interests. emergence of Green Societies and pursuit of community interests and actions.

| Climate change and variability | Decreasing and highly variable inter-annual rainfall. Rising and low variable inter-annual mean temperature. | Decreasing and highly variable inter-annual rainfall. Rising and highly variable inter-annual mean temperature. |

8.3.1 Reactive Scenario (RS)

The Reactive Scenario depicts a business-as-usual future in which the management of rivers and floodplains is unplanned, leading to a significant reduction in the spatial extent of the rivers and floodplains. In this scenario, there is an absence of pragmatic urban and environmental policies, and environmental degradation problems are given low priority in favour of economic and physical development, or sometimes addressed with ad hoc solutions only after they become apparent. Consequently, the rapid and unguided population growth and its associated challenges, such as the shortage of land and housing in Kumasi observed in Chapter 6 continue into the future. On the basis of the anticipated high growth rate noted in Chapter 6, the population of Kumasi more than triples towards 2050 due to high in-migration and this leads to extensive encroachment and land filling of the rivers and floodplains (see Table 8.2). This manifests in a massive physical expansion of Kumasi to engulf most of the adjoining settlements, to the detriment of the rivers and floodplains within the city and the suburban settlements. Indeed, the physical expansion involves conversion of mainly vegetative land cover and ecologically sensitive zones like the rivers and floodplains into urban land uses, particularly residential areas to meet the housing needs of the escalating population.

In addition, as indicated in Chapter 5, solid and liquid waste generation in the city substantially increases towards 2050 due to the rapid population growth. However, there is no corresponding growth in waste collection services and treatment facilities, resulting in large quantities of waste being indiscriminately disposed of into available open areas, especially rivers and floodplains, which causes eutrophication and
sedimentation/clogging (see Table 8.2). Furthermore, given the persistence of high unemployment and worsening poverty revealed in Chapter 6, an increasing number of people resort to farming along rivers and on floodplains as a means of survival and livelihood. However, the urban agriculture is poorly practised by first generation unskilled farmers, who apply high quantities of pesticides and fertilisers, drain water areas for farmlands and divert stream channels to irrigate crops without any expert advice. The adverse impacts of these practices on the rivers and floodplains are aggravated by the increased number of farmers engaged in urban farming (see Table 8.2). Although the present decreasing rainfall and rising temperature trends continue due to increasing urban land cover (see Chapter 6), these do not cause any observable changes in the extent of the rivers and floodplains. This is partly due to Kumasi’s location in a climatic region where (changing) weather conditions do not significantly affect water bodies, as discussed in Chapter 6.

Amidst these significant changes in the pressures/drivers, low priority is given to urban and environmental management, particularly protection of rivers and floodplains, as is the situation now (see Chapter 6). Efforts to protect the rivers and floodplains are reactive and not based on comprehensive urban and environmental policies. Some common short-lived interventions such as dredging streams, demolishing structures in waterways and straightening and lining stream channels with concrete are used, and these are usually done when the problems are very obvious or after flood disasters. Thus, protecting the rivers and floodplains is relegated to the background by official urban and environmental management agencies, and left to the mercy of land owners and the public. However, given the general low environmental consciousness of the public, they show apathy towards protection of the rivers and floodplains, and sometimes engage in or support activities that degrade the aquatic systems. In fact, the poor attitude of the public toward environmental conservation intensifies the unwarranted erecting of structures, farming and disposal of waste in the rivers and floodplains (see Table 8.2).

Consequently, vast changes occur in the spatial extent of the rivers and floodplains through 2050, and these automatically degenerate the flood attenuation functions of the network of rivers and floodplains in the city. Indeed there is a dramatic loss of
rivers and floodplains leading to almost complete non-existence of inland waters in Kumasi. As illustrated in Table 8.2, the rivers/floodplains are intensely encroached, drained or land filled by the populace to develop residential, industrial and commercial structures as the built up areas expands. In addition, the rivers are highly polluted with pathogens, nutrients and toxic materials from indiscriminate solid and liquid waste disposal and urban farming practices. The pollutants promote eutrophication and eventual loss of the rivers, thereby propelling flood disasters. Thus, the combination of exploding population growth, unregulated urban expansion, poor municipal waste disposal and unplanned urban agricultural expansion, as well as negligence of the environment leads to extensive loss of rivers and floodplains (see Table 8.2), with consequential disastrous floods in Kumasi.

8.3.2 Proactive Scenario (PS)

The Proactive Scenario represents a future in which well-planned management practices are pursued to sustain and/or possibly improve the spatial extent of rivers and floodplains. The importance of rivers and floodplains in terms of providing ecosystem services such as conveying runoff and serving as infiltration grounds for the urban environment, is recognised. This leads to adjustments such as reforming and/or introducing new urban and environmental management policies and lifestyle changes to address degradation of rivers and floodplains before it becomes severe in the long term. As a result, there is a decline in the rate of loss of the rivers and floodplains, while flood disasters also reduce to a minimum in Kumasi towards 2050.

With the introduction of local and national migration policies such as small towns’ infrastructure development projects and tax rebates in small towns among others, Kumasi experiences a rapid but planned population growth largely due to an influx of skilled migrants. This leads to a regulated population size with less pressure on land, leading to availability and affordability of developable land within the city and adjoining suburbs, unlike the situation observed in Chapter 6. The built-up areas thus gradually increase, with physical development mainly undertaken on permissible land and aligning with approved land use plans, although a few unauthorised developments continue to occur along and in rivers and floodplains. Thus, the urban land use expansion is planned and occurs in a very compact fashion, and there is a
minimal reduction in the spatial extent of rivers and floodplains, as these urbanised areas replace natural areas and agricultural lands (see Table 8.2).

Commensurate with the population growth, waste generation also increases at a rapid pace, but indiscriminate disposal/discharge decreases in the city because of improved waste collection services and treatment facilities. Waste treatment processes in Kumasi are sophisticated, with wastewater and some solid wastes used as fertilisers/manure and recycled/recovered into raw materials for example. However, it is unlikely that all the enormously increasing waste in the city and peripheral communities can be fully collected and treated; hence there is a very high likelihood that uncollected and untreated/partially treated waste continues to be disposed of into rivers and floodplains to some extent. Further, urban agriculture in the city is revolutionised to ensure high quality and increased produce by delineating farmlands on land use plans. As a result, extensive urban farming becomes the norm in response to higher demand for locally grown and seasonal produce such as fruits and vegetables by the growing population. However, efforts to intensify agriculture to ensure efficient use of land and meet high demand for the produce lead to increased fertiliser and biocide application, with adverse effects on rivers. Although the decreasing rainfall and increasing temperature trends, as well as their variability continue since local policies have little control over the climate; neither accounts for any significant changes in the spatial extent of the rivers and floodplains, as observed in Chapter 6 (see Table 8.2).

Nevertheless, various comprehensive urban and environmental policies are introduced to mitigate or pre-empt the impacts of rapid demographic, physical and socio-economic changes on the rivers and floodplains, as well as provide environmental improvements. Integrated surface water management approaches such as comprehensive river basin management plans and river restoration projects are implemented. These plans and policies identify pressures on the water environment, and urban drainage systems, and are implemented to protect rivers and floodplains and reduce flooding. Further, urban and environmental management regulations and policies are updated, broadened and implemented by local authorities to control pollution, encroachment and land filling of rivers and floodplains. Also, through
adaptive management, local people learn and understand that functional ecosystems are important for obtaining ecosystem services, and as such pursue and maintain community efforts at protecting environmental resources including rivers and floodplains. Indeed, the high environmental awareness gives rise to locally initiated regulations and conservation societies, behavioural changes and high compliance that help safeguard the rivers and floodplains (see Table 8.2).

As a consequence, a moderate reduction in the extent of rivers and floodplains is experienced in Kumasi by 2050. This marginal loss is achieved through the use of proactive approaches that counter the adverse impacts of the population growth, urban expansion and waste generation on the spatial extent of rivers and floodplains (see Table 8.2). In particular, the hydromorphology and aquatic ecology of many rivers are maintained through well-managed riparian buffers, enforcement of novel and tighter legislations on physical development and pollutant discharge, as well as river restoration initiatives by the city authorities and the general public. Through these, the ecosystem functions of rivers and floodplains, such as conveying and absorbing runoff, are sustained to a large degree, leading to reduced flood disasters in the city.

Thus, the above scenarios have provided two diverse perspectives on how the future will unfold for the rivers and floodplains in Kumasi, based on the prevailing urban and water resource management approach. Each scenario narrative has presented an alternative future that reflects different demographic, social, economic, political and environmental changes/developments. Nevertheless, both scenarios have some commonalities, in particular, the constant decline in the spatial extent of rivers and floodplains, albeit to varying degrees. This supports widespread claims that urban change of any kind has some level of impact on the inland water systems, with the prevailing urban and environmental planning and policies being a key determinant of the magnitude of the impact (North, 1990; Joshi, 1993; Fuest et al., 2005). Accordingly, loss of rivers and floodplains is massive in the Reactive Scenario due to weaker protection policies and neglect of the water areas in urban plan-making processes. However, the Proactive Scenario, which is more focused on environmental
protection and has policies that help curtail extreme physical development, is strongly marked by a less loss of rivers and natural areas.

Table 8.2 Plausible future impacts of drivers/pressures (Rivers and floodplains spatial change processes mostly affected are marked with a √. The impacts of the drivers on the spatial extent of the rivers and floodplains are positive (↑), negative (↓) or negligible (→), whilst the magnitude of the impact is depicted by thickness of the arrows as low (↑ or ↓), moderate (↑ or ↓) or high (↑ or ↓) in 2050 under the scenarios)

<table>
<thead>
<tr>
<th>Driver/Pressure</th>
<th>Processes of spatial extent change</th>
<th>Impact on state of spatial extent of rivers and floodplains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Encroachment</td>
<td>Land filling</td>
</tr>
<tr>
<td>Population</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Urban extent (land use/cover change)</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Waste generation &amp; disposal</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Urban agriculture</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Institutional and socio-political environment</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Climate change and variability</td>
<td>√</td>
<td></td>
</tr>
</tbody>
</table>

In conclusion, the scenarios have demonstrated that the deleterious effects of change drivers on rivers and floodplains could be averted if proactively managed, and vice versa. The two scenarios, however, are caricatures and conditional statements, and do not indicate the likelihood that any particular scenario would match the future as it actually occurs. In essence, the real future will probably represent a mix of both, with different drivers dominating at different times, and may be far better or worse than either of the scenarios. Nevertheless, given that the storylines mainly emanate from the local context, the scenarios can usefully inform the design and implementation of
integrated urban and water resource management plans, as well as response options for effective flood mitigation in Kumasi. The next section recommends measures that could be employed to enhance urban growth, river, floodplain and flood management in Kumasi and other similar cities.

8.4 Recommendations for improving urban growth, rivers, floodplains and floods management

The findings from this research have indicated the need for additional and/or pragmatic measures to be instituted to ensure orderly physical development, safeguard rivers and floodplains, and mitigate flooding in Kumasi and other cities in developing countries. The following recommendations are therefore put forth.

8.4.1 Integrating rivers and floodplains management with urban planning

Rivers and floodplains are indispensable components of the natural environment, and possess ecological, socio-economic and physical/spatial functions that are important for sustainable urban development. However, the spatial, quality and hydrological conditions of these water areas are often substantially altered by the surrounding land uses and human activities/processes which are determined and regulated by urban planning. The findings of this research indicate that loss and degradation of rivers and floodplains in cities in developing countries is caused by anthropogenic drivers which are largely consequences of unregulated rapid urban development. Therefore, there is a need for urban planning to substantially incorporate issues about protection and conservation of the rivers and floodplains. This will create the opportunity to protect the water areas and sustain their functions for the benefit of the urban environment, such as ensuring a high level of spatial and environmental quality and natural systems.

This research recommends that urban planning and water resources management, which have for a long time been developed in different disciplines and practised in different institutions of national and local governments, should be integrated at both the strategic and local action levels. Thus urban planning, especially land use plans, should recognise and include water related lands, while water resource management should consider the spatial implications of their interventions in helping to maintain
healthy aquatic ecosystems in urban areas. In this regard, urban managers need to pursue water sensitive urban planning practices such as carefully delineating and reserving riparian buffers, determining land uses within the watersheds/catchments (e.g., fewer impervious areas) and (re)-conceiving riparian buffer zones as urban green structures, among others. In addition, context specific river basin plans and regulations should be developed to assign property rights and (alternative) uses to the water related areas, and the benefits and costs accrued could be distributed among rights holders for management of the water areas. These measures would help to effectively eliminate the negative impacts of the various rapid urban development related anthropogenic drivers, as well as improve the quality of rivers and floodplains.

8.4.2 Strengthening capacity of, and collaboration among institutions/stakeholders

Robust institutions are crucial for effective implementation of policies and legislation for managing urban development and protecting rivers and floodplains. As such the success or failure of urban and water management interventions depends greatly on the institutional setting in which they are implemented (UNEP, 2007; 2012; MEA, 2005). In contrast, the findings from this research show that the low capacity and the modus operandi of the urban growth and water management institutions in Kumasi, just like in many cities in developing countries, prevent adequate tackling of the loss and degradation of rivers and floodplains. As was demonstrated in this research, the low capacity and poor performance of the multiple institutions which have resulted from a complex set of tangible and intangible factors such as inadequate skilled personnel, limited logistics and corruption among others, thwart effective protection and conservation of rivers and floodplains. The problem is compounded by the inadequate institutional collaboration within such a multi-agency management context in Kumasi.

Given the multiple sectoral institutions involved in urban and water management, this research recommends that more efforts should be made to break down institutional segmentation, remove barriers to cooperation and collaboration, as well as promote effective stakeholder consultation and negotiation in the management of rivers and floodplains. Strong stakeholder collaboration and coordination is very much needed
given the low capacity and limited resources of the formal institutions. Further steps should be taken to strengthen the capacities and mandates of the institutions through in-service training, study tours, networking, policy reforms and legislative amendments among others. Additional efforts could include developing much clearer and more cost-effective policies and regulations that draw upon capacities of the institutions and other stakeholders. These steps could end the widespread reliance on reactive interventions, and promote better enforcement and implementation of urban and water management regulations and policies, and hence protect rivers and floodplains in cities in developing countries.

8.4.3 Pursuing participatory relocation/resettlement and enforcing "no development" zones along rivers and floodplains

The research findings reveal that the conversion of water areas into urban land uses is a root cause of loss of rivers and floodplains, and flood disasters in developing countries. This indicates that eliminating the problems requires efforts targeted at removing existing and preventing new urban land use developments in the waterways. However, the complexity of the processes of rivers and floodplains degradation in cities requires that the interventions are not solely based on actions by public institutions. There is a need to relocate the encroachers and enforce zones of no development along the rivers and floodplains, but not without active involvement of the encroachers and the general public. These measures, undertaken within the framework of participatory engagement, would not only save the inland waters but would also lead to other positive outcomes, including reducing and/or avoiding flood disasters and sustaining and/or improving liveability of the cities.

According to UNEP (2007), a participatory approach to water resources management facilitates collaborative efforts among a wide range of stakeholders, and produces a sense of ownership that makes interventions more successful and sustainable. With regards to interventions such as relocation of incompatible land uses from the rivers and floodplains as in the case of Kumasi, this approach could create greater opportunity for the property owners to be actively involved in the designing, planning and implementation of relocation programmes. This may lead to voluntary relocation of the property owners to the new location because of their active
involvement in choice and development of the location. Furthermore, the sense of ownership that may be developed by the general public through their involvement in formulating and implementing policies for managing water resources, can encourage them to pursue common interests to protect the rivers and floodplains. In fact, through these interventions, the public would then be more likely to avoid unapproved land use activities in such areas themselves, while preventing others from doing so through enforcement of locally developed regulations and/or sanctions. Thus, the locally-led relocation and “no development” zone enforcement can help restore degraded rivers and floodplains, as well as preserve existing ones. This approach is suitable for developing countries given their limited resources.

8.4.4 Public education and environmental consciousness campaigns

As indicated in this research, a key factor in the degradation and loss of rivers and floodplains is the notion that the management of environmental resources is the sole responsibility of the government institutions. This apathy towards protection of rivers and floodplains partly explains the widespread encroachment and infilling of, and indiscriminate waste disposal in rivers and floodplains. It is necessary that this low environmental consciousness among the public is changed. Although it is difficult and slow to change a social behaviour, education of the public on the importance of rivers and floodplains to the urban landscape, and the necessity of protecting these water areas remains a viable tool for achieving this change. Such a collective learning approach is essential to understanding the complexity and uncertainty of environmental problems that often become pronounced with the disappearance of rivers and floodplains from the urban fabric. According to UNEP (2007; 2012) an informed population is able to effectively institute and implement local/community programs to protect the environment, as well as identify and address failures in government environmental policies and actions, which ultimately help to safeguard environmental elements including rivers and floodplains.

Thus, there is the need for more public education and campaigns on the values and protection of rivers and floodplains in developing countries. The public education should provide information on the negative consequences of loss of rivers and floodplains on the entire cities, sanctions for undertaking unapproved activities
within water areas, as well as how communities and individuals themselves can impose sanctions on or challenge disapproved activities along rivers and floodplains. These environmental awareness campaigns can build public opinion and attitudes based on sound and relevant information, as well as encourage the public to act responsibly towards safeguarding the environment by: avoiding construction in waterways, disposing of waste in bins and farming on approved lands among others. Also, the rise in environmental consciousness can lead to the emergence of vibrant green parties and civil societies, such as those that are currently transforming the political landscape of several developed countries with green politics by pushing for prioritisation of environmental issues in national policies.

8.5 Conclusion

The disappearance of rivers and floodplains and the incidence of floods are pronounced in cities in developing countries. These are accompanied by socio-environmental problems that create immediate to long term adverse impacts on the urban environment and residents. Consequently, the overarching aim of this research was to explain and understand the changing spatial extent of rivers and floodplains, and how it affects floods in cities in these countries. This research used an interdisciplinary approach within the framework of the case study design to ascertain trends and nature of changes in extent of rivers and floodplains, identify and analyse drivers of the spatial changes in rivers and floodplains, as well as examine the flood impact of the rivers and floodplains spatial changes. Combining multiple methods suggests that protecting rivers and floodplains, and mitigating floods are multifaceted activities that cannot be achieved through a one-size-fits-all approach. The mixed-approach study of Kumasi represent a relatively novel case study that ensured in-depth analysis of diverse and complex research questions, while identifying that more research and application of the method is required in the future.

Following the analysis of the diverse data types, this research has provided new insights into the changing spatial extent and degradation of rivers and floodplains in cities in developing countries. This new knowledge addresses the research questions that were set to guide this study including:
i. Demonstrating that the spatial extent – number and area – of rivers and floodplains has dramatically declined in urban areas. This is because these water areas have been lost to mainly urban land uses through encroachment and land filling.

ii. Revealing that the loss of rivers and floodplains is underpinned by multiple but interrelated anthropogenic drivers. These anthropogenic drivers are mainly processes and manifestations of uncontrolled rapid urban development, as well as poor institutional and political frameworks.

iii. Highlighting that riverine flood disasters have increased in response to encroachment and loss of rivers and floodplains. This is underscored by the extended retention of floodwater, and the prevalence of adaptation methods commonly used for long lasting seasonal effluent floods in the flood affected communities.

This research has therefore transcended the common paradigm in the literature to conceptually explain and understand the trends, processes, drivers and implications of loss and reduction in spatial extent of the rivers and floodplains in cities at the micro level. The research has further demystified the spatial extent change drivers – anthropogenic and natural – as well as their relative importance, thus addressing a critical vacuum in urban environmental planning. The research clearly demonstrated that anthropogenic factors such as rapid population growth and urban expansion, poor waste management practices and weak institutional and policy frameworks among others are more forceful in driving loss of rivers and floodplains, at least in cities, than natural factors like climate change, which have been overly emphasised in recent environmental change literature. This is an important contribution to the environmental change debate and calls for the rethinking of inland water systems loss to place anthropogenic drivers at the centre, at least in urban settings, to help formulate effective policies to address the escalating degradation of these environmental resources that also instigates flood disasters.

Based on the key findings, an adapted DPSIR framework is developed for the reducing spatial extent of rivers and floodplains and the connections with floods in
Kumasi (see Figure 8.1). The model underscores the finding that phenomenon is a complex and continuous one. While the loss of the rivers and floodplains is largely instigated and driven by anthropogenic factors, government and individual responses to the problem and its consequences (that is flooding) lead to further destruction of these water areas. For example, in Kumasi, while human induced processes such as unregulated population growth and urban expansion result in encroachment and land filling of rivers and floodplains, reactive interventions like concreting of river channels to mitigate the loss of rivers and floodplains and the associated flooding in turn undermines self-cleansing capacity and health of the rivers. Therefore, all components of the model/process require equal emphasis in any efforts to arrest the loss of the rivers and floodplains and the resulting floods. Nevertheless, it can be deduced from the findings and the scenarios that a significant positive change in the urban and water resources management practices – legislative, policy and institutional frameworks – can potentially help address the reducing spatial extent of the rivers and floodplains, as well as the floods. This is because mainly anthropogenic drivers, which can be altered and/or fixed by proactive management practices, are responsible for loss of the rivers and floodplains.

To my knowledge, this research is the first attempt to map and ascertain the extent of rivers and floodplains and its changes thereof at city and local levels in Ghana. However, the findings in this thesis are not just important for Ghana, but provide a broader contribution to our knowledge on changes to the extent of inland water systems and thus have wider relevance, especially in developing countries. The findings of this study serve as useful information for urban planners and water managers in understanding spatial issues, problems and solutions related to rivers and floodplains, not only in Ghana but also in other developing countries. Thus armed, urban planners and collaborating professionals may be able to successfully work together to fashion out policies to manage rivers and floodplains in cities. In fact, scenarios analysis in this thesis suggests that the application of proactive water resources and urban management practices, informed by better legislation and policies could salvage the rapid loss of these ecologically valuable lands in cities.
Drivers
Rapid population growth & increasing poor in-migrants
Growing unplanned informal economy
Bad land allocation practice
Inappropriate and poorly unimplemented policies & legislations (Reactive interventions)
Poor management framework

Pressures/Processes
Unregulated physical expansion (encroachment & land filling)
Unplanned urban agriculture (diversion, sedimentation & pollution)
Poor sanitation (eutrophication, sedimentation & pollution)

State
Decreased number of rivers & floodplains
Reduced land area of rivers and floodplains
Highly developed urban land uses in water areas

Responses
Integrate rivers and floodplains management in urban planning
Strengthen institutional capacity and collaboration
People managed relocation & development control practices
Public environmental consciousness campaign

Impacts
Annual disastrous floods
Loss of lives, properties & livelihoods
Social life disruption
Psychological and economic stress
Recurrent expenses on flood adaptation/coping interventions and recovery

Figure 8.1 A model for reduction in spatial extent of rivers and floodplains, and flood incidences in Kumasi
8.6 Suggestions for further research

The study has contributed to the academic discourse on urban inland water systems degradation by providing an understanding of the spatial changes in rivers and floodplains. The study adopted the DPSIR framework to examine and explain the processes, nature, drivers and impacts of changes in extent of rivers and floodplains in cities, using a combination of social, natural and spatial science research techniques. Nevertheless, there are several ways future research could build upon the findings presented here.

First, a further comparative study using cross climatic zone data and time series and/or a panel data analysis procedure is needed to gain an in-depth understanding of the effects of changing climate on the extent of rivers and floodplains. The longitudinal research should go beyond the social and policy science disciplines studied in this research, and embrace natural and engineering sciences by employing long term rainfall, temperature and hydrology data. The studies would also aid in determining the water resource/supply capability of inland water systems in urban areas.

Second, this research found that flood disasters have become a key consequence of the loss of rivers and floodplains, but there is considerable potential to investigate other problems that could emanate from the degradation of these water areas. This is relevant given that inland waters are known to provide several values, of which flood mitigation is only one. Studies that investigate other functions of inland water systems such as water supply and microclimate regulation would help generate holistic and in-depth knowledge of the costs or trade-offs in the loss of rivers and floodplains. Such research could be extended to quantify the economic cost of flood disasters instigated by loss of rivers and floodplains.

Finally, for the purpose of operationalising the policy recommendations proffered by this research, it is suggested that further research is conducted to understand the socio-economic dynamics or characteristics of the property owners along the rivers and floodplains. Such studies should explore attributes such as income situation, migration history, social cohesion, occupational distribution and cultural background among others that characterise the property owners, and drive them to settle in water systems.
areas, as well as determine their abilities to deal with flood disasters caused by their actions. Knowledge of these characteristics would contribute substantially in operationalising solutions to mitigate spatial degradation of water resources and flood disasters, as well as understanding flood vulnerability levels.
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## Appendices

### Appendix 1 Summary of data types, sources, collection and analysis methods

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Type Required</th>
<th>Source of Data/Unit of Enquiry</th>
<th>Data Collection Method</th>
<th>Data Analysis Method</th>
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<tbody>
<tr>
<td>1. How has the spatial extent of rivers and floodplains changed in Kumasi?</td>
<td>Land coverage of rivers and floodplains&lt;br&gt;Land use types and characteristics along rivers and floodplains&lt;br&gt;Process of land acquisition and development within rivers and floodplains&lt;br&gt;Satellite images (Aster images)&lt;br&gt;Local land use plans/maps&lt;br&gt;Topographic and hydrology map</td>
<td>FC; CEGSS; WRC; TCPD; EPA; FRWB; HSD; MBID; LC; KMA; Traditional leaders; Property owners; Secondary sources.</td>
<td>Remote sensing (RS)&lt;br&gt;Spatial survey&lt;br&gt;Institutional Semi-structured interviews&lt;br&gt;Property owners’ Semi-structured interviews</td>
<td>ArcGIS spatial analysis&lt;br&gt;Content analysis and narratives&lt;br&gt;Descriptive statistics (percent, tables, graphs)</td>
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<td>2. What are the anthropogenic drivers of change in the spatial extent of rivers and floodplains in Kumasi?</td>
<td>Population growth and characteristics&lt;br&gt;Urban growth and physical development characteristics&lt;br&gt;Land ownership and acquisition along rivers and floodplains&lt;br&gt;Informal activities location and practices (industrial, commercial and urban agriculture)&lt;br&gt;Waste generation and management practices&lt;br&gt;Rainfall pattern and trends</td>
<td>WRC; TCPD; EPA; FRWB; MWMD; HSD; MBID; GWCL; LC; KMA; Traditional leaders; Property owners; Secondary sources.</td>
<td>Spatial survey&lt;br&gt;Institutional Semi-structured interviews&lt;br&gt;Property owners’ Semi-structured interviews&lt;br&gt;Focus group discussions</td>
<td>Descriptive statistics&lt;br&gt;Content analysis and narratives&lt;br&gt;Descriptive statistics (percent, tables, graphs)&lt;br&gt;Inferential analysis (Mann-Kendall test; Sen’s Slope estimator; multiple correlation and multivariate regression)</td>
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<td>3. How has spatial change of rivers and floodplains contributed to the frequency and intensity of floods in Kumasi?</td>
<td>Perceptions of flood causes</td>
<td>NADMO; WRC; TCPD; EPA; FRWB; MWMD; HSD; MBID; GMA; LC; KMA; Traditional leaders; Property owners; Secondary sources</td>
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<td></td>
<td>Rainfall intensity and runoff yields</td>
<td>Spatial survey Institutional Semi-structured interviews Property owners’ Semi-structured interviews Focus group discussions</td>
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<td>Geophysical characteristics (topography and soil) Flood damages (e.g., properties and loss of lives) Flood coping and adaptation measures Flood management policies, legislations and institutions, and their challenges/limitations</td>
<td>Content analysis and narratives Descriptive statistics (percent, tables, graphs; Mann-Kendall test; Sen’s Slope estimator)</td>
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Appendix 2 Institutional Semi-Structured Interview Guide

Background Information

Name of Interviewer........................................Time ................. Date: ................................

Name of Respondent ..........................Position of Respondent..............Inst. code……

Introduction

Hello my name is Paul Amoateng. I am a research student of Charles Sturt University, Australia undertaking a study on the changing spatial extent of rivers and floodplains and its implications for urban flooding in Kumasi, Ghana. Your institution has been selected as one of the participants for this research. Would you be willing to spend about 60 minutes now in answering questions relating to physical development and water resources management?

YES! Good thank you. Be reminded that participation in the survey is voluntary and you are free to withdraw from the interview at any time if you feel the questions are too intrusive and demanding. The information that will be collected from you will be handled with utmost confidentiality. The results of the survey can be made available to you if interested. To ensure all data is captured, the interview will be tape recorded, is that OK with you?

NO! Is there another more convenient time when I could come over for the interview? ...........................................................

Reason for non-conduct of interview at first attempt at interview .................................................................

Thank you for consenting to participate in this research. What is the main role of your institution in Kumasi?

Now I’ll like us to proceed to the main interview which is divided into these sections: the physical development in and along rivers and floodplains; causes of land use development in and along rivers and floodplains; urban flooding situation; and future scenario of flooding in Kumasi. The responses to these issues will yield insight into the changing spatial extent of rivers and floodplains in the city.

First, I would like to talk to you about the management of physical development in Kumasi and the roles that your institution plays in the management process.

1. How is physical development managed in Kumasi?

[ ] What roles does your institution play in managing physical development in Kumasi?

[ ] Can you tell me about the nature and characteristics of physical development or growth of Kumasi? (e.g., physical expansion, unauthorised development and locations it occurs, direction of growth)
What are the processes involved in undertaking physical development in Kumasi? In what ways do people default these processes?

Are there any particular priority areas or regions for development?

What approaches and strategies are used to regulate physical development in Kumasi? Why these strategies? Are there sanctions for people who undertake unauthorised or illegal development?

What other stakeholders are involved in the management of physical development, and what are their roles?

Thank you, now I would like to ask you questions on the rivers and floodplains in Kumasi and how they are managed.

2. Can you tell me about the state of rivers and floodplains in Kumasi?

How is your institution involved in management of rivers and floodplains? What are the roles of your institution?

How would you describe the physical nature of rivers in Kumasi?

What do you think about the state of rivers and floodplains?

Has the spatial extent of these rivers and floodplains changed?

How has it changed or can you describe the nature of the change?

What role has your institution played in these changes?

Thank you, now I want to ask you questions on the approaches which are used for protecting rivers and floodplains in Kumasi.

3. Have provisions been made to protect rivers and floodplains in land use plans of Kumasi?

What sorts of provisions are in place to protect rivers and floodplains?

Are buffer zones allocated along rivers in Kumasi? Why/why not?

What is the ideal width of the buffer zones along rivers and floodplains?

What is the state of the buffer zones along rivers?

Has the spatial extent of these buffer zones changed?
Thank you, now I would like to talk to you about land use development next to the rivers and floodplains: the types of land uses; the processes involved and effects on rivers and floodplains.

4. Have land uses activities developed in and along rivers and floodplains in Kumasi?

[ ] What land use activities are undertaken in and along rivers and floodplains?

[ ] From the above activities which ones do you encourage or allow along rivers and floodplains in Kumasi? Why/why not?

[ ] What are the processes that drive land uses development that effect rivers and floodplains?

[ ] What are the characteristics of the land use activities in and along rivers and floodplains? (e.g., land ownership or title, permits acquisition, nature of stays or operations, types and quality of structures developed, temporary survival measures, waste generation and disposal, operational characteristics and activities, access to basic services)

[ ] What types of people are usually involved in the development of land use activities in and along rivers and floodplains?

[ ] What are the effects of these land use activities on the rivers and floodplains?

Thank you, at this moment I would like to ask questions on the factors behind the land use development in and along rivers and floodplains.

5. Can you tell me about the reasons for the development of land uses in and around rivers and floodplains in Kumasi?

[ ] What factors account for the development of land uses in and along rivers and floodplains?

[ ] Do you think these factors interact, and how do the interactions occur?
In your opinion what are the relative influences of these factors in causing the development of land uses in and along the rivers and floodplains?

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Thank you, now I want to talk to you about the strategies and measures that are used to regulate development of land uses in and along rivers and floodplains.

6. Is the development of land uses in and around rivers and floodplains in Kumasi controlled?

[ ] What specific approaches does your institution apply to manage the development of land uses in and along rivers and floodplains? Why these strategies?

[ ] How effective are these strategies in controlling the physical development in and along rivers and floodplains?

[ ] What sanctions are you taking against people who undertake development in and along rivers and floodplains?

[ ] What are the challenges faced in enforcing the approaches used for controlling land use activities along rivers and floodplains?

[ ] What efforts are being made to address the challenges?

Thank you, now I would like to ask you questions on the legislations and policies that are used to guide the control of land use activities in and along rivers and floodplains in Kumasi.

7. Are there legislations/policies for controlling land use development in and along rivers and floodplains in Kumasi?
What legislations/policies are available for regulating land use development in Kumasi? What are the objectives of these legislations/policies?

Which of these legislations/policies do you use to control physical development in and along rivers and floodplains and why?

What specific aspects of the policies/legislations deal with control and regulation of land use development in and along rivers and floodplains?

How are these policies enforced to control land use activities in and along rivers and floodplains?

What are the major constraints that affect the enforcement/implementation of these legislations/policies?

What efforts are being made to address the challenges?

Thank you for your responses so far, I want to talk to you about the flooding situation in Kumasi and how the development of land use activities in and along rivers and floodplains influences it.

8. Does the development of land uses in and along rivers and floodplains affect the occurrence of flooding in Kumasi?

Does flooding occur in Kumasi every year, and what is the average number of floods experienced in a year? (Statistics required)

Is there a specific period when floods are more likely to occur in Kumasi?

Can you tell me about the intensity of urban flooding in Kumasi? What is the severity of the flooding and inundation levels?

Are there identifiable flood prone areas in Kumasi and what is the state of rivers and floodplains that drain these areas?

I would like to know more about the effect of adjacent land uses. In your view, how does development of land uses in and along rivers and floodplains increase the frequency and intensity of urban flooding?

I would like to know more about other land use effects. In what ways does physical development away from the rivers and floodplains contribute to flooding in Kumasi?
Aside the development of land uses within the catchment, what other factors do you think contribute to urban flooding in Kumasi?

What is the relative influence of the causes of urban flooding in Kumasi?

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Thank you, at this moment I would like to ask for your views regarding the future state of rivers and floodplains and occurrence of urban floods in Kumasi.

9. What is your impression on the future of rivers and floodplains and urban flooding in Kumasi?

Given the present trend of land use development in and around rivers and floodplains, how do you foresee the conditions of rivers and floodplains in Kumasi? Are there likely to be rivers and floodplains in the city in the near future?

Based on the current pattern of land use development in and along rivers and floodplains with its consequential reduction in the spatial extent of rivers and floodplains, how do you foresee the frequency and intensity of urban flooding in Kumasi?

Thank you for your responses so far. After discussing both the present and future state of rivers and floodplains and flooding in Kumasi, I want to talk to you about management strategies that can be adopted to mitigate the phenomena both now and in future.

10. Are there effective ways of managing land uses development in and along rivers and floodplains, and urban flooding in Kumasi?

What management approaches do you think can be adopted to effectively prevent or regulate the development of land uses in and along rivers and floodplains and for that matter their changing spatial extents in Kumasi?

What management strategies do you think can be employed to help minimise the incidence and intensity of urban flooding in Kumasi?
Thank you, now I would like you to make any additional comment about the issues discussed in this interview.

11. Other comments

- Do you have any other comments about any of the topics covered in the interview or other aspects of the physical development control and rivers and floodplains’ management in Kumasi? [Any comments you make will be recorded]

Thank you, at this moment I would like to make a request for any available report that I can have access to.

12. Reports

- Are there any reports or reviews on the issues discussed in the interview I could receive?

Thank You. That’s the end of the interview today. Thank you very much for your time and for responding to the questions! Have a good day.
Appendix 3 Property Owners' Semi-Structured Interview Guide

Background Information

Name of Interviewer…………………………………………Time ………………… Date: …………………

Name of Interviewee ………………………………Name of Suburb……………….. PO code…….

Introduction

Hello my name is Paul Amoateng. I am a research student at Charles Sturt University, Australia undertaking a study on the changing spatial extent of rivers and floodplains and its implications for urban flooding in Kumasi, Ghana. You have been selected as one of the participants for this research. Would you be willing to spend about 60 minutes now in answering questions relating to physical development and water resources management?

YES! Good thank you. Be reminded that participation in the survey is voluntary and you are free to withdraw from the interview at any time if you feel the questions are too intrusive and demanding. The information that will be collected from you will be handled with utmost confidentiality. The results of the survey can be made available to you if interested. To ensure all data is captured, the interview will be tape recorded, is that OK with you?

NO! Is there another more convenient time when I could come over for the interview? …………………………………………………

Reason for non-conduct of interview at first attempt at interview …………………………………………………………….

Thank you for consenting to participate in this research.

Now I’ll like us to proceed to the main interview which is divided into these sections: the physical development in and along rivers and floodplains; causes of land use development in and along rivers and floodplains; urban flooding situation; and future scenario of flooding in Kumasi. The responses to these issues will yield insight into the changing spatial extent of rivers and floodplains in the city.

First, I would like to talk to you about the rivers and floodplains in Kumasi and their current conditions. .

1. Can you tell me about the state of rivers and floodplains in Kumasi?

[ ] How important are these rivers and floodplains to you?

[ ] What do you think about the state of rivers and floodplains in Kumasi?

[ ] Has the spatial extent of these rivers and floodplains changed?

[ ] How has it changed or can you describe the nature of the change?
Thank you, now I would like to talk to you about the land use development in and along rivers and floodplains: the types of land uses; the processes involved and effects on rivers and floodplains.

2. Have land uses activities developed in and along rivers and floodplains in Kumasi?

[ ] Can you narrate how you or others here went about developing the properties or establishing businesses here?

[ ] What land uses activities develop or are undertaken in and along rivers and floodplains here?

[ ] Can you tell me about how you live and operate here? (e.g., land ownership or title, permits acquisition, nature of stays or operations, types and quality of structures developed, temporary survival measures, waste generation and disposal, operational characteristics and activities, access to basic services)

[ ] What types of people are involved in the development of land use activities in and along rivers and floodplains?

[ ] How do your activities or properties affect the rivers and floodplains?

Thank you, at this moment I would like to ask questions on the factors behind the land use development in and along rivers and floodplains.

3. Are there reasons for the development of land uses in and along rivers and floodplains in Kumasi?

[ ] What factors do you think accounted for the development of land uses or establishment of businesses in and along rivers and floodplains?

[ ] Which of the factors do you think is most influential in promoting development of land use activities in and along rivers and floodplains? Give reasons for your choice.

[ ] In your opinion what is the relative influence of these factors in causing the development of land uses in and along rivers and floodplains?
Level of influence | Low | High | Very High
Factor

Thank you, now I want to talk to you about the strategies and measures that are used to regulate development of land uses in and along rivers and floodplains.

4. Is the development of land uses in and around rivers and floodplains in Kumasi controlled?

[ ] What institutions are responsible for the development control and water resources management in Kumasi?

[ ] What are the problems associated with the methods used by these institutions in regulating physical development in and along rivers and floodplains in Kumasi?

[ ] What approaches do you think should be used by these institutions in controlling physical development in and along rivers and floodplains in Kumasi?

Thanks you for your responses so far, I want to talk to you about the flooding situation in Kumasi and how the development of land use activities in and along rivers and floodplains influences it.

5. Does the development of land uses in and along rivers and floodplains affect the occurrence of flooding in Kumasi?

[ ] What problems are associated with the development of land use activities in and along rivers and floodplains in Kumasi?

[ ] Can you please tell me about your experiences during the last flooding in this area?

[ ] How will you describe the frequency and intensity of flooding? What is the severity of the flooding and inundation levels?
Do you think the state of the rivers and floodplains contribute to the flooding situation here? Explain

I like to know more about the effect of adjacent land uses. In your view, how does development of land uses in and along rivers and floodplains increase the frequency and intensity of urban flooding?

I would like to know more about other land use effects. In what ways does physical development away from the rivers and floodplains contribute to flooding in Kumasi?

Aside from the development of land uses within the catchment, what other factors do you think contribute to urban flooding in Kumasi?

What is the relative influence of the causes of the flooding?

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Thank you, at the moment I want to ask you questions on the problems that are caused by flooding in Kumasi.

6. Does flooding have any effects in Kumasi?

What damages or losses do the flooding cause to you?

What physical problems are caused by flooding in this area?

What measures do you adopt to cope or survive when flooding occurs?

What reliefs or helps do flood victims receive from the city authorities?

Thank you, at this moment I would like to ask for your views on the future state of rivers and floodplains and occurrence of flooding in Kumasi.

7. What is your impression on the future of rivers and floodplains and flooding in Kumasi?

Given the present trend of land use development in and around rivers and floodplains, how do you foresee the conditions of rivers and floodplains in
Kumasi? Are there likely to be rivers and floodplains in the city in the near future?

[ ] Based on the current pattern of land use development in and along rivers and floodplains with its consequential reduction in the spatial extent of rivers and floodplains, how do you foresee the frequency and intensity of urban flooding in Kumasi?

Thank you for your responses so far. After discussing both the present and future state of rivers and floodplains and flooding in Kumasi, I want to talk to you about management strategies that can be adopted to mitigate the phenomena both now and in future.

8. Are there effective ways of managing land uses development in and along rivers and floodplains, and flooding in Kumasi?

[ ] What management approaches do you think can be adopted to effectively prevent or regulate the development of land uses in and along rivers and floodplains and for that matter their changing spatial extents in Kumasi?

[ ] What management strategies do you think can be employed to help minimise the incidence and intensity of flooding in Kumasi?

Thank you, now I would like you to make any additional comment about the issues discussed in this interview.

9. Other comments

- Do you have any other comments about any of the topics covered in the interview or other aspects of the physical development control and rivers and floodplains’ management in Kumasi? [Any comments you make will be recorded]

Thank You. That’s the end of the interview today. Thank you very much for your time and for responding to the questions! Have a good day.
Appendix 4 Focus Group Discussion Guide

1. Can you tell me about the state of rivers and floodplains in Kumasi?
   [ ] How important are these rivers and floodplains to you?
   [ ] How are the rivers and floodplains being protected and what roles do you play in this regard?
   [ ] What do you think about the state of rivers and floodplains in Kumasi?
   [ ] Has the spatial extent of these rivers and floodplains changed?
   [ ] How has it changed or can you describe the nature of the change?
   [ ] What role did you play in these changes? How have you contributed to these changes?

2. Have land uses activities developed in and along rivers and floodplains in this area and Kumasi?
   [ ] Can you tell me about the nature and characteristics of physical development or growth of Kumasi? (e.g., physical expansion, unauthorised development and locations it occurs, direction of growth)
   [ ] What land uses activities develop or are undertaken in and along rivers and floodplains?
   [ ] What types of people are involved in the development of land use activities in and along rivers and floodplains?
   [ ] Can you narrate how people go about developing properties and/or establishing businesses here?
   [ ] Can you tell me about how you live and operate here? (e.g., land ownership or title, permits acquisition, nature of stays or operations, types and quality of structures developed, temporary survival measures, waste generation and disposal, operational characteristics and activities, access to basic services)
   [ ] How do the activities or land uses affect the rivers and floodplains?
What methods are used in regulating physical development in and along rivers and floodplains in this area and what are the challenges faced in this regard?

3. Are there reasons for the development of land uses in and along rivers and floodplains in this area and Kumasi?

What factors account for the development of land uses in and along rivers and floodplains?

Do you think these factors interact, and how do the interactions occur?

Which of the factors is most influential in promoting development of land use activities in and along rivers and floodplains?

4. Can you describe the flooding situation in this area?

Does flooding occur in this area every year, and what is the average number of floods experienced in a year?

Is there a specific period when floods are more likely to occur?

How would you describe the intensity and extents of the flooding? What is the severity of the flooding and inundation levels?

Can anyone tell me about experiences during the last flooding in this area?

5. What causes the flooding in this area?

Does the state of the rivers and floodplains contribute to the flooding situation here? Explain

I would like to know more about the effect of adjacent land uses. In your view, how does development of land uses in and along rivers and floodplains increases the frequency and intensity of urban flooding?

I would like to know more about other land use effects. In what ways does physical development away from the rivers and floodplains contribute to flooding in Kumasi?

Aside from the development of land uses within the catchment, what other factors do you think contribute to urban flooding in Kumasi?

Give the relative influence of the causes of the flooding.

6. Does flooding have any effects and how is the flooding controlled?
What damages or losses do the flooding cause to you?

What physical problems are caused by flooding in this area?

What measures do you adopt to cope or survive when flooding occurs?

What reliefs or helps do flood victims receive from the city authorities?

What specific measures are employed to prevent or control the flooding? Why these strategies and what are the challenges faced in utilising them?

In what ways can the availability of rivers and floodplains help in controlling or minimising urban floods?

7. Can you tell me about the rainfall pattern of Kumasi?

Which month(s) of the year does Kumasi experience rainfall?

What is the duration and intensity of the rainfall?

Have there been any changes in the rainfall pattern in recent time?

What is the nature of the change (timing and quantities) and what are its effects?

What is the drought situation in Kumasi? (frequency of occurrence, period of the year experienced, duration)

8. What is your impression on the future of rivers and floodplains and flooding in this area and Kumasi?

Given the present trend of land use development in and around rivers and floodplains, how do you foresee the conditions of rivers and floodplains in Kumasi? Are there likely to be rivers and floodplains in the city in the near future?

Based on the current pattern of land use development in and along rivers and floodplains with its consequential reduction in the spatial extent of rivers and floodplains, how do you foresee the frequency and intensity of flooding in the area and Kumasi?

9. Are there effective ways of managing land uses development in and along water bodies and flooding in this area and Kumasi?
[ ] What management approaches do you think can be adopted to effectively prevent or regulate the development of land uses in and along rivers and floodplains and for that matter their changing spatial extents in Kumasi?

[ ] What management strategies do you think can be employed to help minimise the incidence and intensity of flooding in the area and Kumasi?

10. Other comments

- Do you have any other comments about any of the topics covered in the focus group discussions? [Any comments you make will be recorded]

Thank You. That’s the end of the discussion today. Thank you very much for your time and for participating in this discussion! Have a good day.
Appendix 5 Spatial Survey Observation Checklist

Background Information

Location/River…………………………….. Time:………………..
Date:…………………………

1. Land use activities along river or within floodplain
2. Types and conditions of structures in and along rivers and floodplains
3. Appearance of water in rivers
4. Nature of vegetation in and along rivers and floodplains
5. Environmental sanitation conditions along rivers and floodplains
6. Floodwater inundation marks
7. Conditions of properties affected by floodwater
8. The condition of the storm drains in communities
27 May 2013

Mr Paul Amonteng
School of Environmental Sciences
Charles Sturt University
Box 785
ALBURY NSW 2640

Dear Mr Amonteng,

Thank you for the additional information forwarded in response to a request from the Human Research Ethics Committee (HREC).

The CSU HREC reviews projects in accordance with the National Health and Medical Research Council’s National Statement on Ethical Conduct in Research Involving Humans.

I am pleased to advise that your project entitled “The changing spatial extent of water bodies and its implications for urban flooding: the case of Kumasi, Ghana” meets the requirements of the National Statement; and ethical approval for this research is granted for a twelve-month period from 27 May 2013.

The protocol number issued with respect to this project is 2013/080. Please be sure to quote this number when responding to any request made by the Committee.

Please note the following conditions of approval:

* all Consent Forms and Information Sheets are to be printed on Charles Sturt University letterhead. Students should liaise with their Supervisor to arrange to have these documents printed;
* you must notify the Committee immediately in writing should your research differ in any way from that proposed. Forms are available at: [http://www.csu.edu.au/_data/assets/word_doc/0010/175833/041373mmrmmrmm.doc](http://www.csu.edu.au/_data/assets/word_doc/0010/175833/041373mmrmmrmm.doc);
* you must notify the Committee immediately if any serious and/or unexpected adverse events or outcomes occur associated with your research, that might affect the participants and therefore ethical acceptability of the project. An Adverse Incident form is available from the website as above;
* amendments to the research design must be reviewed and approved by the Human Research Ethics Committee before commencement. Forms are available at the website above;

However, you must ensure that you are familiar with and comply with the requirements of the National Statement and your University’s Human Research Ethics Committee.

Yours sincerely,

[Signature]

[Contact Information]

[CSU HREC Contact Details]
• if an extension of the approval period is required, a request must be submitted to the Human Research Ethics Committee. Forms are available at the website above;
• you are required to complete a Progress Report form, which can be downloaded as above, by 18 April 2014 if your research has not been completed by that date;
• you are required to submit a final report, the form is available from the website above.

YOU ARE REMINDED THAT AN APPROVAL LETTER FROM THE CSU HREC CONSTITUTES ETHICAL APPROVAL ONLY.

If your research involves the use of radiation, biological materials, chemicals or animals a separate approval is required from the appropriate University Committee.

The Committee wishes you well in your research and please do not hesitate to contact the Executive Officer on telephone (02) 6538 4628 or email ethics@csu.edu.au if you have any enquiries.

Yours sincerely

Julie Iheils
Executive Officer
Human Research Ethics Committee
Direct Telephone: (02) 6538 4628
Email: ethics@csu.edu.au

CC: Professor Jim Pickles, Associate Professor Joe Hillman, Dr Joanne Howard

This HREC is constituted and operates in accordance with the National Health and Medical Research Council’s (NHMRC) National Statement on Ethical Conduct in Human Research (2007)
Appendix 7 Research Participant Consent Form

RESEARCH PARTICIPANT CONSENT FORM

Research Project: The Changing Spatial Extent of Rivers and Floodplains and its Implications for Urban Floods: The Case of Kumasi, Ghana

To be read or given to the participant at the start of the research:

Thank you for agreeing to take part in this research. I am a researcher from Charles Sturt University, Australia, working on the above mentioned project. Please sign below indicating that:

"I understand that I am not obliged to participate in this research and that I am free to withdraw my participation in the research without being subjected to any penalty or discriminatory treatment. The purpose of the research has been explained to me, (including the (potential) risks/discomforts) and I have been given the opportunity to ask questions about the research and received satisfactory answers.

I understand that any information or personal details gathered in the course of this research about me are confidential and that neither my name nor any other identifying information such as positions in government or institution will be used or published without my written permission.

I understand that the chief researcher cannot guarantee my anonymity and confidentiality in the focus group setting, and that I cannot withdraw my contributions after the focus group has been held.

I understand that this interview and focus group will be both recorded in hand-written and/or taped recorded forms as part of this project.

I understand that the signed informed consent is an indication of my willingness to participate in this research.

Interviewee's statement:

I understand the information I have been given and agree to be interviewed and/or participate in the focus group.

Signature .................................................. Date ..............

Interviewer’s Statement:

I confirm that I have carefully explained the nature, demands and foreseeable risks of the study to the participant.

Signature .................................................. Date ..............

Charles Sturt University’s Ethics in Human Research Committee has approved this study.
I understand that if I have any complaints or concerns about this research I can contact:

Executive Officer
Ethics in Human Research Committee
Academic Secretariat
Charles Sturt University
Private Mail Bag 29
Bathurst NSW 2795
Ph: 161 2 6338 4628
Fax: 161 2 6338 4194
If you would like to know more about our project—the contact details of researchers are below:

**Principal Researcher**
Paul Amoueteng  
PhD Student  
School of Environmental Sciences  
Charles Sturt University  
PO Box 789, Albury, NSW, 2640, Australia  
Mobile: +61 431 030 256  
Email: p.amoueteng@csu.edu.au

**Principal Supervisor**
Prof. Colin Max Findlayson  
PhD  
Institute for Land Water and Society  
School of Environmental Sciences  
Charles Sturt University,  
PO Box 789, Albury, NSW 2640, Australia.  
Tel.: +61 260519779  
Email: mfindlayson@csu.edu.au

**Co Supervisor**  
A/Prof. Ben Wilson  
PhD  
School of Environmental Sciences  
Charles Sturt University  
PO Box 789, Albury, NSW, 2640, Australia  
Tel.: +61 260519675  
Email: bwilson@csu.edu.au

**Co Supervisor**
A/Prof. Jonathan Howard  
PhD  
School of Environmental Sciences  
Charles Sturt University  
PO Box 789, Albury, NSW, 2640, Australia.  
Tel.: +61 260519685  
Email: jhoward@csu.edu.au

The contact details of the Principal Researcher while in Ghana are below:

Paul Amoueteng  
PhD student.  
Tel.: +2332 (0229458) 333  
Email: p.amoueteng@csu.edu.au; p.amoueteng@yahoo.com
Appendix 8 Information Sheet for Research Participants

INFORMATION SHEET FOR RESEARCH PARTICIPANTS

Research Project: The Changing Spatial Extent of Rivers and Floodplains and its Implications for Floods: The Case of Kumasi, Ghana

Research Background
This study aims to explain and understand the changing spatial extent of rivers and floodplains in rapidly urbanizing cities in developing countries. The results will provide information useful for the conservation and management of rivers and floodplains in fast growing cities as well as generate insights into what causes changes in the spatial extent of these rivers and floodplains.

You are invited to participate in this research. The data collection will involve semi-structured interviews with officials from relevant organisations and in-depth interviews with property owners. Interviews will last for approximately one and half hours. The interviews will be recorded using digital audio recorder as part of this project. Participation in this interview is voluntary and you can withdraw your participation at anytime, without being subjected to any penalty or discriminatory treatment.

Again, focus group discussions will be organized with officials of the institutions and property owners. The chief researcher would appreciate it if the content of the discussions of the focus group are not discussed with people outside the participants stimulating. However, the chief researcher cannot guarantee the anonymity and confidentiality of participants, as he has no control in ensuring that information given during the focus group discussion remains confidential to the participants after meeting. Also, individual contributions made cannot be withdrawn if disclosure is made to withdraw participant after the focus group has been held.

The data collected by the interviews and focus groups will be analyzed and form part of a post graduate research studies at CSU. The results of the data analysis will also be published in academic publications. The anonymity and confidentiality of the participants will be protected in using the research data for publications. The names of participants will not be put on any publications. The data collected will be stored securely and kept for five years as stated in the Charles Sturt University Code of Conduct for Research. At the end of this period all electronic records of the data will be deleted and any hard copies of the data will be destroyed.

Results of the study will be used as part of a post graduate study at Charles Sturt University and a summary can be made available to participants after completion of the research by request. If you are interested in receiving the results please contact me by email: panamawong@csu.edu.au

The research has been approved by the Charles Sturt University Human Research Ethics Committee and you can contact the committee about concerns on any ethical conduct of the study. You are also welcome to contact the researchers involved at any time.
Contact details:

Principal Researcher
Paul Ameatong
PhD Student
School of Environmental Sciences
Charles Sturt University
PO Box 789, Albury, NSW, 2640, Australia.
Mobile: +61 451030256
Email: pameatong@csu.edu.au

Principal Supervisor
Prof. Colin Max Fielieson
PhD
Institute for Land Water and Society
School of Environmental Sciences
Charles Sturt University
PO Box 789, Albury, NSW 2640, Australia.
Tel: +61 262519779
Email: mfielieson@csu.edu.au

Co-Supervisor
A/Prof. Jem Wilson
PhD
School of Environmental Sciences
Charles Sturt University
PO Box 789, Albury, NSW, 2640, Australia.
Tel: +61 262518675
Email: jwilson@csu.edu.au

Co-Supervisor
Dr. Jonathan Howard
PhD
School of Environmental Sciences
Charles Sturt University
PO Box 789, Albury, NSW, 2640, Australia.
Tel: +61 262519043
Email: jhoward@csu.edu.au

The contact details of the Principal Researcher while in Ghana are below:

Paul Ameatong
PhD student
Tel: +233 (0)24581333
Email: pameatong@csu.edu.au/pameatong@yahoo.com

Note: Charles Sturt University’s Ethics in Human Research Committee has approved this project. If you have any complaints or reservations about the ethical conduct of this project, you may contact the Committee through the Executive Officer:

The Executive Officer
Ethics in Human Research Committee
Academic Secretariat
Charles Sturt University
Private Mail Bag 29, Bathurst, NSW, 2795, Australia.
Tel: +61 263384638, Fax: +61 263384194

Any issues you raise will be treated in confidence and investigated fully and you will be informed of the outcome.
### Appendix 9 List of some urban and water related conventions and treaties ratified by Ghana

<table>
<thead>
<tr>
<th>Convention or Treaty</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 World Summit</td>
<td>Set a framework for providing foreign assistance to developing countries in preparing Integrated Water Resource Management (IWRM) and water efficiency plans.</td>
</tr>
<tr>
<td>Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, (1971)</td>
<td>Sought to promote the conservation and sustainable utilisation of wetlands, and recognised the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value.</td>
</tr>
<tr>
<td>World Water Forums 1- Marrakesh (1997); 2-The Hague (2000); 3-Kyoto (2003); 4-Mexico (2006) &amp; 5-Istanbul, (2009)</td>
<td>Advocated for coherent national, regional and international policies and partnerships to overcome fragmentation, and for transparent and accountable institutions at all levels for integrated water resource management (IWRM) in the face of global changes.</td>
</tr>
<tr>
<td>International Conference on Water and Environment, Dublin, 1992</td>
<td>Encouraged harmonisation of development and environment, and participatory national and international watersheds management.</td>
</tr>
<tr>
<td>UN Conference on Human Environment, Stockholm, 1972</td>
<td>Aimed to ensure that water development is compatible with the need to protect and improve environment.</td>
</tr>
<tr>
<td>UN Water Conference, Mar Del Plata, Argentina, 1977</td>
<td>Encouraged governments to establish plans for comprehensive and effective water resources management.</td>
</tr>
<tr>
<td>UN Framework Convention on Climate Change, New York, (1992)</td>
<td>Aimed to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.</td>
</tr>
</tbody>
</table>