CRANFIELD UNIVERSITY

St John Day

MANAGING WATER LOCALLY: AN INQUIRY INTO COMMUNITY-BASED WATER RESOURCES MANAGEMENT IN FRAGILE STATES

SCHOOL OF ENERGY, ENVIRONMENTAL TECHNOLOGY AND AGRIFOOD

PhD
Academic Year: 2016

Supervisor: Professor E. K. Weatherhead
March 2016

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ABSTRACT

Water resources in many parts of the world, but particularly in Africa, face multiple pressures. These growing pressures, along with rainfall variability, pose significant risks to water resources and livelihoods. Over the past two decades the concept of Integrated Water Resources Management (IWRM) has been presented as a panacea, but subscription to this model has not delivered the results expected. Despite a massive endeavour there is extensive evidence that IWRM remains difficult to implement, particularly in fragile states. In contrast, at local level the responsibility of communities to manage water supply systems forms a central component of Water, Sanitation and Hygiene (WASH) sector policy. But WASH programmes are focused primarily on the supply of services, and not enough on water resources. Consequently, remarkably little has been written about the role of communities in monitoring and managing water resources. Also, few studies have examined the transitions fragile government institutions need to undertake to move from one (inferior) situation, to a much better one. This study used Action Research (AR) to investigate the role community-based institutions can play in monitoring water resources, alongside government authorities. Initial field research was conducted in Darfur and Niger before further work in Burkina Faso and Sierra Leone. It found that communities could monitor water resources with high degrees of success; however, continued external support is also required from responsible government institutions. Community-Based Water Resources Management (CBWRM) is considered a realistic and plausible approach for strengthening the *water* component in WASH programmes. This research argues that in fragile states there is greater potential to develop national water security plans from local-level initiatives. Adopting a “localised” approach is particularly important for countries that face the pervasive obstacles of short rainfall seasons: negligible hydrometeorological monitoring, limited water infrastructure and weak institutions. CBWRM warrants greater attention from the WASH sector and further research is needed to identify how effectively communities can manage water resources and scale up this approach once Water Resource Assessments (WRAs) have been conducted.

ACKNOWLEDGEMENTS

This thesis has taken about eight years to research and write, while studying on a part-time basis. The research has been undertaken entirely in fragile states, which has made it much more difficult to complete. I must, therefore, first of all thank the many resilient rural communities who have supported this research. Without the support and information they provided this study would have been impossible. I hope this thesis reflects the insights and learning they have provided.

Over the past eight years I have had many supervisors. It is a pleasure to thank Professor Keith Weatherhead for his advice and guidance over the past two years. My research also benefitted substantially from the wisdom and encouragement of Professor Sue White, who sadly passed away on 15 March 2014. She was a kind and generous person. I would also like to acknowledge with thanks Professors Richard Carter, Paul Trawick and Dr James Webster. This thesis is much improved as a result of their support. I have also been extremely fortunate to have both WaterAid and Oxfam interested in this work. I would like to single out Vincent Casey and Lucien Damiba at WaterAid for particular thanks. They have helped to establish field activities in Burkina Faso and their support for this work has enabled greater insights into CBWRM.

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LIST OF ABBREVIATIONS

A4P	Agenda for Prosperity
AM	Adaptive Management
AR	Action Research
BWMA	Bumbuna Watershed Management Authority
CBWRM	Community-Based Water Resources Management
CLTS	Community Led Total Sanitation
CPRs	Common-Pool Resources
CRD	Cumulative Rainfall Departure
DFID	Department for International Development
DRAH	Direction Régional de l'Agriculture et de l'Hydraulique
EU	European Union
EVD	Ebola Virus Disease
FAO	Food and Agriculture Organization of the United Nations
FCAS	Fragile and Conflict-Affected States
GCM	General Circulation Model
GoSL	Government of Sierra Leone
GPS	Global Positioning System
GWP	Global Water Partnership
HDI	Human Development Index
ICAI	Independent Commission for Aid Impact
ICE	Institution of Civil Engineers
IDP	Internally Displaced Person
IIED	International Institute for Environment and Development
IOM	International Organization for Migration
IPCC	Intergovernmental Panel for Climate Change

IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Programme
MDG	Millennium Development Goal
MWR	Ministry of Water Resources
NGO	Non-Governmental Organisation
NWRMA	National Water Resources Management Agency
OECD	Organisation for Economic Co-Operation and Development
ONS	Office of National Security
PAGIRE	Plan d'Action pour la Gestion Intégrée des Ressources en Eau
RBMP	River Basin Management Plan
SEPA	Scottish Environment Protection Agency
SSA	sub-Saharan Africa
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO-IHE	United Nations Organisation for Education, Science and Culture – Institute for Water Education
UNICEF	United Nations International Children's Emergency Fund
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WRA	Water Resources Assessment
WRM	Water Resources Management
WSP	Water Safety Plan

1 Introduction

In this chapter the research topic and significance of the research problem are introduced. The original contribution, aim and research objectives are presented, and the concept of Community-Based Water Resources Management (CBWRM) is described. Section 1.6 incudes some personal background information, before the final section of this chapter provides an outline of the rest of the thesis.

1.1 Overview

Even if a water supply system is functioning and used, it can only be sustained if water resources are understood and managed well. If the groundwater or surface water resources on which it depends are deteriorating, in either quantity or quality relative to need, then the system is under threat (WaterAid, 2011).

It is estimated that about 100 million people in rural areas of sub-Saharan Africa (SSA) are reliant on groundwater for domestic supplies and livestock rearing (Adelana and MacDonald, 2008). Groundwater is also an untapped resource for agricultural development in many parts of Africa (see Giordano, 2006, in Pavelic et al, 2012 and Gowing et al, 2016). However, the problem is that systems for routinely monitoring and managing water resources are lacking in SSA (Robins et al, 2006; Carter and Bevan, 2008). Practical and realistic approaches for monitoring and managing water resources are also now required in fragile states[1] where governments face added socio-economic and political constraints (Pavelic et al, 2012). Previous practice has been to encourage all nations in SSA to adopt the concept of Integrated Water Resources Management (IWRM). But more recent awareness has suggested all-inclusive IWRM approaches remain too difficult for weak government institutions to implement. This has led to practitioners and international organisations calling for more pragmatic approaches to be found (see Moriarty et al, 2004; Giordano and Shah, 2013). In

[1] The term fragile states refers to countries where the government cannot or will not deliver core functions to the majority of its people, including the poor (DFID, 2006).

this context, it is desirable to understand the potential role of community-based institutions in monitoring and managing water resources. It is important to be aware of the limitations and applicability of such methods. It is also worthwhile to understand how governments and Non-Governmental Organisations (NGOs) can support communities, as they are key actors in delivering and sustaining rural water supplies.

1.2 Problem statement

Over the past two decades the IWRM model has been presented as a panacea for the achievement of global water security. The concept involves national and multinational agencies managing major river basins including those that cross the boundaries of more than one nation state. Today it is often promoted as the "only" solution for managing water resources. Some water sector professionals believe the concept can be applied in all contexts. It turns out that this may not be the case. Despite high profile declarations and international plans of action, the evolution of IWRM theory continues to run far ahead of its implementation in practice (Jeffrey and Gearey, 2006; Carter, 2009). This belief is reinforced by the fact that the global target to have IWRM plans in place by 2005 was reached by only one-fifth of all countries (House of Commons International Development Committee, 2007).

The state of affairs in the Water, Sanitation and Hygiene (WASH) sector in SSA is also cause for concern. The responsibility of communities to manage their point water sources (such as handpumps) forms a central component of much WASH sector policy and strategy. Yet rural water supply programmes frequently neglect any consideration for monitoring and managing water resources. This is significant because demand for water may outstrip long-term resource potential in some places, which is a cause of water supply failure. As Robins et al (2013a) point out: *"Although there is plenty of groundwater in Africa, it is neither evenly distributed nor universally accessible. There are places where the groundwater resource renewal cannot keep pace with demographic stress and the local aquifer is drying up."* In SSA stewardship of water resources is often afforded low priority in national budgets compared to extending water supply coverage. However, if governments have no hydrometeorological data there is little hope that water can be managed and allocated appropriately. If customary water management[2] practices are evidently sound, then it is important to understand how best to support these approaches, especially in remote rural areas. This study examines whether community-based approaches can be used as a foundation for the development of future Water Resource Management (WRM) policies and strategies in fragile states.

1.3 Significance of the problem

The importance of this study is supported by a wide array of evidence. First, a major criticism levelled at the WASH sector is that community water supply schemes have a short life span. At any one time about 35% of all rural water supply systems in SSA are not functioning (Baumann, 2005; RWSN, 2010). Operational failure rates for individual countries have also been estimated at between 30% and 60% (see Hazelton, 2000; Sutton, 2003). Numerous issues contribute to the failure of point sources but consideration of the water resources that sustain community water supplies is fundamental. Second, if development organisations apply no consideration to balancing water supply and demand they are essentially engaged in an experiment. Following a controversial 37% increase in the United Kingdom's (UK) aid contributions in 2010 (Adam Smith Institute, 2010), and ring fencing of the overseas development budget in 2014, there is an increased requirement for organisations to demonstrate that aid spending is effective and efficient. Third, the scaremongering about international water wars is not well substantiated in Intergovernmental Panel for Climate Change (IPCC) reports and literature. Some scholars (Warner and Jones, 1998; Turton and Ohlsson, 1999; Wolf, 2009) argue that future water conflicts are more likely to occur at smaller geographic scales, involving local users. This is important because that is the scale where WRM problems should be resolved.

[2] Customary water management refers to locally inspired and informal arrangements for managing both water resources and water supply systems (infrastructure). This study is concerned with the aspect of water resources.

This study examines the role of communities in monitoring water resources alongside government agencies in Fragile and Conflict-Affected States (FCAS). This is because there are a many communities living in remote and extreme environments on the periphery of assistance from government. As Ostrom (1990) Dolsak and Ostrom (2003) and Trawick (2001a) have all explained, community-based institutions can manage Common-Pool Resources (CPRs)[3], but communal management requires some basic moral principles to be adhered to. Ostrom's seminal research shows that there must be willingness amongst local users to share resources equitably and to minimise theft. This requires trust to be established between local users. Communities must have high levels of rule-making autonomy and there must be synergies, not trade-offs, between livelihoods (work and employment) and resources management.

Community-based approaches will inevitably have limitations. The approach is not, and should not, be seen as a direct replacement for government-led regional or national water security plans. Indeed, without access to and influence over decision-makers, localised approaches may be viewed, by some, as small scale or isolated. Nevertheless, it is important to understand the extent to which they can build bridges between communities and government agencies and improve resilience. So, this study asks whether it can help lay the foundations for improved stewardship of water resources in FCAS. Limitations are expressed in terms of scale and sustainability. This subject matter is particularly relevant because the UK's Department for International Development (DFID) has committed 50% of its aid spending to fragile states (ODI, 2015).

[3] Common-Pool Resources refers to locally available resources that communities and households draw upon to sustain their health and livelihoods. The resources are available for everyone to use free of charge. (However, they are also finite so monitoring and management structures need to be in place to reduce the potential for over-exploitation.)

1.4 Contribution of this research: Research aims and objectives

Existing research continues to give inadequate attention to water resource assessments (WRAs) and management in FCAS. These countries represent some of the world's most challenging working environments, where governments may be unwilling or unable to provide basic services for their citizens. A starting point is to understand the potential role of community-based institutions in WRAs. A deeper investigation is also required into the barriers (bottlenecks) at central government level that thwart adherence to the values of decentralisation and subsidiarity. There is also a requirement to examine whether the WASH sector adequately engages in WRM, since community water supplies are frequently delivered by NGOs. The principal contribution of this study will be to fill this research gap.

This research is an empirical investigation of the ability of communities in fragile states to engage in WRAs. The insights from this study contribute to existing literature on the ability of community-based institutions to monitor CPRs and identify areas for necessary external support. This research provides new understanding of how to make progress in monitoring water resources in FCAS and offers insights as to why IWRM targets proposed by many have not been realised. This research also demonstrates why conventional rural water supply approaches should evolve. The study introduces a new concept termed CBWRM that builds links between communities and government agencies for stewardship of water resources.

So the research aim is: To investigate the extent to which rural communities can actively participate in monitoring water resources working alongside government authorities in fragile states. The research objectives are set out in bold with justifications below:

- **To assess the potential effectiveness of rural communities in monitoring water resources.**

This is required because the concept of CBWRM will be flawed if rural communities are unable to play a participatory role in WRAs.

- **To determine the barriers to improving community participation in WRM.**

  Before CBWRM can be effectively promoted, it is necessary to understand current barriers in government policy and practice that hinder community participation.

- **To identify obstacles linking WRM and water supply in the WASH sector.**

  Before the principle of managing water locally can be widely promoted, engagement with the WASH sector is an essential step. Ways to interlink the assessment and management of water resources and infrastructure must be found, because the availability of water resources should not be viewed as a foregone conclusion.

An overview of the research process is illustrated in Figure 1-1, while Figure 1-2 shows details of the relationship between the specific research objectives, the methods adopted and data sets generated. The author focused on a research problem that addresses a real need in the WASH sector, based on extensive professional experience working in fragile states. The research objectives were refined following an extensive review of existing literature that helped to identify areas for potential exploration.

Figure 1-1: Illustration of the research process adopted by the researcher

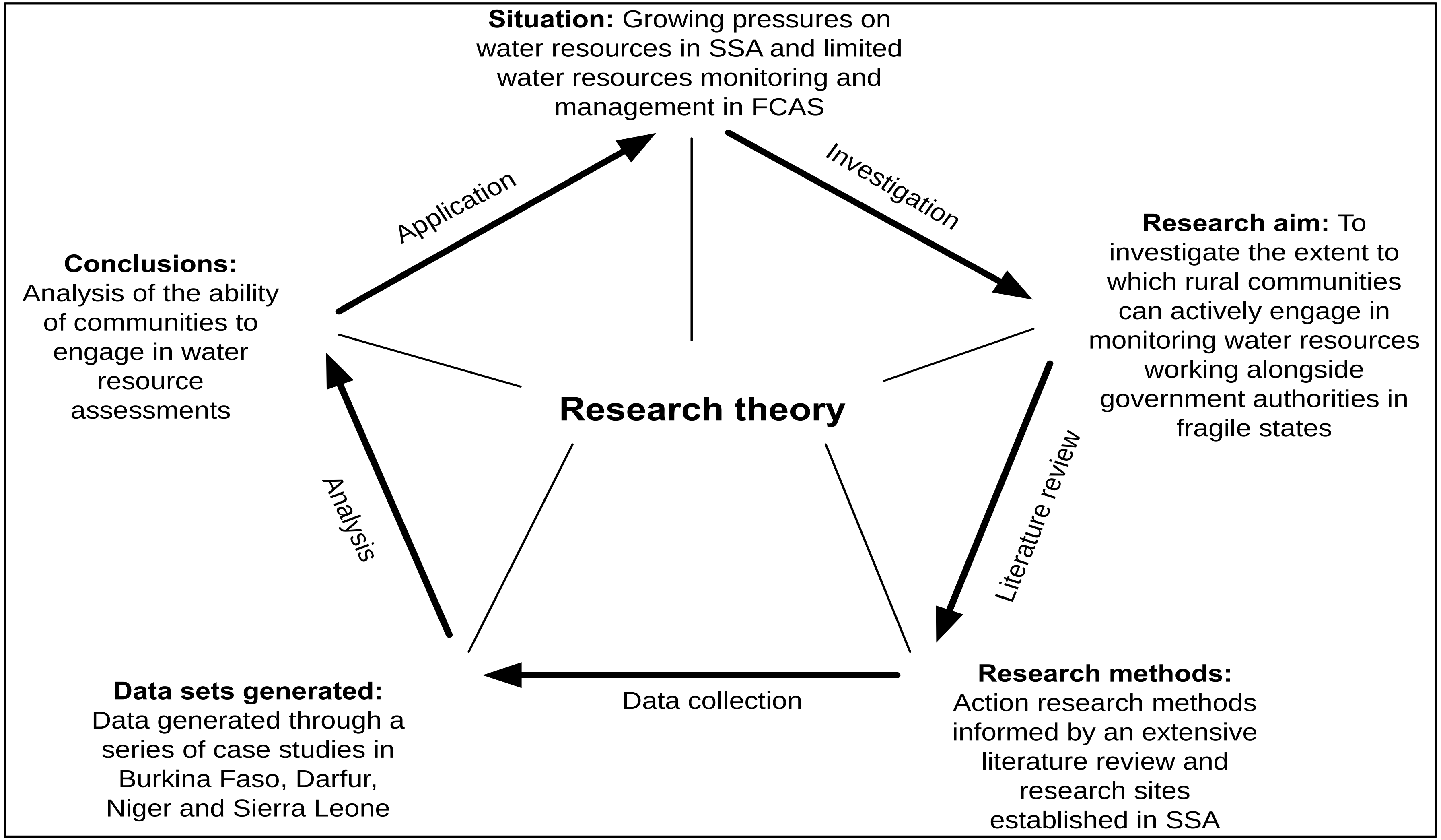
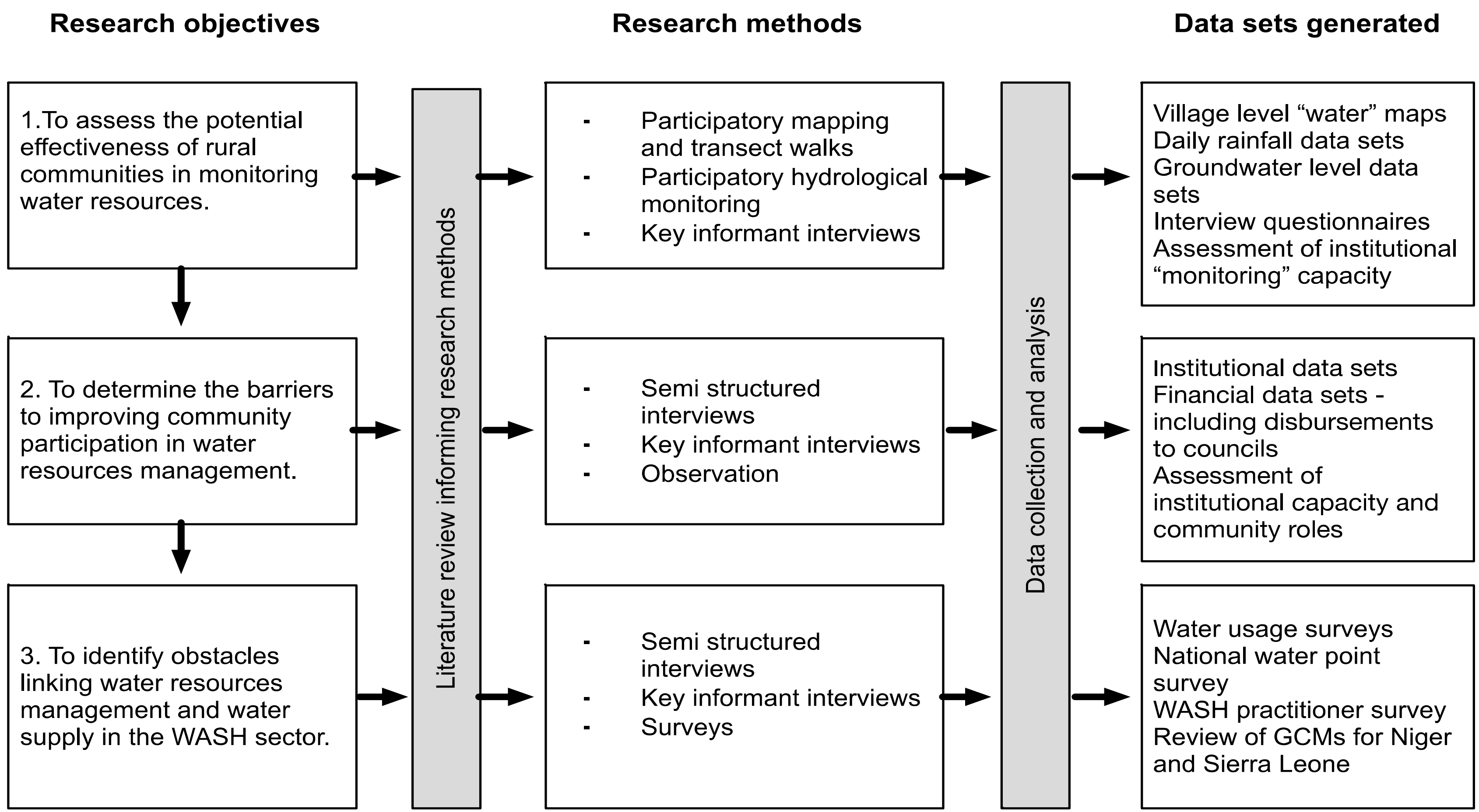


Figure 1-2: Illustration of the relationships between research objectives, research methods and data sets generated.



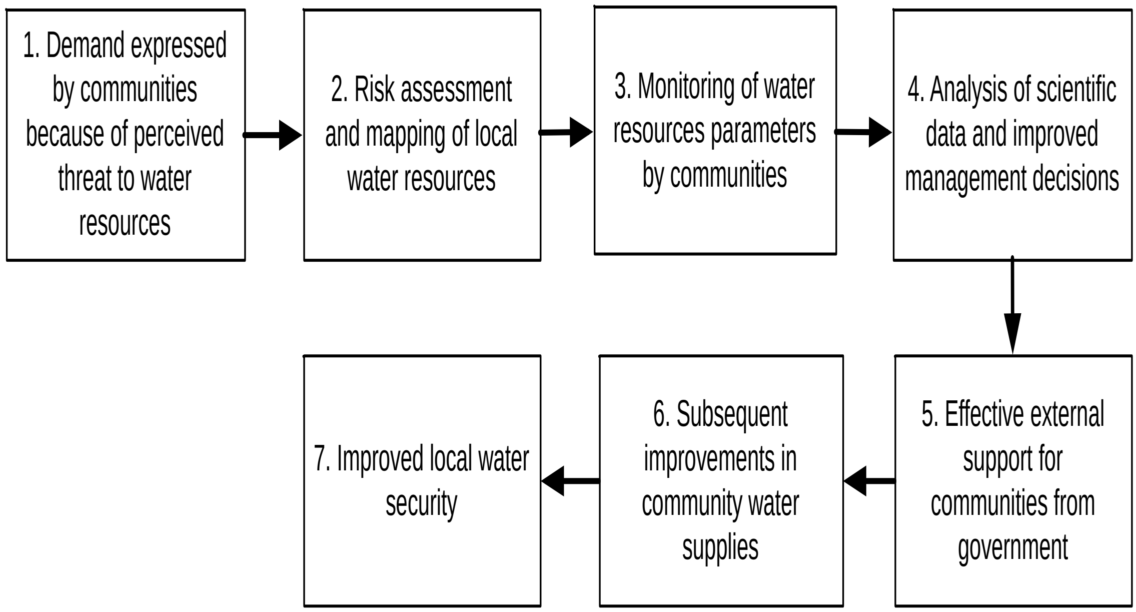
1.5 CBWRM

It is important to understand the concept of CBWRM from the outset so the approach is not misinterpreted. CBWRM is a set of activities and relationships designed to improve stewardship of local-level water resources, and so enhance water security. These are practical activities that can be carried out as part of WASH programming, so that WRA and WRM can be improved, even if higher-level institutional capacity is weak. It attempts to strengthen community resilience by factoring multiple uses of water into the design of rural water supplies and by encouraging better monitoring and stewardship of water resources (WaterAid, 2013). It is important to understand why CBWRM should stand in for IWRM? The primary proposition put forward in this study (revisited in Chapter Eight) is that fragile states are unavoidably complicated. There is a lack of hydrometric monitoring, government institutions may be dysfunctional, water resource infrastructure may be missing and there are complex demands and supplies, neither of which is monitored. To be fit-for-purpose, governments must undertake a series of lengthy transitions because they are not yet at the stage where they can implement ambitious WRM approaches. Furthermore, governments may be unwilling or unable to provide basic services for their citizens. The combination of these factors all conspires to demand realistic solutions that can strengthen the resilience of rural communities.

A simplified logic model for CBWRM is shown in Figure 1-3. It attempts to represent a number of important factors, which can contribute to successful water resource stewardship by communities. This study is primarily concerned with WRAs and areas for external support by government (steps 1–5), while the WRM component (steps 6 and 7) is not fully examined, due to disruptions to the fieldwork. Yet, even to investigate the ability of communities to engage in participatory monitoring in fragile states provides important insights because current literature is limited. This is evidenced in the argument for scaling up CBWRM (see Section 8.2). This study should also help stimulate further research.

It is helpful to provide a quick distinction between WRAs and WRM (see also Section 1.5.1). A WRA includes a process of data collection, validation and analysis and aims to measure water quantity (availability) and quality. WRM is essentially the process of planning, developing, distributing and managing the optimum use of the water resources available. This distinction is important because this study is primarily concerned with WRAs.

Figure 1-3: Simplified logic model for CBWRM, showing the important elements of the process.



The CBWRM process is reviewed in the following parts: First, there must be a real need or demand from communities for better WRM, which is more profound than the demand articulated in government and NGO programmes when new water supply services are offered (1). If interest and demand for engagement in CBWRM is weak there may be little possibility that activities will be sustained. Next, participatory mapping of local water resources is undertaken so seasonal (and other) risks to water resources are identified (2). This information is validated through transect walks. Consideration of water security has rarely integrated quality and quantity aspects, and yet this is vital for sustaining community water supplies (3). The outcome of hydrometeorological monitoring leads to better WRAs and a clearer understanding of the water-related problems to be addressed. Improved WRM by communities requires division of labour and rule setting, with graduated sanctions applied for rule violations (4). Over time and with experience it is possible that community-based approaches may become more sophisticated, but this will likely require effective external support, so observation of water and land outcomes or crops, livelihoods and ecosystem services can take place (5). Lastly, when monitoring is carried out it must lead to subsequent improvements in community water supplies (6) and local water security (7). An explanation as to how the CBWRM process can evolve is provided in Chapter Eight (see Figure 8-3).

1.5.1 Some definitions

This section provides some key terms to help guide the reader:

Water Resources Assessment (WRA): Aims to measure quantity and quality of water in a system, including data collection, validation and analysis using simple monitoring techniques. The outcomes of hydrological monitoring should lead to improved decision-making and follow-up action in the form of better water supply infrastructure. WRAs are essentially a sub-set of WRM.

Water Resources Management (WRM): Refers to the activity of planning, allocating and managing the optimum use of water. Typically rules, laws and institutions are established to achieve this, although this may rarely happen in practice in fragile states.

Water, Sanitation and Hygiene (WASH): It is widely believed that the combination of improved water supply and sanitation services, coupled with positive hygiene behaviour has a positive impact on improving health. WASH approaches are prevalent throughout fragile states and developing countries in extending water supply coverage and NGOs play a vital role in delivering these services.

Water Security: In this study water security is defined as: *Reliable access to water of sufficient quantity and quality for basic human needs, small-scale* *livelihoods and local ecosystem services, coupled with a well managed risk of water-related disasters* (WaterAid, 2012a).

1.6 Personal Background

Some autobiographical information is included for the following reasons: details about the researchers working background may be of interest to the reader of the thesis; it may also be useful to explain why the research topic was of interest and to record events that led to the commencement and continuation of the work.

After graduating from the University of Hertfordshire in 1999, the researcher was employed on the river engineering team for the Twin Rivers Diversion project at Terminal 5, Heathrow Airport, working with TPS Consult and Black and Veatch. After completing a part-time MSc in Water Management at Cranfield University in 2003, I joined Oxfam in 2005. From 2006 to 2009, the researcher worked in Darfur, North Sudan. A significant amount of time was spent working on water security problems with displaced households and communities who were on the periphery of support from government. This was not a normal time for people to live through. It was a time when households and communities were being displaced through violence and hostility – led by the government in Khartoum – with wells being poisoned by corpses. But it was also a time when displaced communities displayed great hospitality, a willingness to sit and talk about the customary water and land management practices that people have practised for millennia. Were these traditional systems perfect? Of course the answer is no, but there was a clear sense that communities had self-initiated systems to help them cope. Discussions with communities alerted the researcher to the importance of customary practices. This knowledge is important because most development practitioners are never truly working at the "coalface." However many field visits are undertaken, workshops attended, or publications written, most development workers are really bound up in their own world, which is far removed from the hardship and realities of rural communities. Oscar Wilde once quipped: *"an expert is an ordinary person away from home giving advice."* When developing new ideas or concepts the researcher was mindful to focus on the actions and interventions that should be undertaken by local communities and governments on a daily basis if any results are to be achieved. These seemingly mundane activities – such as measuring groundwater levels, observing rainfall, and record keeping – are vitally important and ultimately determine whether concepts like CBWRM will be successful. This led to the researchers enrolment on a part-time research programme.

In 2011, the researcher began working at the Ministry of Water Resources (MWR) in Sierra Leone and remained there throughout the West Africa Ebola outbreak. It was a time when generous feelings and warm handshakes were replaced by anxiety and fear. The struggle to contain the Ebola virus was a steep learning curve for many organisations – not least because it requires close interaction between WASH, health and social mobilisation sectors. During this period there was a lot of propaganda and blame apportioned to the British-led response effort and the performance of international NGOs. State actors, who had failed to build strong resilient institutions, drove much of this propaganda. Whether the fallout from the Ebola crisis will lead to improved governance, less corruption and a renewed commitment to deliver water, food and energy security is highly questionable. The backbone of the Ebola response was often the commitment and bravery of local medical workers and communities, and the need for local people to participate in solving problems became clear.

1.7 Thesis structure

This thesis consists of nine chapters, of which this Introduction is the first. Chapter Two introduces the wider context of WRM in fragile states and describes the current state of knowledge for this thematic area. It explains how the pressures on global water resources are increasing and examines current thinking about WRM, including IWRM, Adaptive Management (AM) and Water Safety Plans (WSPs). The role of community-based institutions is also examined. Chapter Three introduces the research areas and describes the similarities and differences between the case study sites. Chapter Four provides a review of the theoretical basis for the research and describes in detail the Action Research (AR) methods adopted. Chapter Five focuses on the first research objective: To assess the potential effectiveness of rural communities in monitoring water resources. Data analysis evaluates communities' ability to monitor local-level water resources. The importance of effective external support for CBWRM is also examined. Chapter Six is based on the second research objective: To determine the barriers to improving community participation in WRM. It examines the underlying obstacles to community participation from the perceptions of government, practitioners and communities themselves. Chapter Seven is linked to the third research objective: To identify obstacles linking WRM and water supply in the WASH sector. The argument of this chapter is that WRM and rural water supply should be inter-linked. Chapter Eight highlights the links between the insights presented in earlier chapters and shows how CBWRM could hypothetically sit within a broader WRM system; the chapter also describes research limitations. Chapter Nine draws conclusions from the three research objectives and revisits the research aims and objectives. It also makes recommendations for further applied research that is relevant to scholars and development practitioners.

2 Literature review

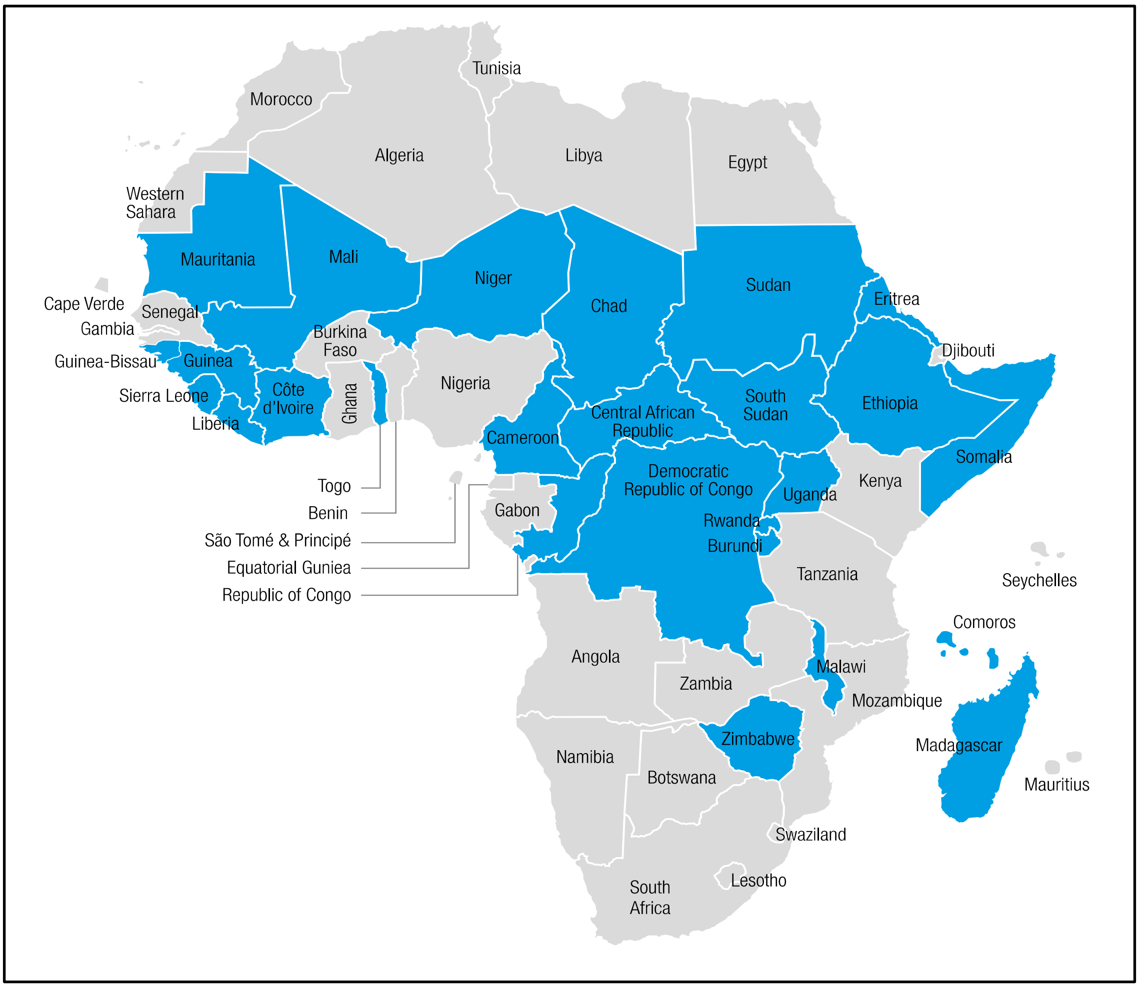
This chapter explores the research topic through existing literature and the main theories are presented and examined. The scale of the fragile state problem is introduced in Section 2.1 and the unique challenges encountered when working in fragile states are discussed. In Section 2.2 the pressures on water resources are presented and the necessity for a localised approach for monitoring and managing water resources is argued. Current WRM approaches are discussed in Section 2.3 and the suitability of their application in fragile states is examined. The nature of community management arrangements for rural water supplies is discussed in Section 2.4, while the importance of community-based approaches for managing CPRs is argued in Section 2.5. The evidence presented in this chapter form the basis for the research methods selected, and the final section summarises how the literature review informs the research.

2.1 Fragile states: The context and scale of the challenge

For analytical purposes, countries of the world are often sorted into one of three broad categories: developed economies, economies in transition and developing countries (World Economic Situation and Prospects, 2014). Within each broad group numerous sub-groups may exist and countries can be further divided into fragile, crisis or failed states. These states are typically confronted with war, violence and extreme poverty and they represent an extreme challenge in the fields of security and development assistance (Nay, 2013).

Although there is no universally agreed list of fragile states, the number of people living in these nations is substantial. It is estimated at least a third of the world's most vulnerable people, around 1.5 billion, live in fragile states and it is estimated that this number could grow to 1.9 billion by 2030 (OECD, 2015). The majority of these countries are in SSA (see Figure 2-1) and they all face severe and entrenched obstacles to economic and human development.

Figure 2-1: Map of Africa's more fragile states – shaded in blue (Source: Institute for security studies, Cilliers and Sisk, 2013)



Collier (2007) describes four poverty traps the most vulnerable countries often face: the conflict trap, the natural resources trap, the trap of being landlocked with bad neighbours and the trap of bad governance in a small country. Governments lack the ability to construct mutually constructive relationships with society and often struggle to carry out basic governance functions. This makes the transition out of fragility neither rapid nor simple. The achievement of the MDG[4] targets by 2015 has been particularly difficult and, while good progress has been made in some more resilient nations, fragile states are at the

[4] The Millennium Development Goals are a UN initiative consisting of eight international development goals to be achieved by 2015. Goal 7c was to half the proportion of people worldwide without access to improved water supply and sanitation services.

bottom of the global economic system. They have been described as “falling behind and falling apart” (Collier, 2007), and are increasingly seen as an area for growing intervention. The post-2015 development framework[5] calls for a greater understanding of fragility, risk and vulnerability (OECD, 2015), because these states can destabilise regional and global security. Of all the SSA countries shown in Figure 2-1, 26 are classed as fragile and only 12 can expect to become more resilient by 2039 (Cilliers and Sisk, 2013). Burkina Faso has been described as Africa’s most coup-prone state (The Washington Post, 2015) and is projected to face an uncertain future, which will further decrease its stability beyond its current “alert” status (Fund for Peace, 2015).

A variety of definitions for FCAS can be found in current literature, but all agree they are characterised by a legacy of conflict and insecurity, with governments affected by corruption and low institutional capacity to adapt to economic shocks and environmental disasters (Warrener and Loehr, 2005; OECD, 2015). The World Bank (2005) describes fragile states as having weak governance, policies and institutions, while DFID’s 2006 White Paper describes them as not being capable, accountable or responsive to the needs and rights of citizens (DFID, 2006). They remain susceptible to recurrent shocks and struggle to build resilience (OECD, 2015). Even when fragile states remain conflict free for a decade (such as Sierra Leone and Liberia) they continue to face intractable problems. The 2014 Ebola Virus Disease (EVD) outbreak in West Africa, which was the largest and longest EVD outbreak in history, bears testimony to this problem.

Current literature points to some crucial challenges that should be addressed if FCAS are to become more effective at alleviating poverty. They also provide some indication why CBWRM should stand in for IWRM in fragile states. These can be reviewed in four parts: First, it is essential to understand the national and local context and to recognise the different constraints of institutional capacity and political will that exist (see OECD, 2007). This knowledge is underpinned in

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[5] The Post-2015 Development Agenda, refers to the global development framework, led by the UN, that will succeed the MDG targets.

Fragile State Principle 1 (OECD, 2015). Second, there is a requirement for development actors to strengthen indigenous capacities (OECD, 2007). A related argument is that donors should invest more in community-based initiatives so people have more confidence to hold their governments to account (OECD, 2015). Third, international experience has shown that development approaches in fragile states must deliver both short-term and long-term results. Interventions must be tailored to the local context and where possible they should contribute to initial peace building and state building. Lastly, international agencies working in fragile states should develop and articulate a "theory of change" (Vogel, 2012). This implies transitional steps need to be clearly articulated. However, current literature informs us the aid environment in these countries is typified by short funding cycles and demands for rapid results (OECD, 2011). Collier (2007) highlights that international aid does not work well in fragile states and change must often come from within, with governments focusing on a few key priorities. International aid is often delivered outside of state structures, through short-term, uncoordinated projects that are not part of a broader development strategy (see DFID, 2005).

2.1.1 The water dimensions of fragile states

2.1.1.1 Water supply problems

The specific water-related problems fragile states experience need to be investigated, because they are often more acute than those in developing countries. During conflict, armed groups may be involved in widespread destruction and citizens are left without the most basic water supply and water resources infrastructure. Government institutions are characteristically weak, which means their capacity to implement change is severely limited. Humanitarian policy in post-conflict situations often aims to provide emergency water supply services. However, if the objective is to provide sustainable water supply services this is not easily achieved because services are being delivered on weak institutional foundations. The construction sector has also withered away during years of violence and destruction (Collier, 2009).

Table 2-1 shows an overview of progress in extending rural water supply coverage in the four case study countries over the past 25 years. Progress is characterised as being frustratingly slow and in the case of Sudan coverage is declining. It should also be borne in mind the figures in Table 2-1 represent "high-end" estimates because Joint Monitoring Programme (JMP) data does not factor in issues of functionality and seasonality. Thus actual rural water supply coverage rates may be significantly less. According to the States of Fragility Report 2015, two-thirds of FCAS will fail to halve poverty by 2015, in accordance with the Millennium Development Goals (MDGs), and 72% will fail to halve the number of people who do not have access to clean water (see OECD, 2015). Either way, progress in extending water supply coverage has been frustratingly slow for many rural communities.

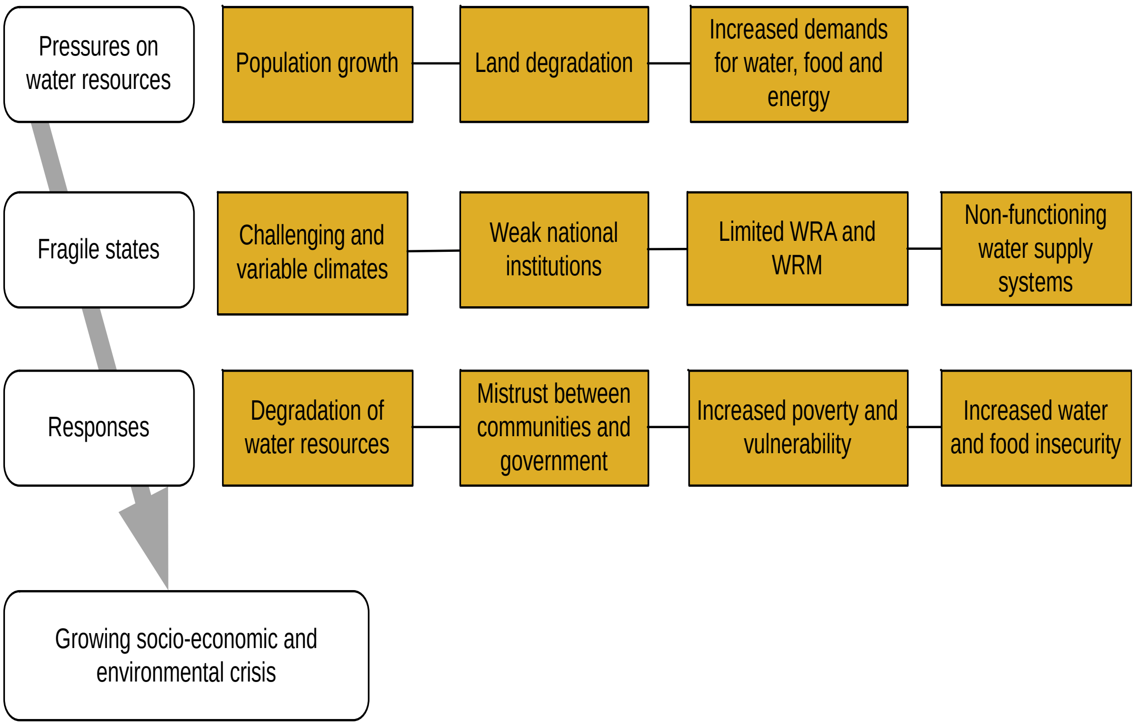
Table 2-1: Source JMP survey (2015): estimated coverage of rural water supply in Burkina Faso, Niger, Sierra Leone and Sudan

Estimated rural water supply coverage				
Year	**Burkina Faso**	**Niger**	**Sierra Leone**	**Sudan**
1990	32%	29%	27%	61%
1995	46%	33%	27%	59%
2000	55%	37%	31%	56%
2005	63%	41%	38%	53%
2010	72%	45%	41%	50%
2015	78%	49%	42%	No data

2.1.1.2 WRM problems

An argument often invoked is that rural water supply systems can only be sustained if water resources are known and managed in a sustainable manner. Many of the WRM problems faced in fragile states comprise a system of growing pressures, weak states and inadequate responses, (see Figure 2-2). Pressures on water resources (such as population growth, increased water demand and land degradation) are increasing at a rapid rate, especially where countries are rich in extractive natural resources. This is complicated further by ongoing climate instability and climate change. The necessary response from government is often insufficient due in part to poor governance and capability. The mentality of national politics in a post-conflict situation has been described as a *zero sum game*. Collier (2009) points out that vulnerable groups in society may be excluded after national elections and a mind-set of, *"I can only go up, if you go down"* exists. All this is leading to environmental catastrophe and a crisis for water and food security.

Figure 2-2: Water dimensions in fragile states (adapted from Carter in Institution of Civil Engineers et al, 2011)



Remote rural communities are particularly vulnerable in fragile states because governments may be unresponsive to their needs. Often communities are required to build their own resilience and take responsibility for finding solutions where governments have failed (Danish Refugee Council, 2013). This understanding implies bottom-up approaches are essential in FCAS. Empirical research has shown that in developed economies the ability of central and local governments to respond to water stress is far more robust than fragile states. For example, Spain is a relatively water stressed country, yet it maintains reasonably high coping capacity to respond to water shortages. Elsewhere coping capacity is much lower. Niger and Burkina Faso may be classed as water stressed countries but with low coping capacity. According to Ohlsson (1999) the adaptive capacity of a society should be regarded as a resource. A society that does not have sufficient adaptive capacity to make the relevant adjustments needed to cope with increased resource scarcity can be regarded as having a second order scarcity (Ohlsson, 1999). This refers to the inability of a social entity to find the social tools to deal with the consequences of resource (or first order) scarcity.

2.1.2 Current WRM literature related to fragile states

There is extensive literature regarding pressures on global water resources, climate change and the importance of managing water resources. However, remarkably little has been written about WRM in FCAS. No literature could be found that explicitly examines *how* to undertake WRAs or WRM in such difficult environments. As Tearfund (2007a), Barsi (2013) and the UNEP (2014) highlight, achieving IWRM in Darfur is not an easy task. The importance of community-based approaches in fragile states is widely referred to in the literature but there is no consensus on the role of community-based institutions in monitoring and managing water resources. Surprisingly the WASH sector has engaged relatively little in WRM. Smits et al (2009) suggest this is because it has been little affected by water scarcity or resource conflict, compounded by the fact that many of the IWRM initiatives have remained at the higher levels of national policies and river basins. What needs further research (and appears to be a gap in the literature) is a clearer understanding of the role of communities in monitoring and managing water resources in FCAS alongside government. This is required because there is growing discourse relating to the adoption of foreign blueprints for WRM. Existing literature has identified the problem of a solitary IWRM blueprint or model for WRM. Notable examples include Biswas (2004), Jeffrey and Gearey (2006), Lankford and Hepworth (2010) and Giordano and Shah (2013). The context of these works is the recognition that wide-ranging approaches are perhaps only practicable in nations with well-equipped and highly professional institutions (Butterworth et al, 2010). Thus, practitioners require improved guidance that bears resemblance to the messy reality of working in fragile states. The following section looks in detail at the multiple pressures on water resources in SSA and in doing so highlights the importance of managing water resources locally.

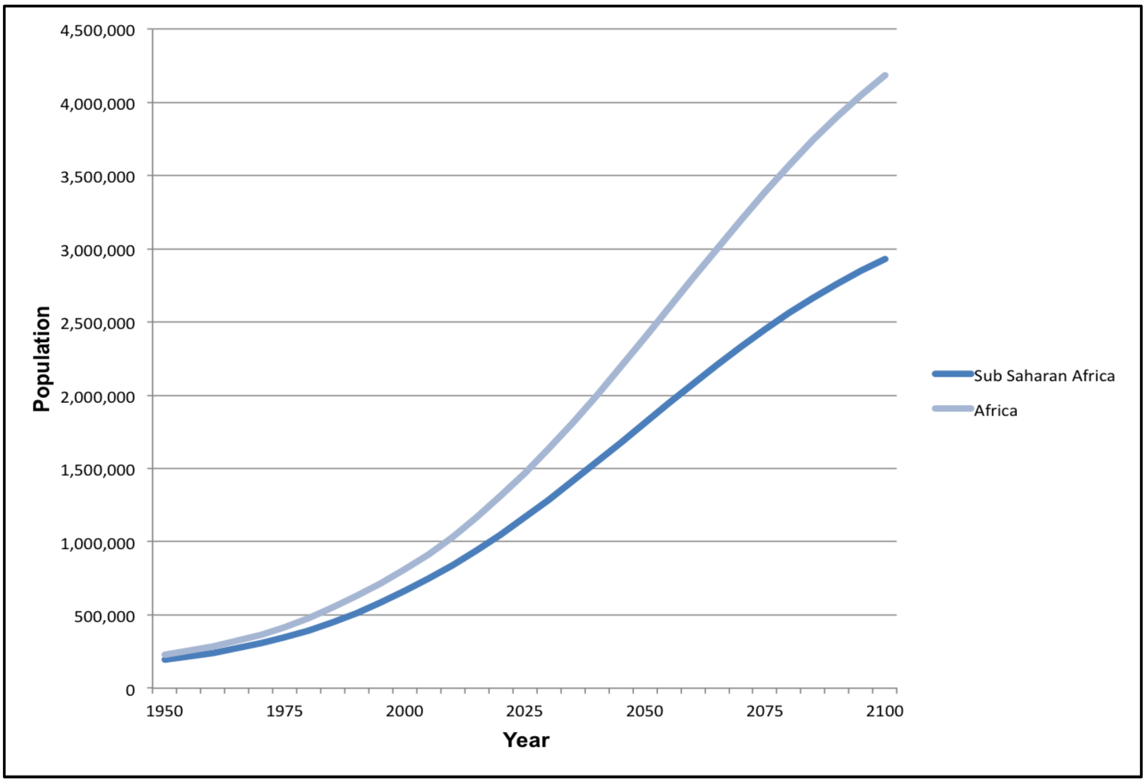
2.2 Pressures on water resources in SSA

2.2.1 Population growth

The first pressure on water resources is population growth. Until recently, population growth and the impact it has on water resources tended to be ignored – the "elephant in the room." However, the adverse impact that burgeoning population growth could have on water resources can no longer be ignored. Global population reached 7 billion in 2011 with projections of an increase to 9.6 billion by 2050 (United Nations Department of Economic and Social Affairs, 2013). It is projected that population growth and economic development will dictate water demand over the next 25 years, leading to some clear trends, such as urbanisation, differential rates of growth across the globe and an increased gap between rich and poor (Vörösmarty et al, 2000). The rate of human population growth is particularly alarming in SSA. Figure 2-3 illustrates that African population will grow by about 196% between 2000 and 2050 under the United Nations (UN) medium variant. It is well documented that water demand will grow as a consequence of increasing population as countries try to increase per capita water consumption (Carter and Parker, 2009). Africa's mean population density is also projected to rise from 27 to 66 people per km^2

between 2000 and 2050 (Carter and Parker, 2009). Rural population densities in Africa are also rising, which suggests the management of water resources should not be confined to densely populated urban areas. Carter and Parker (2009) observe that in Uganda and Ethiopia rural population densities are projected to increase from 93 and 53 persons per km^2 in 2000 to 256 and 96 in 2050 respectively. This will have significant implications for population per unit of cultivable land and water usage. Current literature suggests population growth projections should not be ignored, because demographic change in SSA is known with some certainty.

Figure 2-3: Past and projected population growth in Africa and SSA. Source: United Nations Population Division, World Population Prospects: The 2012 Revision, medium variant (source United Nations, 2013).



One of the impacts of spiralling population growth in fragile states is that it can lead to internal, inter-regional and international migration, as people struggle to escape dysfunctional social models (Collier, 2013). The International Organization for Migration (IOM) place refugees and migrants into three categories: first, political refugees; second, economic migrants; and, third, environmental refugees – those driven from their villages by harsh environmental conditions (IOM, 2014). Although those most vulnerable to environmental change may not be able to migrate far, increased population densities and resource demands are obvious and present major challenges for governments and humanitarian organisations (The Royal Society, 2012).

Large-scale human displacement, either within or outside a nation's borders, may result in the formation of camps for refugees or displaced people. Densely populated camps place significant demands on local water resources and require WRAs to be undertaken. This knowledge has major implications for international organisations that may be tasked with establishing emergency water supply systems. In such circumstances, a fundamental requirement is to assess medium and long-term water demand, ensuring the delivery of safe and adequate water supplies in accordance with Sphere minimum standards (2011)[6].

To make sense of the potential demand on water resources it is helpful to take a closer look at resultant population densities. An article published in the journal Waterlines (Carter, 2007) notes that a densely populated refugee or Internally Displaced Person (IDP) camp, designed to Sphere minimum standards (The Sphere Project, 2011), can result in a population density in excess of 22,000 people per km^2. Assuming each person receives 15 litres per person per day, the recommended minimum in Sphere guidelines, this implies a daily water demand of $330m^3$ per day per km^2. Annually this amounts to $120{,}450m^3$ per km^2. This volume of water equates more to a city's water demand than to a rural settlement. A related argument is whether NGOs should routinely engage in wider WRM if resource provisions threaten the sustainability of water supply systems (see Chapter Seven).

[6] Sphere minimum standards (2011) require, amongst other things, that each displaced person receives $45m^2$ of living space. In reality this space requirement is rarely achieved in humanitarian emergencies and population densities might be much greater.

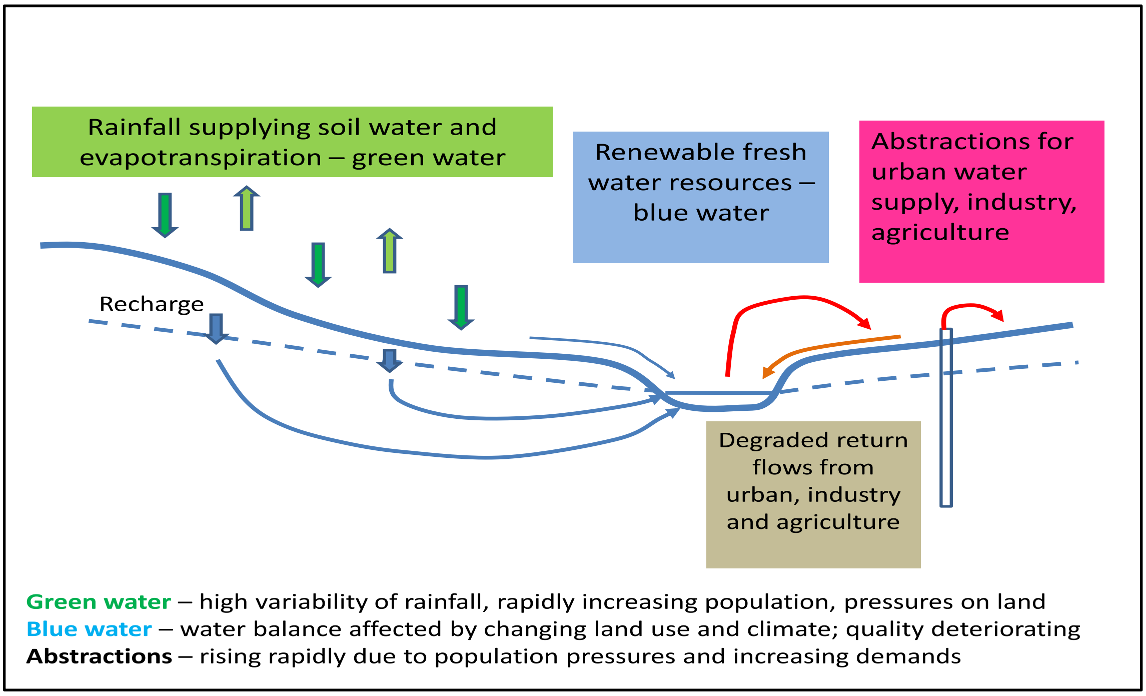
2.2.2 Land degradation

The second pressure on water resources is land degradation. Environmental degradation, such as deforestation, can alter the local water balance and lead to scarcity of supplies. It can also potentially act as a *threat multiplier*, combining with other factors, such as climate variability, to displace people from their traditional lands (OECD, 2012). New land is often cleared of vegetation for the creation of additional cropland. Subsequent changes in land use continue to affect the local water balance and have severe consequences for land and soil quality. According to the International Centre for Soil Fertility and Agricultural Development, Alabama, *"…three-quarters of Africa's farmland is plagued by severe soil degradation caused by wind and soil erosion and the loss of vital mineral nutrients... [As a consequence] agricultural productivity in Africa has remained largely stagnant for 40 years, while Asia's productivity has increased threefold"* (Henao and Baanante, 2006).

The term "land degradation" encompasses land use and land cover, erosion, salinisation, compaction, nutrient depletion and other negative impacts on land and soil (Conca, 2005). One important issue to highlight is that water resources and land management are intimately linked and some water sector professionals have advocated that IWRM should in fact be termed Integrated Water and Land Resources Management (Falkenmark et al, 2014). In arid regions the consensus would appear to be that land use and land management can be at least as important as climatic factors in determining groundwater and surface water recharge (Scanlon et al, 2006).

Referring to land and water issues specifically, the water balance of soil containing vegetation and crops is a function of three broad factors (Rushton et al, 2006): first, weather related factors, particularly rainfall and evapotranspiration; second, properties of the soil, including its infiltration capacity and water-holding capacity; and, third, properties of the vegetation, including seasonality and cover. Together these three factors determine what proportion of water enters the soil and is available for rain-fed agriculture (referred to as "green water") and what proportion either runs off the soil or drains deep into the aquifers to form groundwater recharge (part of what is referred to as "blue water")[7]. This relationship is presented in Figure 2-4.

Figure 2-4: Conceptual diagram of green–blue water relationship (Source: Carter, 2011a)



Referring specifically to Figure 2-4, Falkenmark and Rockstrom (2006) inform us that the green water flow system describes the water consumption by forests, grasslands and rain-fed croplands as well as rain-fed crop production. The blue water system carries water that is available for human populations. After use, it goes back into the water system as wastewater. This may be classed as grey water (wastewater that can be treated) and brown water (that may be laden with pollutants).

Ongoing land degradation caused by deforestation, population growth and changing land use patterns results in nutrient mining and soil degradation. It also makes analysis of the natural water balance difficult. For example, research conducted on nine major river basins in SSA found that robust

[7] The distinction between green water and blue is accredited to Malin Falkenmark's article "Freshwater as shared between society and ecosystems: from divided approaches to integrated challenges."

identification and attribution of hydrological change was severely limited by difficulties in quantifying the effects of land use change, and other human influences, combined with a lack of hydrological data (Conway et al, 2009). Carter (2009)[8] points out the way in which future rainfall timing and intensity affect surface runoff and groundwater recharge depends on simultaneous changes in evapotranspiration, but also, importantly, on changes in land use and land cover. Protection and conservation of soil and vegetation is usually good for the conservation of water resources and intuitively this is good for the recovery and recharge of water resources. It is often assumed that a decrease in rainfall will automatically lead to a reduction in water availability and a decline in water resources, but the reality may be somewhat different. Empirical research has shown the result of this green–blue water relationship is that in some circumstances an increase in (blue) water availability may occur despite a decrease in rainfall, as experienced in the West African Sahel (Descroix et al, 2009). If this pattern were reversed the results would be alarming. How might this relate to WRAs? The proposition is about the difficulty in understanding the relationship between rainfall, runoff and resultant impacts on water resources and the requirement for localised analysis.

2.2.3 Food security

The third pressure on water resources is food security and resultant water demand. The crises occurring in many developing countries stem from an increased demand for food production, as a result of population growth. In SSA this has been achieved by expanding the area under cultivation rather than intensifying crop yields. Agricultural water demand is very large and drastically outstrips domestic water requirements. Cairncross (2003) observes that *"a flow of 1 litre per second is enough to meet the domestic water requirements of roughly a thousand people, but to irrigate only one hectare of land and feed no more than a couple of families."* It is estimated that 82% of water abstracted from fresh (blue) water resources is used for agricultural production in low-and

[8] Speaking at the Institution of Civil Engineers in December 2009.

middle-income countries. This compares to 10% for industrial usage and 8% for municipal supplies (World Business Council for Sustainable Development, 2005).

Research conducted at the International Institute for Environment and Development (IIED) shows that many soil and water conservation methods in developing countries have failed (Reij 1991). This is because they have ignored existing traditional systems and techniques, focusing instead on modern methods that involve technology transfer and a reliance on machinery. Reij (1991) proposes that indigenous methods may provide the most effective foundation for future land and water management strategies, by placing more emphasis on existing skills and knowledge. Examples of such indigenous practices include water-harvesting systems in Somalia, water conservation techniques by the Dogon in Mali and traditional irrigation systems in Algeria, Tunisia and Morocco. The recent introduction of planting pits, traditionally used in Peru, has yielded immediate benefits to subsistence farmers in the Sahel (Graef and Halgis, 2001).

Increased pressure on land in rural areas will necessitate an increase in the development of irrigation, thereby stressing water resources. By 2050 the absolute growth in rural population is projected to be nearly 240 million in Africa, a 45% increase compared to 2000 (Carter and Parker, 2009). Food security will only be achieved through re-emphasis on water conservation, irrigation and water management. Allan (2009) points out that farmers in Africa have strong justification for using and managing water efficiently, because they use and manage the big volumes of water used and consumed by society. Better management of water and land resources and better data could improve productivity, which would require WRAs (Lankford, 2005; FAO, 2011).

2.2.4 Climate variability

The fourth pressure is rainfall seasonality and variability. African water resources are sensitive to climatic variability, as seen in assessments of water security, agriculture and health (Ominde and Juma, 1991). In many parts of the tropics and sub-tropics, but particularly in Africa, the climate, and more specifically the seasonality and variability of rainfall, pose significant challenges to livelihoods and WRM. This is also true in well-watered countries (such as Sierra Leone) where there is an absence of significant surface water storage or major aquifers (MWR, 2015).

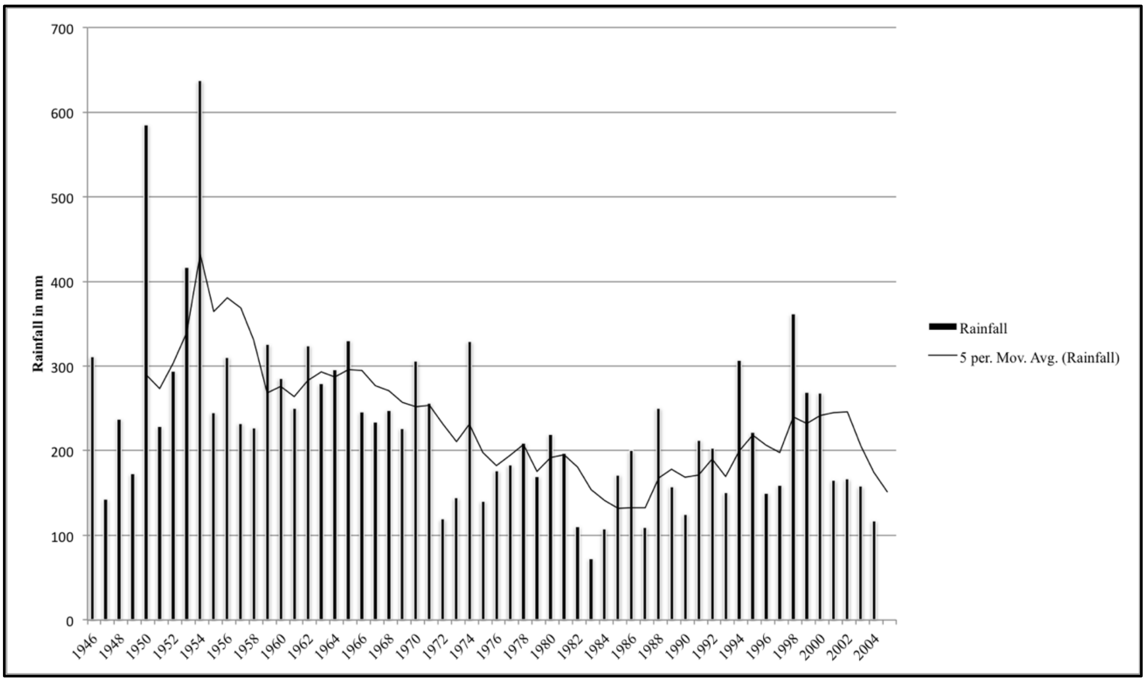
The Sahel[9] region provides a dramatic example of the impacts of rainfall variability. According to Brooks (2004) and the Food and Agriculture Organization (FAO) (2012), the rural population in the Sahel is amongst the most vulnerable on Earth. The inter-annual and multi-year variability of rainfall is illustrated in Figure 2-5, which shows rainfalls for Al Fasher (North Darfur) for the period 1946–2004. In addition to the spread of yearly rainfall, a downturn is evident from the 1960s onwards and runs of repeated low rainfall years are evident in the 1980s. The amount of rainfall variance on multi-decadal timescales is unique to the Sahel. Mortimore and Adams (2001) note the population of the Sahel has experienced several severe droughts since the early 1970s, largely due to the variability of the West African monsoon. As a result of low, temporally and spatially variable rainfall patterns, small-scale irrigation in the dry season has become a very popular risk coping strategy, in preference to migration (Barbier et al, 2008).

The challenge for many Sahel countries is to break the poverty trap of repeated crop failures and stimulate demand for productive water usage. Falkenmark et al (1998) suggest the primary requirement is to bridge the gap between dry seasons by supplying relatively small amounts of blue water for small-scale irrigation and livestock watering, while still encouraging high value cash crops to be grown using green water. They state, *"We need smarter ways of combining green and blue water."* Rockstrom (1997) proposes the most probable way of achieving this is through improved stewardship of groundwater resources linked with soil and water conservation projects. However, achieving this in FCAS may be extremely difficult if government institutions are fragile or absent. The broad

[9] The term "Sahel" refers to the transition zone between the Sahara desert and the rainforests of Central Africa and the Guinean Coast.

consensus across the literature appears to be the recognition that these problems need to be solved locally as communities, farmers and responsible government officials make scientifically informed decisions about what needs to be done (Christoplos and Pain, 2014; Institution of Civil Engineers et al, 2011, Allan, 2009). Muller (2008) points out the management of rainfall variability poses major challenges and the "localness" of the water economy in SSA makes it difficult to provide generic responses.

Figure 2-5: Mean annual rainfall in mm for Al Fasher, North Darfur: 1946–2004, showing 5-year moving average (Source Tearfund, 2007b).

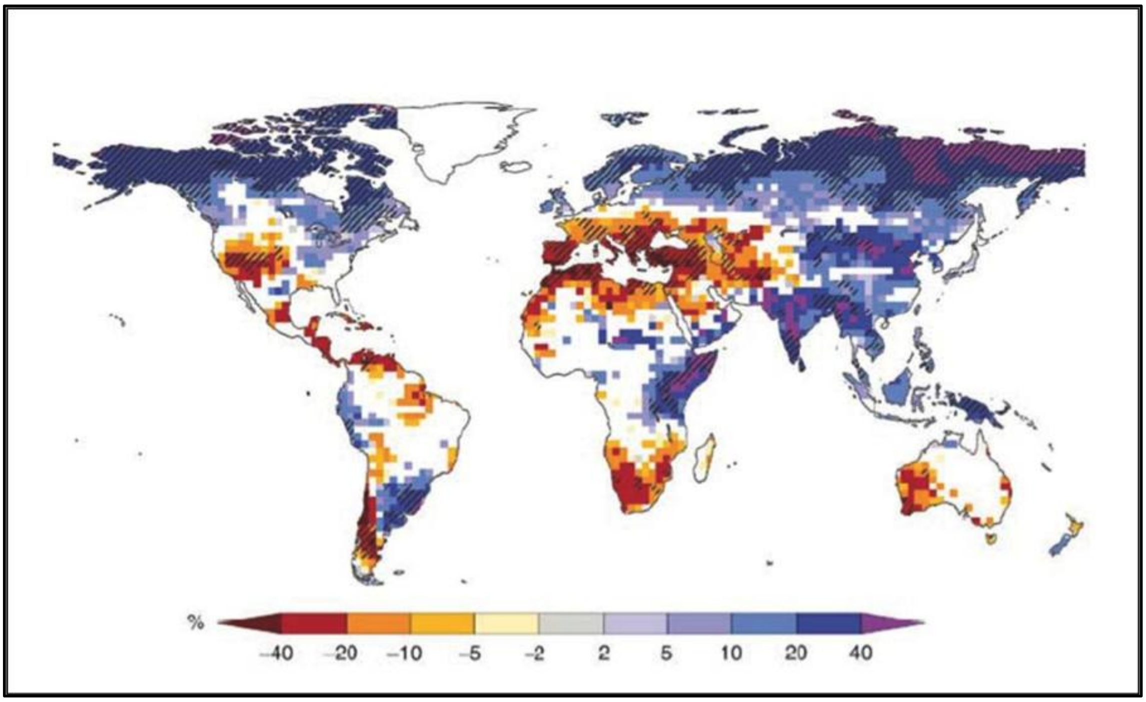


2.2.5 Climate change

Climate change, caused by anthropogenic activity is the fifth driver. There has been a tendency in recent years to lay great emphasis on the impact of climate change and how it will affect the hydrological cycle (Stern, 2006; Bates et al, 2008). The IPCC's Assessment Report 4 (AR4) warns that by 2020 between 75 and 250 million people in Africa will be exposed to an increase of water stress due to climate change. The IPCC state (IPCC, 2007): *"Water managers have long dealt with changing demands for water resources. To date, water managers have typically assumed that the natural resource base is reasonably* *constant over the medium term and therefore that past hydrological experience provides a good guide to future conditions. Climate change challenges these conventional assumptions and may alter the reliability of water management systems."*

To make these assertions more precise it is fruitful to look at climate change modelling in greater detail. A fundamental objective for climate science is to project with confidence how climate conditions will alter throughout this century and beyond. Climate models, termed General Circulation Models (GCMs), are the only approach available for making climate change projections. Models attempt to predict the effects of climate change, starting with assumptions about future greenhouse gas emissions scenarios and concluding with the likely corresponding changes in rainfall, temperature and other climate variables, at various spatial scales (Held et al, 2005). Projections of annual runoff from the IPCC indicate large-scale changes in runoff for 2090–2099 compared with a baseline period of 1980–1999 (see Figure 2-6). Agreement on these changes is greater in some areas than others. For example, the white areas in Figure 2-6 indicate regions where the projections made by different global climate models do not agree on the direction of changes and considerable uncertainty remains about future runoff levels. Current assessments of the impacts of historical and projected climate variability and water resource changes also commonly exclude groundwater (Taylor et al, 2009). Questions have been raised concerning the uncertainties involved in assessing climate change impacts on green and blue water. This work is often termed the "uncertainty cascade" or the "propagation of uncertainty" and is well documented (Mearns et al, 2001). Research undertaken shows that climate uncertainties fall into three categories (see Stainforth et al, 2007; Washington, 2009). Briefly, these are: 1) Initial condition uncertainty: natural climate variability will continue to be a feature that makes interpretation of anthropogenically-forced climate change complex. Consequently no single rainfall event, past or future, can or could be attributed unequivocally to climate change; 2) Model uncertainty: regional climate change is less-well modelled and understood than global change. Current climate models are limited by their relative inability to describe detail at national or regional scale compared to continent or global scale descriptions. Fung et al (2011) believe no single model can be adopted for climate change projections and basing projections on a single model is a risky approach; 3) Forcing uncertainty: future atmospheric greenhouse gas concentrations are indeterminate for various reasons, not least because future emissions depend on numerous international, national and individual corrective actions, as well as the enforcement of legally binding agreements.

Figure 2-6: IPCC projections of annual runoff 2090–2099 (Source: IPCC, 2007)



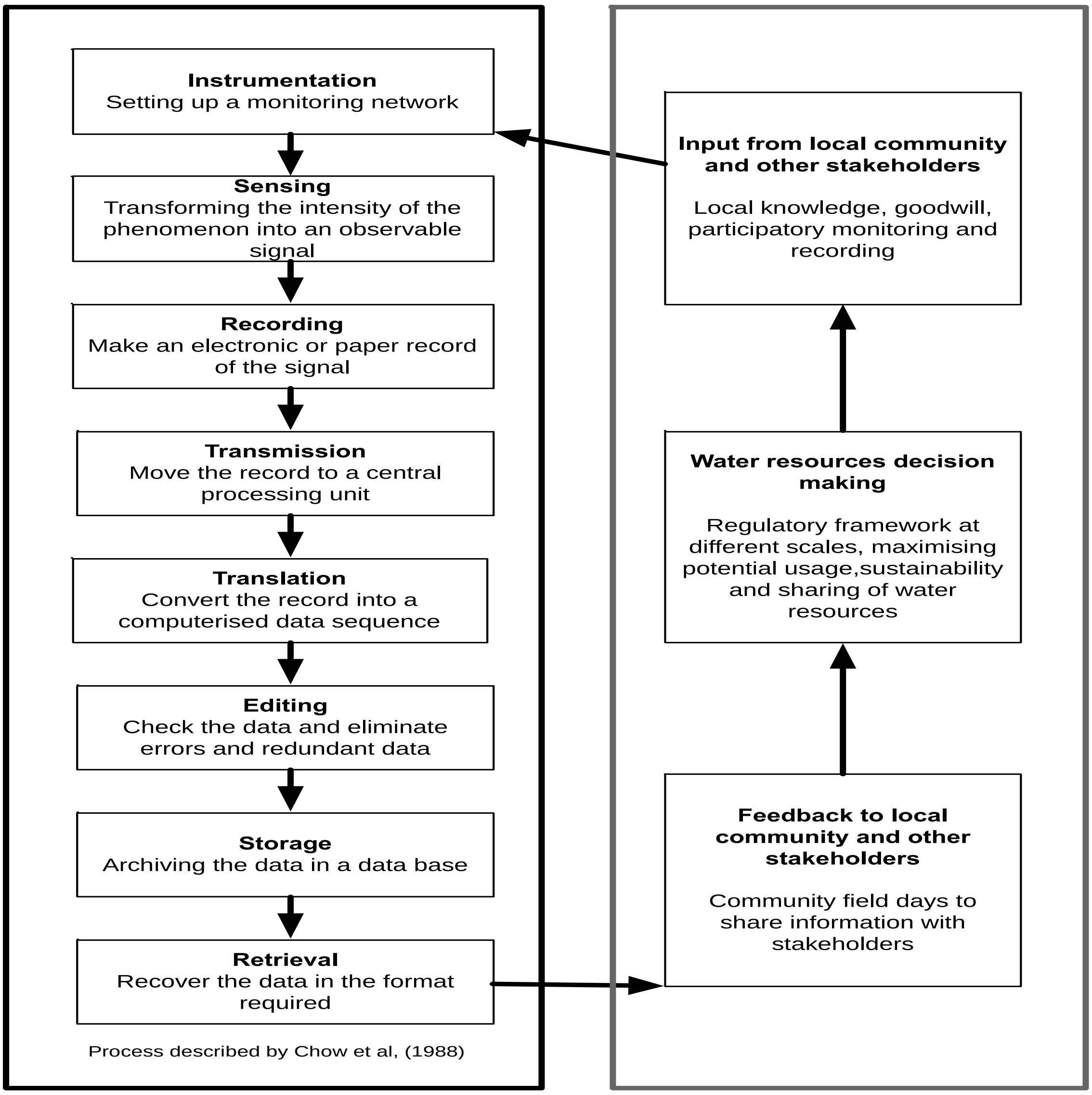
Although some improvements have been noted in performance between GCMs used in AR4 and the newer climate models utilised in the IPCCs fifth assessment report, many researchers report finding little or no improvement. Major imperfections in the models prevent important elements of the climate system being simulated (see Lupo et al, 2015). Conway (2011) observes the rapid increase and concern about climate change, and the need to identify concrete adaptation approaches risks driving demand for certainty beyond what the science community can realistically accomplish. The sensible conclusion therefore is that climate change is real, but the precise impacts of climate change locally are exceedingly difficult to predict. Untangling the predicted impacts of climate change from the many other direct and indirect pressures on water resources remains challenging, especially given the lack of hydrological data collected in Africa (Oates et al, 2014). Despite much impressive work, GCMs have severe limitations and there is still much improvement needed to link macro and micro scales. Current literature suggests GCMs provide a poor lookout for predicting future water security at micro level in SSA. Grand ensembles based on a range of climate models are likely to expand uncertainty ranges (see Stainforth et al, 2007), and when models are downscaled resolution remains coarse and levels of uncertainty are high, particularly for rainfall (Oates et al, 2014). There is little indication that GCMs could be used within a CBWRM approach, other than to provide an indication of a projected increase or reduction in rainfall at regional or continent scale. Empirical research suggests even if a single climate model and scenario could be selected with confidence, the timing, intensity and duration of rainfall remains uncertain, which makes analysis of the subsequent impact on surface water and groundwater resources difficult. Consequently, their usefulness for improving adaptation decisions and local water management has been widely questioned (Stainforth et al, 2007).

2.2.6 WRA and the potential role of citizen science

Based on the literature review so far, the author would argue the evidence currently available allows the solution of the water resources problem in FCAS to focus on the requirement for better localised WRAs. All countries need comprehensive, accurate and better-integrated water information for planning, development and management (FAO, 2011). At the very least countries require basic hydrometric monitoring networks to understand how much water is available. Hydrogeologists must process monitoring data for applications, such as understanding the water balance, water quality management and flood and drought forecasting. WRAs have the potential to help rural communities and farmers build resilience if monitoring outcomes are understood and they provide a better lookout for future water scarcity. FAO (2011) highlight hydrometric data should be collected on a countrywide basis using existing monitoring networks. However, building the resilience of rural communities is by no means certain if national networks are non-existent, not sustained or raw data is not validated, analysed and published. A major problem in SSA is that the number of meteorological and hydrological stations has been declining over the past 30 years (GWP, 2008; Washington et al, 2006; Parker et al, 2011). Grey (2012) notes: *“There is a massive information shortfall in many developing countries. Africa has only 10 per cent of the monitoring stations found in Europe.”* FAO (2011) also observe that: *“The most significant gap in data regards the present use of land and water, especially land under irrigation and rain-fed agriculture.”* However, the current literature reaffirms the quality and maintenance of national hydrometeorological monitoring networks in SSA is considered inadequate (GWP, 2008; Conway et al, 2009; Oates et al, 2014). Most fragile states in SSA do not have functioning networks for measuring rainfall, river flows, groundwater levels and water quality as a minimum. They have limited financial, human and technical resources to operate and maintain monitoring networks (GWP, 2008). Furthermore, the importance of monitoring water resources is afforded low priority in national planning strategies, compared to extending water supply coverage (MWR, 2015).

It is helpful at this stage to provide an overview of the process of hydrological monitoring. Chow et al (1988) describe a sequence of logical steps, which are commonly followed for hydrometric monitoring. In summary, it starts with the installation of monitoring equipment, records data automatically by reacting to the physical phenomenon being monitored and requires a process of data processing and storage. The monitoring model of Kongo et al (2010) is shown in Figure 2-7. It is a reworking of the process identified by Chow et al (1988) but incorporates an additional participatory component that ensures data is shared and fed-back to local communities and stakeholders.

Figure 2-7: Establishment of a monitoring network at catchment scale through a participatory process (Source: Kongo et al, 2010)



Kongo et al (2010) correctly identify that without this component the establishment of monitoring networks is biased to understanding the hydrological process of the catchment but void of the participatory component whereby the local community understand the data and respond to the key hydrological parameters being monitored. For application in SSA the process outlined by Kongo et al (2010) is an improvement compared to the earlier model, however, its application in FCAS is still questionable. Major institutional advancements in the ability of government institutions to collect, validate, analyse and publish hydrological data may be required. Another reason is that community participation is not central to the process; rather it only becomes effective at the end of the monitoring cycle. The discussion in Section 2.1 suggests institutional capacity in fragile states will be extremely low and community participation in hydrological monitoring cannot be solely reliant on the effectiveness of government institutions.

Although hydrological data collection can involve sophisticated technology, the advancement of robust, cost-effective and accurate equipment provides unprecedented opportunities for data collection in a citizen science[10] context (Buytaert et al, 2014). This data can help to create new hydrological knowledge and improve decision-making, especially in remote, data scarce, regions. However, the nature and quality of data collected in citizen science experiments is potentially very different from those of formal government monitoring networks – where they exist. This poses challenges in terms of data collection and processing (Buytaert et al, 2014). The potential of citizen science is only just receiving increased scientific attention and in order to leverage community participation for sound WRM, Buytaert et al (2014) identify four potential challenges to overcome: First, scientists and government officials may be sceptical of households and communities collecting data, if they deem data collection methods derisory. The second concern relates to technology choices and ensuring technology is affordable, reliable, user friendly and acceptable. Newman et al (2010) highlight that appropriate technology choices, if used effectively, could help to empower communities to deliver for themselves some solutions to particular problems they face. The third factor concerns the resources required to train and educate interested communities and the level of continued external support required to sustain community-based approaches indefinitely (Gura, 2013). The fourth factor concerns ways in which data will be collected, interpreted and understood by communities themselves. A particular concern is whether data is of sufficient quality and reliability to allow it to be shared with a wider audience outside of the immediate community. The primary

[10] Citizen science refers to scientific research and hydrometric data collection conducted, in whole or in part, by nonprofessional scientists.

focus of citizen science approaches thus far has been in developed nations, which already have robust networks and institutions for monitoring water resources. The approach taken in this study is to assess the potential effectiveness of citizen science in fragile states, because national monitoring networks typically do not exist. Full details of the research methods applied in this study are described in Chapter Four.

In the past, one way in which scholars have tried to address the problem of limited hydrological data is to promote water stress indicators as a method for assessing future water scarcity problems. However, the literature suggests these have severe limitations. Savenije (2000) observes the water stress indicators used to indicate the level of water shortage in different parts of the world are seriously flawed. He highlights two important factors. The first is that they ignore the important contribution of green water. The second is the fact that they are based on averages and hide the temporal and spatial variability that may occur. For example, the Falkenmark Water Stress Indicator (see Falkenmark, 1989) is one popular approach for assessing water scarcity. Falkenmark's indicator looks at a nation's annual renewable fresh water availability per person and puts forward three classifications of water stress: *"a country faces water stress when water resources fall below 1,667 cubic metres per capita; water scarcity threatening economic development and human health and well-being occurs when there is less than 1,000 cubic metres per capita, and absolute water scarcity when water resources are less than 500 cubic metres per capita."* Despite much inspiring work this pointer has some shortcomings. Chenoweth (2008) writes, *"Falkenmark's indicator does not account for transboundary water usage between riparian countries, nor does it consider water availability and access for multiple in-stream water users."* Ohlsson (1999) states that Falkenmark's indicator does not consider a nation's ability and resilience to adapt to reduced per capita water availability; for example, through the use of grain imports as virtual water. Thus, in order to improve understanding of national and local-level hydrology, all countries should undertake continuous WRAs. This requires pragmatic WRM approaches that can be applied in difficult working environments.

2.3 Great expectations: IWRM as the key to sound WRM globally

2.3.1 Introducing IWRM

The Post-2015 Development Agenda sets the ambitious target of achieving IWRM in all developing countries (including fragile states) by 2030. However, the achievement of sound WRM is an objective fraught with difficult problems (Muller, 2015). Similar ambitious targets have been set in the past with previous calls for all countries to develop IWRM and "water efficiency" plans by 2005 (Jønch-Clausen, 2004). These previous goals were not realised and people living in developing countries and fragile states are entitled to know how this aspiring new target will be achieved. From this emotive perspective any water resources policy and strategy must consider specific problems to address.

The central idea of integrated water and land management is nearly a century old (see White, 1998), although the more recent origins of IWRM can be traced back to a defining conference in Dublin in 1992 (ICWE, 1992) and its inclusion in Agenda 21[11] (UNCED, 1992). Prior to the 1990s it was widely acknowledged there was a lack of progress in improving global coordination of water management within the water sector (Conca, 2005). Recurrent emergencies related to drought, flood and deteriorating water quality encouraged decision-makers to seek more comprehensive solutions that included transboundary water management. Consequently over the past three decades, the debate concerning the most suitable approach for managing water resources has focused on the adoption of the IWRM paradigm (see Allan, 2003; Jeffrey and Gearey, 2006; Mehta and Movik, 2014). As a direct result, the aperture of water governance has widened way beyond local and regional schemes to include a growing number of organisations with a global focus (Varady et al, 2008). Prominent examples of this transition include the formation of organisations such as the Global Water Partnership (GWP) and International Water

[11] Agenda 21 is a non-binding, voluntarily implemented action plan of the United Nations with regard to sustainable development. It is a product of the Earth Summit (UN Conference on Environment and Development) held in Rio de Janeiro, Brazil, in 1992.

Management Institute (IWMI). So to, the emergence of international water conferences, such as the World Water Forums held every three years and the Stockholm World Water Week held annually since 1991.

So far the uptake and current geographical distribution of IWRM is large (Sokile et al, 2005; Kemper et al, 2006; Stålnacke et al, 2008). It is estimated that 80% of countries around the world have IWRM principles in their water laws and policies and two-thirds have IWRM plans (Cherlet, 2012). Some important underlying IWRM principles that host countries should adopt include: establishing overarching water policies, strategies and laws, adopting river basins as the unit of water management, providing reliable and sustained financing, recognising the role of women in water management and ensuring participatory decision-making (Shah and van Koppen, 2006). Proponents of IWRM maintain the concept is constructive because it directly challenges the fragmented nature of WRM. It also places emphasis on a more common sense, integrated and adaptive approach with more coordinated decisions, horizontally and vertically, across sectors and scales (see Medema et al, 2008; Sadoff and Muller, 2009).

2.3.2 Understanding IWRM

A prerequisite for implementing IWRM is that practitioners can articulate what the concept is and how progress can happen. A number of groups have attempted to define IWRM:

"*IWRM is a process, which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."* (GWP-TAC, 2004)

"*IWRM includes gathering information, analysis of physical and socioeconomic processes, weighing of interests and decision-making related to availability, development and use of water resources."* (van Hofwegen and Jaspers, 1999)

“*IWRM is a framework for planning, organising and controlling water supply systems to balance all relevant views and goals of stakeholders, which includes two dimensions of interdependence, namely social interdependence and ecological interdependence.”* (Grigg, 1999)

One of the difficulties that hinder any attempt to interpret IWRM is that the concept is couched in somewhat opaque terms. Thus many activities get passed-off in the name of “IWRM” and it cannot be claimed that government technicians in fragile states can easily interpret and implement what proponents have in mind (Muller, 2008). Contemporary literature suggests IWRM is a complex and ambitious approach and inevitably trade-offs are required between policy requirements and rigour in solving real water management issues. Matching programmes to the skills and competencies available within government is an essential component of good development work. For IWRM to work effectively, the enabling environment must be established (GWP-TAC, 2000). This relies on the existence of popular awareness and political will to act. There must be the right attitude: government as an enabler rather than a top-down manager. Multiple agencies and organisations at all levels and across all sectors should be participating and talking to each other. Specialists in the technical wings of government must possess the practical tools to implement IWRM and be capable of applying them (GWP-TAC, 2000).

Unsurprisingly host countries vary enormously in their ability to implement IWRM. They vary in terms of climate and context. They vary in terms of institutional capability and whether principles such as decentralisation and subsidiarity will be encouraged. They vary in terms of accountability and governance. Thus differences between developed countries and fragile states are pronounced. A set of indicators, identified by Andrews (2013) reflects what portrays an effective government: “*It is small and limited in engagement, formalised in mission and process and drawing limited revenues primarily from domestic sources. High quality personnel devise and implement needed programmes and deliver efficient and effective services via participatory processes and through formalised, disciplined, efficient and targeted financial* *management. Responsiveness to the citizenry's changing needs is high, effected through transparent, decentralised and politically neutral structures; consistently, even during political instability without impeding, (indeed supporting), the private sector."* Biswas (2008) in his critique of IWRM asks: "*Can any general water management paradigm be equally valid for monsoon and non-monsoon countries, deserts and very wet regions, and countries in tropical, sub-tropical and temperate regions, with very different climates, institutional, legal and environmental regimes?"* He concludes the answer is most probably an emphatic *"no."*

As it currently stands, it remains uncertain exactly what aspects of IWRM should be "integrated" and case studies of successful implementation are often lacking (Castelletti and Soncini-Sessa, 2006). South Africa and Burkina Faso are often cited as examples of successful IWRM implementation but closer inspection reveals some major issues exist, such as a lack of funding, difficulties in addressing local problems and ineffective institutions for catchment management (Petit and Baron, 2009). It could be argued that many countries claim to be implementing IWRM but it is less clear how successful implementation can be demonstrated. It is also not well documented how IWRM policies are adapted in FCAS and, if there is limited knowledge or understanding of the concept, exactly who is altering or adapting the IWRM process?

2.3.3 Politicisation of IWRM

Numerous international organisations and donors actively promote IWRM and offer incentives for host countries that are prepared to adopt the concept and its principles. A consequence of this approach is that IWRM has been politicised before it has been analysed. Other scholars (see Dixit et al, 2002 and Allan, 2003) highlight that IWRM is essentially a political process in terms of getting WRM policy in place in Africa. Allan (2003) argues that policy-making dialogue is partial in that it is often made by coalitions who can deliver the most persuasive arguments. In reality elite groups at national level determine policy outcomes without adequate engagement with rural farming communities, or applying scientific rigour. A major concern in FCAS is what will happen to marginalised groups that are facing resource scarcity while at the same time having a scarcity of adaptive capacity (Turton, 1999).

As mentioned in Chapter One, the stewardship of water resources in fragile states is often concerned with transitions, the change from one (inferior) situation where virtually no water management is taking place, to a much better one. Water resources policy needs to address this interim complexity. There is a clear obligation to help fragile states safeguard their water resources in a realistic manner. However, it is vitally important to keep up intellectual curiosity and scepticism, and asking how the IWRM concept can be applied in fragile states is one example. Scholars have long warned of the dangers of falling into the *panacea trap* (Ostrom, 2007). In a recent revealing study, the IWMI criticised the IWRM concept for becoming a dogma, an end in itself (see Giordano and Shah, 2013). They highlight that future donor funding is often contingent on countries adopting and complying with IWRM principles. The implied problem being that the concept dominates and inadvertently diverts attention from other pragmatic approaches.

2.3.4 IWRM: Focusing on solutions not problems

Section 2.1 outlined the unique challenges fragile states face. Government agencies responsible for data collection often struggle with unrealistic budgets and inadequate resources (Evans, 1997). Evans notes: *“in many developing countries data collection has almost been abandoned.”* Others highlight that technical capacities to implement IWRM in fragile states are still weak, and the necessary hydrological monitoring networks to collect information are either missing or limited in size (German Federal Ministry for Economic Cooperation and Development, 2006). Andrews (2013) argues that when government institutions are weak they should focus on solving real problems rather than implementing perceived best practice solutions. Reason suggests that: “issues” have to be politically and socially constructed to gain attention as “problems.” This approach encourages institutions to deconstruct problems, identify root causes and reflect on contextual challenges (Andrews, 2013). The rationale is that agents typically focus on IWRM as “the out-and-out solution” rather than beginning by understanding the immediate problems that should be addressed. The author gives credence to this issue, based on practical experiences in Sierra Leone during a meeting with GWP in 2011. For instance, a government technician may simply say the major problem faced is a lack of money to implement IWRM, but when asked repeatedly why this matters the following scenario could emerge:

- The problem is a lack of money.
- *Why does this matter?* Because we do not have enough hydrometric equipment.
- *Why does this matter?* Because we cannot assess water resource availability.
- *Why does this matter?* Because water resources cannot be managed if they are not measured (monitored).
- *Why does it matter?* Because water resource usage goes unregulated.
- *Why does it matter?* Because contamination or over-abstraction of water resources is leading to tension between communities and major water abstractors.

More detailed specification of the problem could potentially lead to promoting the re-establishment of hydrometric monitoring at local level. This in turn means a problem that matters to multiple stakeholders is being addressed. Many theorists (such as Andrew, 2013; Snow and Benford, 1992) argue such a process is a vital part of institutional reform. This iterative approach encourages people to use evidence to make decisions rather than to make snap judgements.

2.3.5 Implementing IWRM

Significant challenges exist for realising IWRM in African contexts (see Mehta and Movik, 2014), and evidence of successful implementation is limited due to the requirements for extensive coordination and integration, as well as limited institutional capacity. These factors place severe operational limits on IWRM.

The author agrees with the observation by Kemper et al, (2006) that the IWRM concept has been widely promoted by international donors but with little guidance on how it may actually be applied. Jeffrey and Gearey (2006) have questioned whether there is any real evidence that IWRM has actually been applied in practice. While Butterworth et al (2010) state that IWRM has often been interpreted and implemented in a way that is only really suited to countries with the most developed water infrastructures and management capacities. Biswas (2004 and 2008) states that IWRM has become so broad and all encompassing as to make discussion worthless. He argues if the IWRM concept is to be fully adopted, at least 41 separate issues need to be integrated and monitored. He concludes that this simply cannot be achieved – let alone sustained.

Other common IWRM issues host countries should address include: examining the entire water cycle system from the outset by taking multiple water management problems into account; incorporating the views of multiple stakeholders at various scales to bring people together (Viessman, 1998); and adopting a broad geographic approach by working at river basin scale. However, these “hydrologically” inspired ideas have been criticised because the social and economic aspects of WRM are not sufficiently addressed (Allan, 2003; Giordano and Shah, 2013).

This study argues that IWRM is not bad, but no WRM is bad, and IWRM is extremely difficult to implement so can lead to stagnation. A fundamental requirement, therefore, is to unpack the IWRM concept otherwise governments are faced with unrealistic expectations (Biswas, 2008). A contentious issue relevant to this study concerns the adoption of river basins as the sole unit of water management (GWP-TAC, 2000). The European Commission (1998) explains the rationale: *“The river basin is seen as a means for developing an integrated approach. Its closed geographic boundary system permits various sectors and users in a basin to work together: agriculture, flood control, industry, settlements and communities.”* Thus, advocates maintain a river basin authority should bring together different functions of the administrative departments that usually have responsibility for these different sectors. The adoption of Integrated River Basin Management is often seen as a dominant regulatory approach culminating in an apex regulatory authority. However, river basins vary in size and complexity from micro-catchments up to major river basins such as the Niger River Basin. The alternative is a more decentralised decision-making approach encouraging user-to-user interaction (Lankford and Hepworth, 2010). This can be achieved by subdividing river basins into smaller management units, termed domains or “holons” (Institution of Civil Engineers et al, 2011). In some circumstances subdividing river basins using the *Strahler* or *Horton–Strahler* methods may be impractical due to the sheer density of catchments and the number of resultant sub-management committees required. The topological structure of river networks can be examined from topographic maps, but such an approach does not necessarily provide the level of detail required for river basin planning. This is demonstrated in Table 2-2. Within the context of the new Sierra Leonean Water Resources Act (forthcoming) the country is divided into 12 river basins and provision is made in the Act for subdividing river basins into smaller sub-catchments. However, the exact method for achieving this remains unclear as river basins are subdivided alongside current institutional arrangements.

The literature suggests there is a clear distinction between westernised engineering approaches that aim to manage surface water at the river basin scale and a service delivery approach that uses administrative boundaries for natural resources management. Moreover, the SSA context differs significantly to the European or North American contexts, because a much smaller proportion of landmass and catchment area is represented by surface water. McMahon et al (1992) point out that Africa has the lowest rainfall runoff of any continent in the world: 10%, as opposed to 40% for North America and 50% for Europe. A common issue that emerges from this literature review is that river basins are not necessarily the only unit of water management and may inadvertently inhibit community participation because they vary in terms of scale and complexity. Lankford (Institution of Civil Engineers et al, 2011) writes:

"Water issues – especially in rural locations – need to be resolved locally, involving community leaders and community representatives."

Table 2-2: Current institutional arrangements for water supply and WRM in Sierra Leone

Water Supply Service Delivery	Water Resources Management
International	Transboundary
National or Provincial	River Basins
Local Councils – divided between city and district councils	Catchments (Not geographically defined)
Chiefdom – governed by Paramount Chiefs	? (Not defined)
Ward	? (Not defined)
Village	? (Not defined)

Furthermore, in dryland areas of SSA that experience low rainfall, communities are often dependent on groundwater resources and hydrological boundaries that are not easily identifiable. Thus some arid regions experience problems from beyond the river basin or watershed (Allan, 2003). Niger, for example, has more than 17,000 villages, many of which are situated in arid environments, often without surface watercourses (Skinner, 2009). The challenge of implementing IWRM in such a resource-poor nation may be overwhelming, unless new flexible options for WRM can be found. Menkhaus (2014) observes that in fragile states institutional building at national level can be difficult to achieve, particularly those derived from western models. He adds that the most successful examples have been through hybrid government partnerships at the local level, where demand is greatest. However, national elites often contest the authority of local authority coalitions.

2.3.6 AM: addressing the gap between expectation and reality

As a result of the challenges described above, AM has been promoted as an alternative approach to managing water and land resources. In its simplest form AM is a conceptual approach for the management of natural resources and organisational learning. The concept emerged from the International Institute for Applied Systems Analysis in Vienna and is based on the common sense understanding that foresight for future ecosystem changes is extremely limited (Holling, 1978; Medema et al, 2008).

The concept of AM has been discussed widely in ecosystem management and is based on the principle that water management practices must be flexible and dynamic with the ability to evolve and improve (see Holling, 1978; Walters, 1986). For a system to be able to adapt or respond to future uncertain change, two important components are required. First, new information, most likely generated by hydrological and environmental monitoring, must be available to the system and the system must be able to process this information. The second factor is that the system must have the ability to change, at multiple levels, based on information received. Thus at its core, AM includes an assessment and learning cycle of action, monitoring and adaptation (Pahl-Wostl et al, 2007).

Adaptive capacity refers to the ability to design and implement effective adaptation strategies or to react to evolving stresses and hazards (Brooks and Adger, 2005). It requires the ability to learn from previous experiences and to apply the lessons learnt. In other words, adaptation will only occur in a system that is able to adjust its own characteristics and behaviour. A view held by some scholars is that IWRM is a goal to be achieved through a process of AM. For example, Pahl-Wostl (2002) states: *"More attention has to be devoted to understanding and managing the transition from current management regimes to more adaptive regimes that take into account environmental, technological,* *economic, institutional and cultural characteristics of river basins. This implies a paradigm shift in water management from a prediction and control to a management as learning approach."* Advocates describe this as: learning to manage by managing to learn (Pahl-Wostl et al, 2007).

At the heart of the AM process is the need to experiment with and learn from complex systems. For AM to be effective, it requires strong integration between environmental monitoring, interpretation of results and the corresponding messages to higher-level policy makers and authorities. The nature of AM required will, therefore, depend on the outcomes of monitoring. The reader should keep two important considerations in mind. The first is that many development programmes are not necessarily appropriately designed to solve complex problems (Barder, 2014). This is evidenced by the ubiquitous presence of rigid log-frames[12] with numerous quantitative targets. The second is that an incremental approach is necessary for AM to be applied effectively. Jeffrey and Gearey (2006) point out that for AM to be applied successfully other clarifications are also required, such as: How should IWRM be applied? What aspects should be integrated? How should this be done? Some of these issues may remain unresolved in developed countries, and more so in fragile states where institutional roles and responsibilities remain unclear.

The challenge for fragile states is that they lack ability to perform essential functions and have limited ability to respond to shocks (Corendea et al, 2012). Thus adaptation is most urgently needed where it is most difficult to implement (Houghton, 2012). This is largely due to corruption, fragmented international aid projects and a lack of political will. In situations where ruling elites in fragile states use social exclusion as a political tool, international development projects should also focus on bottom-up approaches (Hamza and Corendea, 2012). Adaptation strategies need to be approached in a comprehensive way that maximises the capacity of local communities (Corendea et al, 2012). This

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[12] A log-frame is a tool for improving the planning, implementation, management, monitoring and evaluation of projects. It is a tool for structuring the main elements of a project and highlighting the logical linkages between them.

highlights the need for in-situ adaptation measures with communities working alongside responsible government authorities who provide effective external support. Smith and Vivekananda (2007) note that the appropriate level for adaptation in fragile states is at the local level. This is because communities suffer the vagaries of pre-existing under-development and increased climatic variability.

Medema et al (2008) offer a helpful comparison between IWRM and AM approaches. They suggest the former is primarily concerned with transforming or reforming water management arrangements. In contrast, AM is predominantly focused on reforming responsible authorities and encouraging a learning process to deal with complexity and uncertainty. Both approaches are concerned with aspects of institutional reform in the hope they will yield more functional governments in the process. However, there may be risks if IWRM or AM is imposed from outside to make governments look better, as opposed to being realistic solutions to make governments perform better. Andrews (2013) observes that many governments remain dysfunctional despite lengthy reform processes. He posits that lessons from institutional reform experiences suggest that reform limits can be overcome by focusing more on problem solving through an incremental process rather than imposing final solutions (Andrews, 2013). Giordano and Shah (2013) call for more pragmatic politics and solutions to be pursued and draw attention to the work of Ostrom, Stern and Dietz (2003) that highlighted: 1) there is no one best system for governing water resources; and 2) many more viable options exist for WRM that fall outside common policy literature. Current literature emphasises the importance of working at local level, alongside community-based institutions, and the requirement to find practical solutions, as government capacity grows.

2.4 Characteristics of community management in rural water supply

A significant proportion of rural water supplies in SSA are delivered by international and national organisations (NGOs) working alongside government. The responsibility of communities to manage these rural water supplies forms an essential component of much WASH sector policy and strategy (WaterAid, 2011). This approach is practiced because central and local government institutions struggle to deliver services directly themselves. Widespread community participation is also viewed as a vital component to strengthen local governance. To quote OECD (2012): *“these local institutions may provide valuable routes to empower poor people and can act as building blocks to gradual engagement with the state as its capacity grows.”*

Currently perceptions on community management of rural water supplies vary considerably and are shaped by the issue of sustainability of handpumps. Some organisations actively promote community management in its current form (see Moriarty et al, 2013); whereas others warn it has become a triumph of hope over realism (WaterAid, 2011). In some circumstances there is also talk of building professional water institutions so that communities should progressively be seen as valued customers rather than operators and managers of point water sources (World Bank, 2012). However, there are thousands of communities who will be responsible for managing their own point water sources for the foreseeable future (Carter, 2015). The problem of community management discussed in this study hinges on three main issues: first, the fact that community management structures in the WASH sector have focused entirely on infrastructure (hardware) and have neglected consideration for water resources (Day, 2009); second, the homogenisation of communities, rather than understanding their internal attributes; and, lastly, the propensity to give communities complete responsibility, rather than recognising they have a role to play alongside government institutions.

So what does conventional community management look like? Two points are obvious: it focuses solely on physical infrastructure (hardware) and inadvertently places all post-construction management responsibility on communities. To take stock, it is helpful to unpack the typical activities communities may perform: contributing labour and locally available materials during construction; electing voluntary management committees; responsibility for all minor and major operation and maintenance repairs; maintaining records of financial contributions; establishing rules for the management and protection of water points; and collecting tariffs to meet all post-construction finance, as well as keeping records of individual and household contributions (Wood, 1994; World Bank, 2012). From a glance at the list of duties, it is possible to spot a major difference between water supply and WRM approaches. In rural locations, water supply operation and management has been skewed towards communities. However, at the same time government assumes complete responsibility for monitoring and managing water resources. The result is confusion and non-sustainable service delivery. So, improved distribution of roles and responsibilities between communities and government is crucial, along with meaningful external support (RWSN, 2010, WaterAid, 2011).

The ability of households and communities to manage their rural water supplies successfully is highly context specific. Some communities succeed; others struggle and fail (Schouten and Moriarty, 2004). A common misconception is that rural communities can manage modern technology after a short period of training without continued external support (WaterAid, 2011). The community management model continues to be driven by international donors and NGOs (Schouten and Moriarty, 2004) and it is still seen as the most viable approach for scaling up water supply in rural areas across SSA. However, practitioners stress the importance of providing continued support to communities (Harvey and Reed, 2004). NGOs also carry a message of responsibility to both communities and government. Although NGO's do not typically carry out large-scale service delivery the author argues there is a wider requirement to: a) try to ensure the services delivered directly and indirectly to rural communities function year round; and b) to support state socio-economic capacity building through innovative work (WaterAid, 2011).

2.4.1 WSPs

The dominant water narrative of the WASH sector over the past three decades has been to supply small quantities of potable water to rural communities. However, in more recent years it has also been the fashion to talk about WSPs, because they are seen as a practical approach for improving water quality.

Since publication of the Third Edition of the World Health Organisation (WHO) 2003 Drinking Water Quality guidelines, the global adoption of WSPs has been gathering momentum. The former president of the International Water Association, Michael Rouse, posits WSPs are: *“the most significant water-related public health development since the introduction of chlorine”* (WHO, 2004). In the words of its promoters, they are a preventative “catchment to consumer” risk management approach for the provision of safe water (Summerill et al, 2010). WSPs involve the assessment, control and management of all risks to drinking water quality; they encompass all aspects of management, both routine and incident-related, to ensure delivery of safe water to consumers (Davison et al, 2003; Carter, 2011b).

According to WHO, the approach focuses attention on threats to water quality because of the risks of ingested water quality to health. While the concept has been popular for some years in high-and middle-income countries, WSPs *per se* are still rare in SSA (Summerill et al, 2010). A common criticism is the model retains too narrow a focus because people need numerous beneficial aspects from their water supply in addition to health (Carter, 2011b). This is not an argument about trying to improve water quality in rural water supply programmes, but it highlights the requirement to draw attention to other equally important beneficial aspects, such as access, quantity and reliability. Clearly if a water source is too distant, low yielding or non-functioning it will deliver few, if any, health benefits. Cairncross (1990) points out that looking specifically at the alternatives of improving water quality or improving people’s access to sufficient quantities of water as a means to reducing the transmission of diarrhoeal diseases, there is a good case to be made for claiming that too much attention is given to water quality. Indeed it is difficult to find unambiguous epidemiological evidence distinguishing between the effects of improving water quality and providing improved access to water. While a number of studies have demonstrated the importance of providing more water to poor households, the evidence with respect to water quality is more ambiguous (Esrey and Habicht, 1986). People invariably want water security for a number of reasons other than water quality. Indeed, it is ironic that attention is focused on water quality when the functionality and sustainability rates of water sources in SSA are so poor. In the dry season, surface water and groundwater sources can dry up leaving people to access more distant and unprotected water sources (RWSN, 2010).

To be successful, WSPs require commitment and buy-in from local communities. Indeed, they aim to empower individuals to take responsibility for improvements within the scope of their role and to understand how they can contribute to safer drinking water within the overall drinking water management structure. This replaces the traditional approach of end product testing. WSPs are seen as promoting a practical, structured and achievable approach for managing water but the author argues that ultimately their focus needs to be broader. The current approach erroneously considers water quality *per se* to be people's greatest priority and neglects other important benefits. A common view held (see Carter, 2011b) is that *WSPs* should evolve to become *water security plans* so that the multiple threats to community water supplies are identified and mitigated. This approach may better reflect what end users want, and would provide a more realistic approach for addressing multiple risks that are also of high importance to rural communities and households.

At this stage it is helpful to pull together the evidence presented in the literature review so far. There seems to be reasonable evidence that fragile states present unique challenges for the achievement of sound WRM. Water resources matter in fragile states, because of growing pressures and demands, but skilled and well-resourced government institutions are not abundant. Democratic political institutions only function well if ordinary citizens are informed so they can hold politicians to account but many issues may prevent this from happening in fragile states (Collier, 2010). In the short term the sustainability of rural water supplies is a major problem. In the medium term governments are expected to implement all-inclusive IWRM approaches. The narrative of panaceas can spread rapidly to all countries, but they can also stray a long way from reality. Panaceas can inadvertently undermine institutions and they can be slow to implement. In reality, many of the rules that govern day-to-day water usage in fragile states are informal, so the analysis in this study can extend beyond government institutions and look at the role of community-based institutions. A key requirement is to understand the potential role of communities in monitoring and managing water resources.

2.5 The role of community-based institutions in WRA and WRM

Current literature shows all countries must have robust institutions available if sound WRM is to be achieved at transboundary, national and regional levels (see Ostrom, 1990, Kurian, 2007). Yet, effective and adequately resourced institutions for WRM rarely exist in fragile states. In such circumstances, community-based institutions can potentially play an important role in managing CPRs. In many community irrigation systems, farmers have developed a wide diversity of rules to specify rights and responsibilities amongst themselves. Farmers enforce these rules themselves without involving external organisations (Tang, 1992). Ostrom's inspiring work, notably in "The challenge of common-pool resources" (Ostrom, 2008) also draws attention to the fact that when regulation for the management of natural resources comes from a distant authority, and is uniform for a very large region, it is not likely to succeed. Local people are much more likely to respect rules when it is they who set them (Ostrom, 1990). This argument applies largely to natural resource units that are sufficiently small in size, where spatial variability is low, so that communities can identify their own boundary limits for resource management. This information challenges the IWRM concept that asserts that the river basin is inevitably the most appropriate unit of management because the management unit is of significantly larger scale than that of the community. In such circumstances, national or state policies and laws should be adjusted to accommodate community-based institutions. Clearly communities should not be expected to monitor and manage their water resources in isolation and expectations placed on communities should be realistic. Tod (2006) points out this means community-based institutions should be placed within a comprehensive policy framework for managing water resources in rural areas. Ostrom (2008), writing in "The challenge of common-pool resources," observes that government and citizens must craft out institutions at multiple levels built on accurate data, which is gathered at appropriate scales. This knowledge is of direct significance to this study and implies governments should support community-based institutions to play an effective role in WRA and WRM, as their own institutional capability is strengthened.

2.5.1 Disadvantaged communities in fragile states

In FCAS there are many reasons why communities may choose to work for the common good even in the absence of effective external support from government. Four in particular stand out: The first is that many governments have been visibly unsuccessful in their efforts to effectively monitor and manage natural resources over a large geographical area. This is despite the fact that many countries in SSA nationalised their water and land resources in the 1950s and 1960s (Woodhouse and Chhotray, 2005). Empirical research shows that management arrangements for CPRs have fluctuated from government property regimes to a system of open access. This has led communities to establish their own management arrangements (see Arnold, 1998; Arnold and Stewart, 1991). The second is that appropriators who have lived and appropriated from a resource system over a long period of time have often developed informal techniques for understanding how the resource system works, since the very success of their appropriation efforts depends on such methods. They also know others living in the area well and know what norms of behaviours are considered acceptable (Ostrom, 1999). The third factor relates to the ineffectiveness of government. Central and local government institutions often lack skills, knowledge and motivation, and receive low salaries. Consequently, they are often perceived as being weak and ineffective. Policies are handed down to local government from central authorities and the technicians of central and local governments see their own motivation constrained by the systems within which they work (Hunter et al, 2010). The fourth consideration relates to a feeling of limited citizenship. The Chronic Poverty Report (2008–2009) lists five main poverty traps that hinder relationships between the state and their citizens. They include issues such as spatial disadvantage, poor work opportunities, limited citizenship, insecurity, poor health and social discrimination. Often improving social inclusion is dependent upon communities having legal rights, political representation, economic and natural resources, available and functioning public services, and attitudes and perceptions that reflect local opinions (Chronic Poverty Research Centre, 2008). Without this, dissociation may exist between government and community interests (Boelens, 2008). This knowledge emphasises that communities may already have their own informal arrangements for monitoring and managing local water resources that can be used as a basis to develop more robust WRAs. Indeed, there are many examples of effective local management from across the world, some of which have been used for millennia by populations that have exploited rainfall, annual floods, groundwater and surface water to satisfy their needs (Institution of Civil Engineers et al, 2011). Practical examples of local user involvement in WRM can be seen in Spain, Peru, the Middle East, India and the Philippines (Trawick, 2010[13]). The most notable of these includes the Huerta of Valencia, and the water market in Alicante, Spain, where farmers have continued to meet with other community members for the purpose of specifying and revising the rules for water management and distribution – a process that has lasted for close to 1,000 years (Institution of Civil Engineers et al, 2011). This knowledge is of significance in contexts where governments may be viewed as absent in monitoring and managing water resources.

However, the ability of communities to monitor and manage natural resources has been rigorously questioned in the past (see Hardin, 1968). Previously, many scholars believed that natural resources (such as fertile land, forestry and water resources) should be vested in state control to avoid misuse and over-exploitation. More recent empirical research by other contemporary social scientists has disputed these earlier arguments initiated by Hardin (1968) (see Ostrom, 1990; Dolsak and Ostrom, 2003; and Trawick, 2003). These studies have all demonstrated the role community-based institutions can fulfil in managing CPRs if certain operating principles are adhered to.

[13] Professor Paul Trawick speaking at the ICE in 2010.

2.5.2 Background to collective action

The willingness and ability of people to participate in collective action and overcome social dilemmas is multifaceted. It is based on a complex series of variables. It describes the situation whereby *"a group of principals who are in an interdependent situation can organise and govern themselves to obtain continuing joint benefits when all face temptations to 'free ride' or act irresponsibly"* (Ostrom, 1998). This approach is often seen as a prerequisite for social change and an enabling tool for community-based management of natural resources (Hogg and Abrams, 1988; Tajfel and Turner, 1979). Other academics (see Schofield and Pavelchak, 1989; Wolf et al, 1986) view collective action as a belief that the specific goals of a small collective group can be achieved. Collective action can take many forms. This includes monitoring, establishing rules for resource management, coordinating activities, and sharing information in a transparent manner (Poteete and Ostrom, 2004). Such practices have occurred in many parts of the world for centuries and there are numerous examples of individuals and communities working in a cooperative manner (Institution of Civil Engineers et al, 2011). This serves to provide mutual benefits, to reduce risks and to take active measures to safeguard the natural resources that sustain health, livelihoods and cultural identity.

2.5.3 Collective action problem

The term "collective action problem" describes the situation in which multiple individuals would all benefit from a certain action, but has an associated cost which makes it implausible that any individual can or will undertake and solve it alone (Ostrom, 2004). Political scientists, including Ostrom (1998), highlight that *"social dilemmas occur whenever individuals in interdependent situations face choices in which the maximisation of short-term interest yields outcomes leaving all participants worse off than feasible alternatives."* Poteete and Ostrom (2004) note that complex variables include (amongst other things): group size, heterogeneity of participants, their dependence on the benefits received and the level of information available to participants. Given these multiple variables, it is extremely difficult to predict or develop a coherent explanation of the relationship between social variables and the likelihood for groups in society to take collective action and act for the common good – thereby solving social dilemmas. Consequently, given the variation in CPRs, their patterns of use and the complexity of social dilemmas it is widely acknowledged by scholars that no single institutional design or model can be applied to a multitude of contexts (Dolsak and Ostrom, 2003). Therefore, rather than attempting to construct a complex theoretical framework focusing on how communities take collective action, based on a conception of human behaviour, it is more fruitful to understand why end water users may choose to engage in collective action. This leads us to the principle of reciprocity.

As Kahan (2002) writes, strong reciprocators see themselves, and want to be understood by others, as cooperative and trustworthy, willing to engage in collective action. They do not want to be seen as freeloaders or wealth maximisers. According to Kahan, people are inclined to engage in collective action if they believe others around them are willing to cooperate. Conversely, people will likely free ride if they believe others will free ride. Reciprocity is based on the importance of promoting trust and not on the premise that individuals seek to maximise wealth. Thus individuals who care about maximising wealth are considered poor reciprocators. Kahan (2002) puts forward the argument that a wealth maximiser is less likely to contribute to collective goods and instead will free ride on the contributions made by others. This understanding is important because it implies CBWRM might work well in some places and less so in others.

The alternative proposition, aligned to Hardin’s theory, is that rural communities, living on the periphery of government support, are unlikely to cooperate, even when cooperation would be to everyone’s mutual benefit. This is known as the zero contribution theory (Ostrom, 2000). This rather depressing idea emerged from Mancur Olsen (1965) in his first book *The Logic of Collective Action*. Olsen theorised that individuals can be expected to act collectively in accordance with the interests of the group to which they belong. He maintained that actually too few individuals will contribute to collective action and the wellbeing of the group will suffer (Gintis et al, 2006). He maintained that collective action could only be successful where group numbers were sufficiently small or where there was some form of coercion.

Ostrom (2009a) points out that self-organisation is more likely to occur when the natural resources in question are highly significant to users and when users have a common understanding of the problems they face. Mutual trust amongst end users should also exist, and resource users should have autonomy to make their own rules. Ideally organisers would also have prior organisational experience. Ostrom (1990), and Baland and Plateau (1996) identify a number of resource attributes that lead to self-organisation. This study focuses on four in particular: The first consideration is that resources should not be at a point of deterioration, so that self-organisation can lead to some tangible benefit or impact. People need an incentive to engage in collective action. The second consideration is that end users should have the ability to assess the reliability of the resource, which implies regular or periodic monitoring is required. Next the availability of the resource needs to be relatively predictable, not precisely, but at least by those with some experience. The fourth consideration is that the resource base needs to be relatively small in size and communities must be able to define their own boundaries for resource use. This information relates directly to the ability of communities to map and monitor their local water resources and an investigation enhances our understanding of community attributes. According to Ostrom, if self-organisation exists, coupled with organisational design principles, communities are likely to be able to sustain their own institutional arrangements over a reasonable length of time. Writing in *Governing the Commons: The Evolution of Institutions for Collective Action*, Ostrom (1990) identified a series of design principles deemed necessary for successful collective action. These are summarised below in Table 2-3:

Table 2-3: Operating principles for management of CPRs (Source: Ostrom, 1990)

1. Clearly define boundaries with defined rights for who can withdraw from the resource.
2. Match rules governing use of common-pool resources to local conditions.
3. Ensure that those affected by the rules can participate in modifying them.
4. Make sure local authorities respect the rule-making rights of community members.
5. Undertake monitoring of the resource and people's behaviour.
6. Apply graduated sanctions are applied to rule breakers.
7. Put local conflict resolution mechanisms in place – with rules clearly understood by local people.
8. Build responsibility for governing the resource in nested tiers from the lowest level up to the entire interconnected system.

In the case of CBWRM it is clear that WRM should not be done for its own sake and instead should solve real problems on the ground, linked to people's livelihoods (Jembere, 2009). People need to assess and monitor the resource base, boundaries for resource usage needs to be established, and water allocation should be transparent and equitable. Resource usage should be bounded by clear rules and laws, termed operating principles, and free riders should be excluded or face graduated sanctions. This is encouraging but we should also be aware of the limitations of collective action.

According to Varughese and Ostrom (2001), firm self-governing enterprises may be undermined when the interests of appropriators differ. In their article "The Contested Role of Heterogeneity in Collective Action: Some Evidence of Community Forestry in Nepal," the authors conclude that differences amongst users do pose challenges for groups of resource users in overcoming the incentives to free ride. They also identify that a key requirement for community groups is to be able to assess the cost–benefit of collective action compared to free riding. In their opinion, self-organisation can be greatly strengthened where actors can engage in face-to-face bargaining over resource allocation, actors have the autonomy to change their rules, and there are substantial net benefits to be obtained in doing so. In the context of catchment management, a fundamental requirement for community-based institutions is to engage with neighbouring management units, facilitated by local authorities or regulating agencies. Self-organised regimes provide the basis for improving or strengthening CBWRM and inevitably provide a basis for learning. Consequently, CBWRM does not need to be restricted to fully functioning self-activated regimes.

Some scholars remain sceptical about the ability of communities to manage CPRs. Mosse (1998) writes *"there is today a pervasive policy consensus in favour of the transfer of resources management from state to community."* Mosse puts forward several propositions regarding the ability of local institutions to take collective action. Mosse argues that ideas of community are sociologically naïve and inaccurate in their assumptions of homogeneity, cooperation and autonomy of the state. He cites variations in collective action for the management of tank irrigation systems in Southern India and makes some revealing observations. The first is that collective action is not always generated through trust generated or reciprocity. In his experience it was founded upon relations of caste power, graded authority and the redistribution of resources (through bribes and payoffs). Mosse (1998) maintains that coordination of resource usage and management does not depend on the existence of organisations or associations. He describes a more hierarchal process, which is also an outcome of the caste system. He points out that a traditional management regime does not necessarily imply interest and motivation in collective action, ensuring investment in safeguarding resources. Furthermore, the presence of water user associations does not necessarily lead to the assumption that collective action arises from the association of free and independent appropriateness bound by operating principles and rules for water usage. Mosse's research implies CBWRM may work well in some places and less so in others. This is to be expected, and the same logic can be applied to community management models globally. This study maintains that groups in civil society must be fully involved in WRM in the context of fragile states, but governments and regulating water authorities also carry much responsibility in the form of providing continued support in managing water and land resources at catchment or basin scale. Mosse concedes that his intention is not to challenge management transfer policies that aim to empower communities. He writes, *“It is no more possible to abandon the concept of community than that of development”* (Mosse, 1998). He argues improvements need to be made to engage with the multiple and subtle roles community plays as a cultural construct in mediating resource use. Furthermore, effective engagement by local institutions will only serve to strengthen development projects and appropriate policies.

If community-based institutions are to play a meaningful role in WRAs and WRM the state will need to lay the foundation for local democratisation. According to Kyed and Engberg-Pedersen (2008), support to local institutions should focus on three areas: First, a focus on local governance. Second, strong emphasis on local service delivery and solving real problems related to poverty. Third, it requires active participation from non-state actors and civil society organisations. Berry (2009) state that community-based approaches are an entry point for setting up local governance structures, which can then act as a platform for better service delivery interventions. These actions must be aligned with the state to facilitate handover as institutional capacity strengthens. Lessons from empirical research highlight some key requirements in building local state capacity (Kyed and Engberg-Pedersen, 2008; Berry et al, 2004). These include, but are not limited to: 1) Strong national leadership but with a shift away from state centralisation; 2) Adequate transfer of resources to local government, with reduced financial bottlenecks; 3) Improved local service delivery with a better balance between Capital Expenditure on infrastructure and institutional capacity building; 4) The state must have adequate institutional recurrent budgets so they can meet the costs associated with service delivery; 5) There must be flexible approaches that allow trade-offs between meeting immediate needs and planning for sustainability; and 6) Recognition of non-state actors. Given the ubiquitous challenges, current literature suggests comprehensive local government reform may be difficult in fragile states. However, building the capacity of local government and community-based institutions is a worthy pursuit, and should be aligned to the longer-term objectives of government. This information informs this study because it highlights important requirements that central government in FCAS should be adhering to if support to community-based institutions is to be decentralised.

2.5.4 A way forward: Examination of community-based approaches in fragile states

This section summarises what aspects of the literature inform the study and the research methods selected. The literature review asked the reader to think of different groups of countries: developed economies, economies in transition and developing countries. Within developing countries there are further sub-groups where countries may be categorised as fragile and conflict affected. This study argues theories and evidence are much needed in relation to how water resources can be monitored and managed in such difficult working environments. Some intriguing recent studies (see Giordano and Shah, 2013, Muller, 2015) suggest that new pragmatic and localised approaches that move beyond the dominant IWRM concept are much needed. However, although this analysis is striking, there are as yet too few studies to judge how progress can be made in FCAS.

The first perspective – that of the role of communities in monitoring water resources – is the central theme of this study. There are remote rural communities that remain on the edge of government support. Recognising the ability of communities to engage in WRAs is crucial for the success of CBWRM. Empirical research, discussed in Section 2.2, described the importance of managing water locally, because of the difficulty in assessing the relationship between rainfall, surface runoff and groundwater levels. Section 2.5 illustrated the role that communities can play in managing CPRs, but this research needs to be extended in a FCAS context. If communities can demonstrate an ability to monitor water resources there is a possibility they could play an important role alongside government institutions and strengthen their own resilience to climate extremes. The second perspective considers whether governments in FCAS support groups in society, or whether they resist meaningful decentralisation? The literature shows that institutional reforms can be difficult processes and institutional capacity is often weak, with governments focused on perceived solutions rather than addressing problems incrementally (see Andrews, 2013). Ostensibly, for CBWRM to be most effective there must be willingness from central government to adhere to the principle of subsidiarity, because there must be cooperative outcomes between government and communities. Thus the success of community-based approaches does not depend solely on the ability of community members. Effective external support is also likely required. The final perspective concerns the WASH sector. Section 2.4 described how service delivery in the rural water supply sector remains focused on infrastructure and hardware. The author argued that resource issues should not be overlooked, and if NGOs are engaged in WRM they could potentially assist in building the resilience of communities and strengthening government institutions. A number of studies (such as Trawick 2002 and 2003) have focused specifically on the role of community-based institutions in managing CPRs. However, this approach has not been adequately integrated into rural water supply programmes and government approaches more widely. Thus, there is a lack of an integrated framework for such studies. To move WRA and WRM forward in fragile states a new, more comprehensive approach is required that better understands the potential role communities can play alongside government authorities, influenced by organisations working in the WASH sector. The argument for CBWRM and more consideration of the complexity involved in its adoption is comparable to the current rural water supply approach. In essence, communities work alongside government institutions with assistance from NGOs. This approach is seen as a positive building block until government institutions build levels of capability and professionalism.

Within the WASH sector today, Community Led Total Sanitation (CLTS) is probably the best-known example of collective action behaviour. CLTS is a facilitator-led process, which aims to trouble and empower rural communities to cease open defecation and to build and use household latrines (Kar and Pasteur, 2005). It uses participatory methodologies to develop awareness of the risks of open defecation and facilitate community self-analysis of their health and sanitation status. Although the sustainability of CLTS interventions has been questioned, the concept is widely promoted by the UN as one of the most effective approaches to promoting sanitation and achieving the MDGs for sanitation coverage (Ahmed, 2008). However, the importance of collective action by communities in monitoring water resources has largely been ignored in current theory and practice. Although some recent studies (see GWP and UNICEF 2014) have provided limited insight into the links between WRM and WASH, the impact of these approaches is not yet known because they are not informed by direct empirical research.

2.6 Summary

The first section of the literature review explored some of the challenges encountered when working in fragile states. In doing so it introduced the necessity to work with civil society. The second section presented multiple pressures on water resources and explored the limitations of both GCMs and water scarcity indicators to accurately assess local water scarcity. This section also highlighted the lack of hydrometeorological monitoring in SSA. The necessity for localised hydrometric monitoring was demonstrated by discussing uncertainty associated with rainfall, changes in land use and the resultant impact on groundwater sources. The next section examined current WRM approaches in detail and identified that despite widespread promotion there are very few examples of successful WRM in fragile states. This discussion highlighted the need for more realistic approaches that recognise the multiple transitions governments must undertake to achieve a basic level of WRM. In the fourth section the role of NGOs in delivering rural water supplies in SSA was also demonstrated and the lack of any WRM within WASH programmes was identified as a major problem. The fifth section demonstrated the important role of community-based institutions in weak or fragile states. This section presented the primary proposition that community-based institutions have a vested interest in monitoring and managing water resources in fragile states because by definition government capacity is weak and rural communities remain on the periphery of any government assistance. By drawing together these five sections this literature review illustrated the potential application of CBWRM. The next chapter introduces the research countries and research sites.

3 Background to case study sites

This chapter introduces the research countries and the background information pertinent to each case study. The second section presents the case study sites and describes the similarities and differences between case study areas, which have implications for the generalisability of the research.

3.1 Introduction to research countries

Research was conducted across four case study sites located in SSA. The number of case study sites selected was largely enforced, due to major disruptions that occurred that were beyond the control of the author (see Section 4.5). Each of the case study sites is discussed below.

3.1.1 Sudan

3.1.1.1 Overview

Darfur is the name given to the western region of Sudan, covering an area of 493,180 km^2 (Wikipedia, 2015). Sudan ranks 166 out of 187 countries on the Human Development Index (HDI) although it should be borne in mind that Darfur is by far the poorest region of the country (UNDP, 2015). It is located in the Sahelian region in Western Sudan, between 11^o and 17^o north and is divided into three states, namely North Darfur, South Darfur and West Darfur (see Figure 3-1). The region has experienced drought, famine, violent armed conflict and genocide, which have led to widespread suffering and internal displacement. The source of the conflict dates back to the nineteenth century and the relations between Darfur and the central Sudanese authorities, related to tribal territories, land disputes and systems of administration (Young et al, 2005). Since February 2003, the UN estimate as many as 300,000 people have been killed and around 2,700,000 displaced (UNICEF, 2016). The region has also been subject to highly variable rainfall, recurrent dry spells and droughts – most notably the devastating drought from 1984–85 that was extensively documented in Alex de Waal's important work “Famine that Kills” (de Waal, 1989).

Figure 3-1: Sudan map (Source: FAO AQUASTAT, 2015a)

3.1.1.2 Rainfall

Rainfall across Darfur is characterised as being low and variable, with a short rainy season followed by a protracted dry season. Isohyets vary from 50mm in the far north to 800mm in the wetter south. In and around Al Fasher, seasonal rains are limited to 2–3 months with the rest of the year being dry. Rainfall usually occurs in isolated showers that vary in duration, location and year-to-year. The coefficient of rainfall variation is high (20–30%) and increases in the northern regions of the country (FAO AQUASTAT, 2015b). Figure 2-5 in Chapter Two demonstrated the high inter-annual rainfall variability in Al Fasher, North Darfur and the risk of repeated low annual rainfall events. As a result, many agricultural activities are concentrated in the south of the country and rural communities are reliant on groundwater sources for their domestic water supply during the dry season months.

3.1.1.3 Groundwater

Fractured basement complex rocks that are known to have limited groundwater storage capacity, underlie much of Northern Darfur. The more productive water points lie in the alluvial deposits along the wadis[14]. Groundwater and surface water is more plentiful along the wadi corridors and adjacent land is much sought after by agro-pastoralists and nomadic pastoralists because of its fertility. These alluvial aquifers serve to feed the adjacent basement complex aquifers. This pattern of water availability is important because it explains the difference between water-rich alluvial wadi deposits used for cropping and human settlement and drier rangelands used for migratory pastoralism (Bromwich, 2015).

In Darfur there is a lack of knowledge concerning the water resources of the region. Groundwater data is often absent or spread across multiple government agencies (FAO AQUASTAT, 2015b). Due to decades of under-investment and institutional capacity building there is also a lack of skilled hydrogeologists and hydrologists, and water resources infrastructure often goes unmanaged. As a result, communities have often established their own customary arrangements for managing land and water resources (UNEP, 2014). However these traditional approaches, administered by the Native Administration[15], have been gradually undermined since 2003. Large-scale human displacement and the formation of densely populated IDP camps have also placed major pressures on groundwater resources and forestry.

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[14] A valley, ravine or channel that is dry except in the rainy season.
[15] The Native Administration is a century-old and evolutive system of traditional leaders that underpins the traditional justice system.

3.1.2 Niger

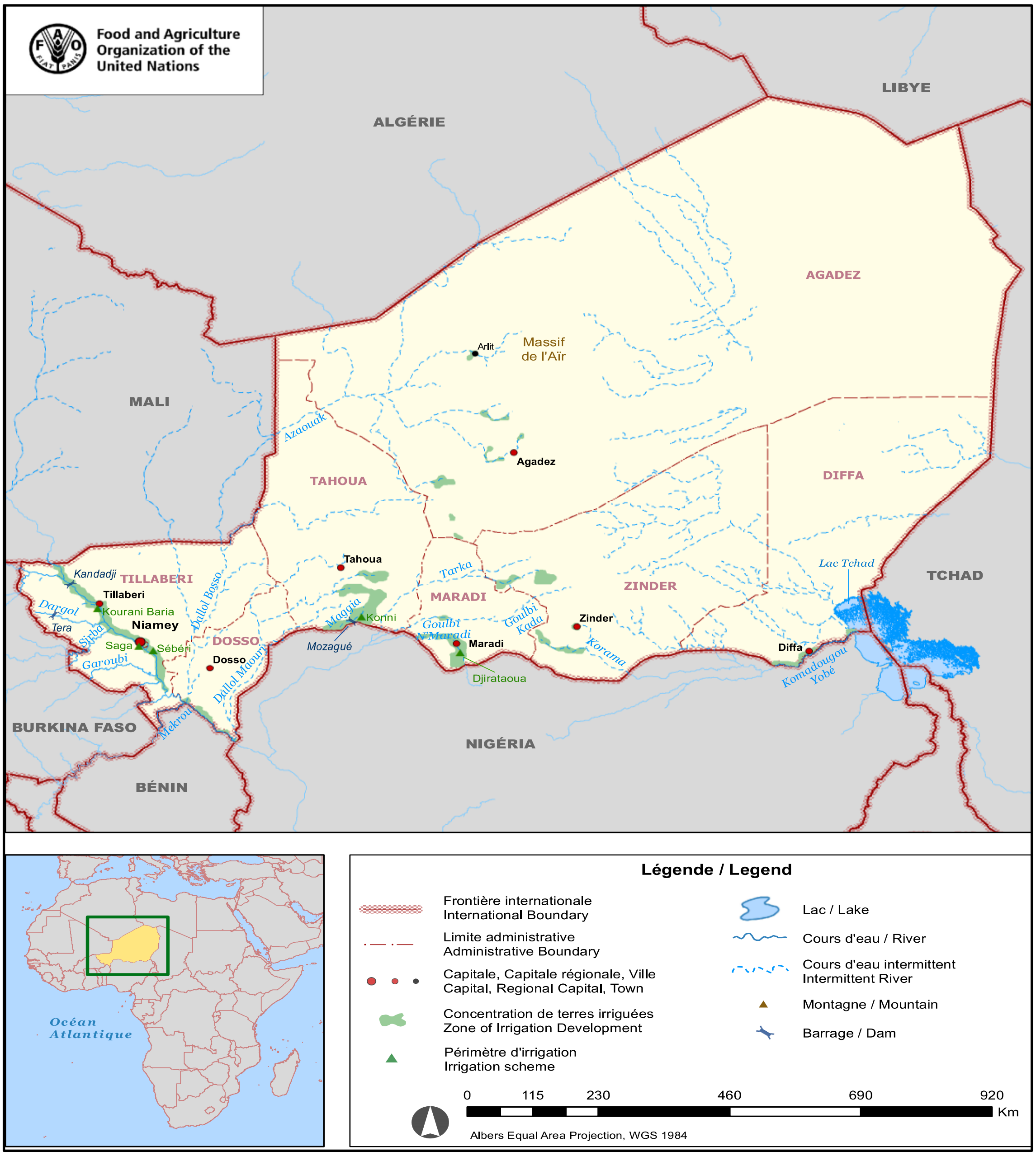
3.1.2.1 Overview

Niger is a landlocked country in West Africa, whose name derives from the River Niger. It is bordered by Libya to the north-east, Chad to the east, Nigeria and Benin to the south, Burkina Faso and Mali to the west and Algeria to the north-west (see Figure 3-2). Niger covers a land area of 1,267,000 km^2 (FAO AQUASTAT, 2015c). It is the largest country in West Africa with 80% of its land area covered by the Sahara Desert. Its population is estimated at 17 million with the vast majority of people living in the south and west of the country. Poverty is widespread across Niger and it ranks bottom (187 out of 187 countries) on the HDI, making it statistically the poorest country in the world (UNDP, 2015).

3.1.2.2 Rainfall

The Sahel and Guinea coast is governed by the West African monsoon, which brings rain to the West African region in the boreal summer months, reaching its most northerly extent over the Sahel and the Saharan boundary in July - September. These zones extend along lines of latitude across West Africa and are demarcated by annual rainfall totals with seasonality and inter-annual variability serving as secondary criteria. As a result of the West African monsoon the climate in Niger is characterised by two seasons: a short rainy season (June to September) and a lengthy dry season (October to May). Northern regions of the country typically receive less than 100mm of rainfall annually, while southern areas (Sudano-Sahalien region) receive slightly higher rainfall, typically between 300–600mm annually. The Sahel is generally taken to extend from 12^{o} to 18^{o} N and 15^{o}W to 30^{o}E. This sub-region has a July–September maximum and a coefficient of rainfall variability of 30–50%. The Soudan region covers 10^{o} to 12^{o}N and 5^{o}W to 30^{o}E, has higher mean annual rainfall and lower coefficient of variability (20–30%). The rainfall covers a longer season of up to 5 months, centred on July–September. The rainfall in this sub-region and the regions to the south vary on inter-annual timescales such that the decrease in rainfall from the Sahel is not evident here or in the zone further south (Washington, 2009). Rainfall is low, spatial and variable and the country has suffered repeated droughts that impact on agriculture, forestry and pastoral production. According to FAO AQUASTAT (2015) less than 3% of Niger's groundwater and surface water resources are utilised, with many rural communities reliant on shallow hand dug wells for domestic water supply.

Figure 3-2: Niger map (Source: FAO AQUASTAT, 2015d)



3.1.2.3 Groundwater

Groundwater is plentiful and of good quality in Niger, but annual recharge is low, so the sustainable yields are much lower than the substantial storage suggests (World Bank, 2000). Some large aquifers are located in the driest parts in the north of the country. The main sedimentary aquifers are to be found in eastern and western Niger. The country is also underlain by crystalline basement aquifers, which, despite their discontinuity, play an important role in water supply of rural centres, such as Tillaberi, Zinder, Maradi and Agadez (World Bank, 2000). Sparsely populated rural communities are also reliant on shallow groundwater resources and seasonal surface water ponds for their domestic and productive water requirements (FAO AQUASTAT, 2015c).

Niger has struggled to sustain the information base it has on water resources. The main constraints to data collection, storage and processing are the state of the monitoring equipment, the scattering of data, the lack of qualified staff to process data and the limited financial resources to ensure the sustainability of WRAs. For example, in recent years the number of hydrometric stations was cut from 265 to 90 because of financial constraints and lack of security. It is also not clear how traditional and modern water law coexist, as customary water management and law is not discussed in Niger’s Water Resources Master Plan (see World Bank, 2000).

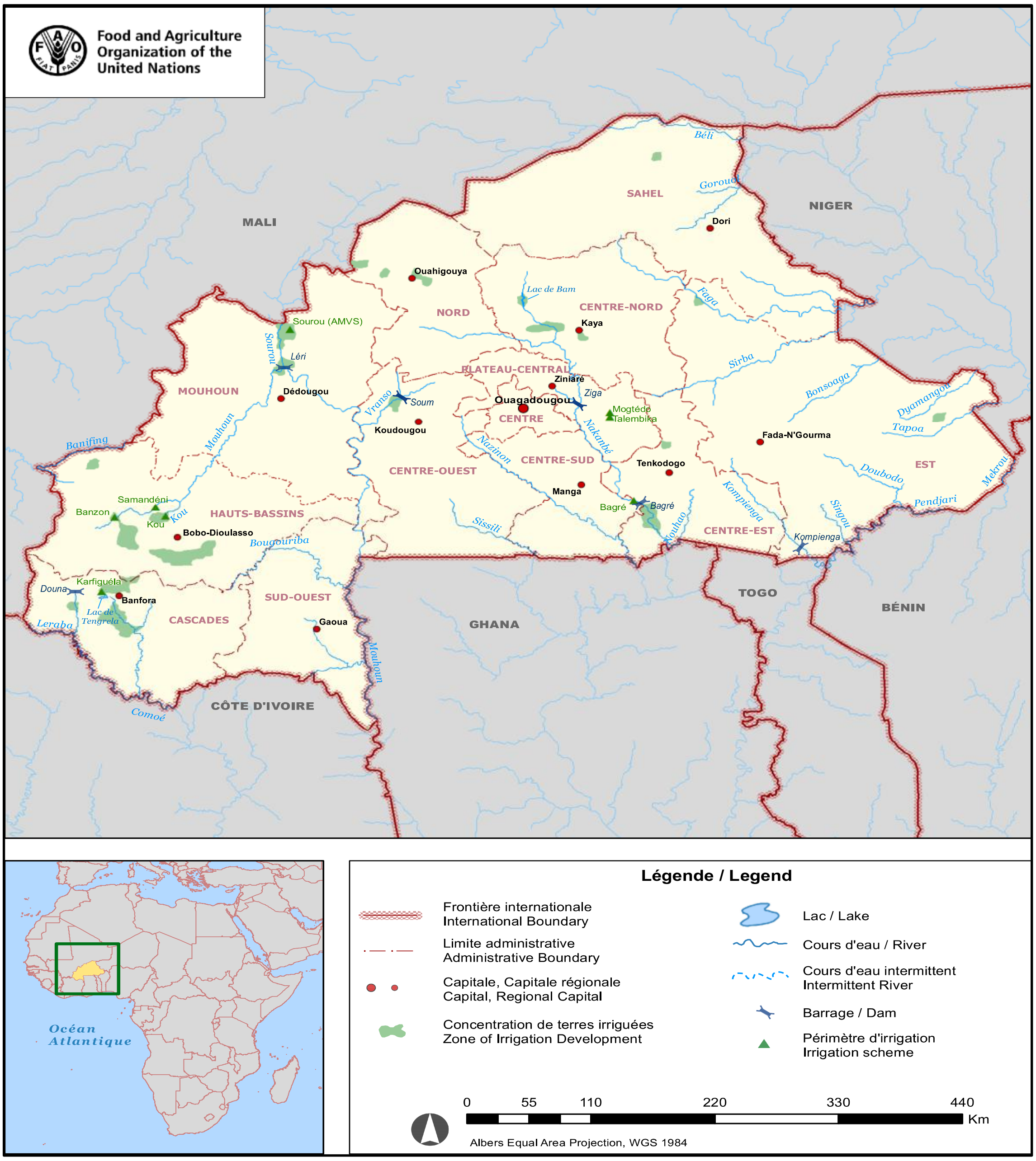
3.1.3 Burkina Faso

3.1.3.1 Overview

Burkina Faso is a landlocked country in West Africa (see Figure 3-3), situated to the west of Niger that covers an area of 273,000 km^2 (FAO AQUASTAT, 2015e). The country gained independence from France in 1960 and since then has experienced relative political stability. However, poverty is widespread and it ranks 181 out of 187 countries on the HDI, making it one of the poorest countries in the world (UNDP, 2015). The population of Burkina Faso continues to grow at a rapid rate, estimated at 3% per annum, with a current estimated population of 17 million (World Bank, 2013). It is projected that as much as 75%

of the population live in rural areas with a high population density, when compared to neighbouring countries (FAO AQUASTAT, 2015e). The population is highly mobile and over the past three decades a large population in the north has moved southwards to more favourable regions with higher rainfall and better soil fertility (FAO AQUASTAT, 2014c). Rural populations are heavily reliant on exploitation of natural resources, particularly agriculture, livestock, fishing and mining (FAO AQUASTAT, 2015e).

Figure 3-3: Burkina Faso map (Source: FAO AQUASTAT, 2015f)



3.1.3.2 Rainfall

Burkina Faso has a tropical climate with a distinct wet and dry season. In the north the wet season covers a two-month period, July and August, whereas in the south the rainy season extends up to six months from April to September (World Bank, 2014). Rainfall across Burkina Faso declined rapidly from the 1950s–1980s, which reflects the downturn in rainfall that has occurred across the Sahel region. Like Niger, Burkina Faso can be divided into three different climatic zones: the Sahel in the north, Sudan-Sahel in the centre and Sudan-Guinea in the south. Rainfall in the Sahel zone is typically between 300 and 600mm per annum. The Sudan-Sahel zone is 600 and 900mm and the Sudan zone to the south between 900 and 1,200mm (FAO AQUASTAT, 2015e). There is no cold season, but temperatures are generally between 22 and 33 degrees centigrade in the north, and 27 and 30 degrees centigrade in the south (FAO AQUASTAT, 2015e), with the hottest months in March, April and May.

3.1.3.3 Groundwater

The geology of Burkina Faso comprises predominantly ancient (Precambrian) crystalline rocks, consisting of metamorphosed sediments, meta-igneous rocks and abundant intrusive granite (British Geological Survey, 2002). Basement rocks form discontinuous aquifers and groundwater storage and flow occurs where the crystalline rock is weathered or fractured. Recharge occurs from rainfall infiltration and is typically low, which makes the possibility of localised groundwater depletion real if over-abstraction occurs. Thus indirect recharge from local depressions can also be important to sustain groundwater resources (Obuobie and Barry, 2012). Given the climatic conditions of Burkina Faso, surface water is in limited supply and groundwater is therefore an important resource. Rural water supply projects rely mainly on shallow groundwater, although this is also scarce in many areas. Traditional sources of water are hand dug wells, as well as ponds used in the rainy season. Today, groundwater is also abstracted from a number of tubewells, typically equipped with handpumps (British Geological Survey, 2002).

3.1.4 Sierra Leone

3.1.4.1 Overview

Sierra Leone is located on the West African coast surrounded by Guinea to the north and east, and Liberia to the south (see Figure 3-4). It is a relatively small country covering an area of 71,740 km^2. The country gained independence from the UK in 1961 but since then has suffered a brutal civil war (1991–2002), which destroyed much of the nation's water supply and water resources monitoring infrastructure (MWR, 2015).

Figure 3-4: Sierra Leone map (Source: FAO AQUASTAT, 2005a)

The population of Sierra Leone continues to grow at a rapid rate, estimated at just fewer than 3% per annum, with a current estimated population of 6 million. Despite political stability since 2002 the country ranks 183 out of 187 countries on the HDI (UNDP, 2015). The country has extensive natural resources wealth (such as iron ore, rutile, gold, diamond and bauxite) however, the socio-economic benefits have not been realised by the vast majority of the population. Furthermore, unregulated mining activities continue to impact on land and water resources. In 2014 Sierra Leone suffered an outbreak of EVD. This had a devastating impact on local communities, the economy and national health systems, which reflects the fragility of the country.

3.1.4.2 Rainfall

Sierra Leone has a tropical climate that is also heavily influenced by the West African monsoon. The wet season is between June and November and the West African monsoon can cause high rainfall events during this period. The average annual rainfall varies from around 2,500mm in the far north-west of the country to more than 3,000mm across the western coastline. Although Sierra Leone is exceptionally well watered, this should give no grounds for complacency. The FAO has estimated Sierra Leone's internal renewable freshwater resources as 160km^3/a (FAO AQUASTAT, 2005b). This is almost certainly a gross over-estimate (given that the mean annual rainfall of 2,526mm amounts to 181km^3/a, and the difference, 21km^3/a, would be a serious under estimate of evapotranspiration) (MWR, 2015). The true figure for renewable freshwater resources is probably in the range 80-100km^3/a. In the absence of significant surface water storage or major aquifers, much of the runoff discharges to the sea unused (MWR, 2015). Furthermore, trends in population, land use, minor and major abstractions and effluent discharges all conspire to put Sierra Leone's water resources under threat.

3.1.4.3 Groundwater

Sierra Leone is divided into four main relief regions: coastal, interior lowland plains, interior plateau and mountains. Sierra Leone's geology can largely be divided centrally along a NW–SE axis. The geology and hydrogeology of Sierra Leone is described as follows: The Precambrian basement complex covers approximately 78% of land area in Sierra Leone. This rock type comprises of water bearing weathered zone (termed a regolith) that is typically up to 20m in thickness. This weathered zone overlays hard crystalline igneous and metamorphic rocks that are reliant on the presence of fractures to store and yield water. The Bullom Group covers approximately 12% of the land area and is comprised of sands and clays distributed in low-lying coastal areas with potential from the more permeable (sandy) strata to yield groundwater, tempered by vulnerability to saline intrusion by seawater. The Rokel River Group covers 9% of the land area and comprises ancient consolidated sediments with a weathered zone over fractured rock. To a first approximation, these are expected to behave similarly to the basement complex (MWR, 2015). The Freetown complex group accounts for just 1% of the land area and these comprise of gabbros and other ultra-basic intrusives with similar hydrogeology to basement complex, but with very sharp relief. The vast majority of rural communities are reliant on shallow groundwater sources for their water supply or local surface water sources, such as rivers and streams.

3.2 Introduction to case study sites

This section introduces the case study sites and highlights important issues that are pertinent to the research topic. This information provides the context in which to place the three results chapters (Chapters Five to Seven inclusive) as well as discussion in Chapter Eight.

3.2.1 Case study one: Kabkabiya and Al Fasher

Kabkabiya and Al Fasher in North Darfur are the locations of the first case study. Kabkabiya lies to the west of Al Fasher and sits in the northern foothills of the Jebel Marra mountain range. The rains in this region are normally better than other places of comparable latitude in Darfur because of the “rain-shadow” created by the proximity of Jebel Marra. However, Kabkabiya has experienced repeated droughts and multiple famines have occurred throughout the twentieth century (de Waal, 1989). In response to these recurring food security problems, Oxfam established development programmes in the Kabkabiya locality following the 1984–85 famine. Oxfam had a long-term presence in Darfur and the author worked in Darfur from July 2006 until March 2009.

The study areas were remote rural villages and displaced communities in IDP camps, who were reliant on groundwater sources and seasonal wadi flows for their survival. Kabkabiya and Al Fasher are both located in the Sudan-Sahel climatic zone with average annual rainfall volumes of 200–500mm occurring between July and September. This is followed by long hot dry spells from October to June. The town of Kabkabiya expanded significantly in 2005 as a result of violence and hostility across the region. Many rural communities from the Kabkabiya and Jebel Si region were also displaced to Abu Shouk and Al Salaam IDP camps, adjacent to Al Fasher. Large-scale human displacement in Darfur caused unprecedented concentrations of people to depend on groundwater resources in areas of low and variable rainfall. The problem of water scarcity in both locations was further compounded by the protracted nature of the humanitarian crisis, as people's daily water demand evolved beyond small quantities of safe water for human survival.

Villages in and around the Kabkabiya area have an acknowledged head, normally the Sheikh of the village. He will often be responsible for resolving disputes that arise; this will often be following consultation with other men in the village. In addition, each tribe will have its own social organisation on a wider scale. For example, for the Fur tribe the paramount authority is the Shertai of the Fur, who lived in Kabkabiya in 2007. Within the formal structures of government, the village will send members to the village council that might represent half a dozen settlements. The government civil servants who serve these councils work closely with council members at all levels.

One traditional social structure particularly important to this research is the system for managing local natural resources (including water, fertile land and forests) referred to as the *talaig*. The system allows nomadic pastoralists to negotiate access to grazing land and water points of settled agro-pastoralists.

This system worked on the principle of local dialogue and included rules for resource usage and graduated sanctions for rule violations. It also required a system of informal monitoring to assess the vulnerability of local natural resources. Regretfully, the traditional systems for managing natural resources were increasingly undermined by the influx of firearms from across the region, with armed groups seizing control of fertile land and water resources (Young et al, 2005). Despite widespread problems, communities in Darfur continued to organise themselves around the native administration, wherever possible. In IDP camps Omdas and Sheikhs were responsible for organising their communities and managing water points. They were also the representative focal persons for organising the distribution of Non-Food Relief Items, such as jerry cans, plastic sheeting and soap. IDP camps also had several other community groups organised around water management and security, and included both men's and women's groups. The workload faced by women is daunting; they are the haulers and fetchers of water, amongst a number of other tasks. For that reason it was vital to ensure they were consulted in this study. In the IDP camps, displaced communities introduced water rationing and rules for water usage and management, in an attempt to reduce growing water scarcity problems. Importantly for this study, it was community members and not NGOs who led these local water management initiatives.

3.2.2 Case study two: Banibangou

Following Oxfam's expulsion from Darfur in March 2009, the second case study was located in southwest Niger. Research was conducted in remote rural communities in Banibangou located to the north of Tillaberi region. Banibangou is an agro-pastoral zone that covers 43 villages over an area of 6,010 km^2. The commune falls within the administrative control of Ouallam District and extends north to the border with Mali. As a result of its proximity to Mali it received an influx of refugees from Mali in 2012.

Oxfam had established a close working relationship with a national NGO called Karkara through which research activities could be undertaken. The context differed slightly to Darfur insofar as communities were not displaced; however, they suffered similar contextual problems to rural communities in Kabkabiya, Darfur. Banibangou has a dry and arid climate with a desert landscape and sparse vegetation. The area is recognised for its recurrent food crisis, despite the fact that the area is recognised for its agricultural productivity. Low, spatial and variable rainfall has meant the economy of the town has gradually orientated towards farming.

Banibangou commune has several water management groups and livestock and farming committees, including the Women's Gardening Committee. The women's committee in Banibangou consists of more than 50 regular members and they cooperate to irrigate crops and grow food (such as lettuce, cabbage, potato, carrot, onion, chilli and rice cultivation during the rainy season). The vast majority of water points in Banibangou and Soumatt where shallow hand dug wells that run dry soon after the seasonal rains end. As a result some members of the Women's Gardening Committee attempted to adopt informal mechanisms for assessing whether rainfall had been "good or bad," which included listening to the radio and recording daily rainfall readings. The town of Banibangou conceals important water resources consisting of shallow alluvial aquifers and deep fossil aquifers. However, external emergency interventions often focused on digging shallow hand dug wells, the vast majority of which dry up. Rural villages in Banibangou do not sit within any functioning river basin board and as a result water management issues are localised in nature.

3.2.3 Case study three: Tenkodogo

Following further disruption to fieldwork in Niger in 2012, new research sites were established in Burkina Faso. Study sites were selected in the villages of Sablogo, Basbedo and Kampoaga to the southeast of Ouagadougou. Basbedo and Kampoaga are located in Tenkodogo Department, while Sablogo is located in Lalgaye Department. All three villages are located in the Sudan-Sahel climatic zone with a wet season occurring between July and September and a long hot dry season from October to June. Like many rural areas in Burkina Faso, villages remain vulnerable to changes in rainfall patterns and commodity prices. Economic and social development is contingent, in part, on political stability within the country and sub-regions. All three villages were reliant on shallow hand-dug wells and boreholes for domestic and productive water needs. The shallow wells were susceptible to drying up and only the deeper boreholes continued to function year round. Communities were reliant on agriculture (farming) and livestock rearing for their livelihoods. The villages all had existing water user committees organised around the management of water points. The villages also coordinate between themselves but primarily through the farming unions. Sablogo, Basbedo and Kampoaga also have important external links with a number of NGOs and government institutions, such as local partner NGOs DAKUPA, Direct Direction Régional de l'Agriculture et de l'Hydraulique (DRAH) and Direction des Etudes et de l'Information sur l'Eau. WaterAid has been working with communities in Sablogo, Basbedo and Kampoaga since 2009. By 2012 it had so far provided basic water supply and sanitation facilities to a significant proportion of the 7,549 people (1,166 households) present (WaterAid, 2012b). This study was conceived as a method to build on these earlier project activities that focused on the provision of infrastructure (wells and sand dams). It worked directly with community *lecteurs (monitors)* and water user associations in the three target villages, as well as representatives from Tenkodogo, Lalgaye and Comin Yanga Communes.

Previously the WaterAid programme has recognised the importance of WRM in this region. Activities undertaken included the training of six *lecteurs*, six members of the water user committees in each village, ten animators from DAKUPA, three representatives from the communes and two from DRAH between December 2011 and March 2012. The main driver for the project being undertaken in Tenkodogo was that communities were perceived as having a real need or demand for improved WRM. Therefore they were seen to be highly motivated. The study sought to understand the ability of communities to monitor their local water resources.

3.2.4 Case study four: Rokel-Seli River Basin

A fourth case study area was established in the Rokel-Seli River Basin in Sierra Leone. The Rokel-Seli River Basin rises in the highlands of the Sierra Leone–

Guinea border, in the north-east of Sierra Leone, at an elevation of about 900masl. It runs a total distance of about 390km, discharging into the Atlantic Ocean north of Freetown. The catchment area is estimated to be 8,236 km^2. The mean annual river flow at Bumbuna (measured over the period 1971–78) was 112.9m^3/s or 3,560Mm^3/a. The flow is highly seasonal with mean monthly discharge in September of 330.5m^3/s and in March only 6.1m^3/s (MWR, 2015).

The Bumbuna hydroelectric power dam is located 2.5km upstream of the Bumbuna falls. It was commissioned in November 2009, although construction had originally commenced in the 1990s. Construction was abandoned in 1997 when the dam was 85% complete, as a consequence of the war. A second dam, Bumbuna II, is under detailed design at the time of writing. It is to be located 28km upstream of Bumbuna I at Yiben, and it will significantly add to the power output of the Rokel-Seli River; however, construction has been delayed as a result of limited river flow data. Other major water users and potential polluters in the upper catchment include the iron ore mine operated by African Minerals at Tonkolili and the Magbass irrigation scheme developed in the 1980s. Further down the catchment, Addax Bioenergy abstracts water from the Rokel-Seli River for irrigation of sugar cane, while a number of other mining concessions exist too (including Marampa, near Lunsar, operated by London Mining since 2011). There are current plans and intentions to extend Freetown's water supply, based on abstraction from the Rokel-Seli River at Makeni Ferry Bridge, about 24km upstream of Freetown. The Rokel-Seli River Basin flows through parts of Koinadugu, Tonkolili, Bombali and Port Loko Districts. Within these districts, rural and small town water supply is needed for domestic use, and the demand for clean water is likely to go on increasing as the population grows. In short, the Rokel-Seli River Basin is a microcosm of all the competing demands for water from rural and urban domestic users, industry, energy and agriculture, together with the risks of water pollution, which accompany all these uses. In the absence of well-informed decision-making, water security in the Rokel-Seli River Basin, and elsewhere in Sierra Leone, is at risk.

Villages in Sierra Leone fall under a political hierarchal system consisting of localities, wards, chiefdoms and villages. There are 149 chiefdoms in Sierra Leone led by a Paramount Chief who sits above a Section Chief and Village Chief. At village level, water user committees may be responsible for operating and maintaining water points, although the vast majority of rural communities are reliant on unprotected water sources for their water supply. In the absence of any river basin boards and regulating agencies, Paramount Chiefs often have custody of the water and land resources within their Chiefdom and are responsible for negotiating access with industry (such as mining companies and agribusiness). A major concern is that Paramount Chiefs may not always represent the best interests of their communities if they collude with industry (see Fanthorpe and Gabelle 2013).

3.2.5 Similarities and differences between case study sites

A number of observations can be drawn from a brief analysis of the similarities and differences between the study locations. This is important because it has implications for the generalisability of the research findings, discussed in Chapter Eight. The first is that all of the case study sites are located in SSA, although they were not geographically clustered. All of the countries, Burkina Faso, Niger, Sierra Leone and Sudan, rank low on the HDI and have experienced poor governance and high levels of poverty for decades. Darfur was by far the most extreme working environment because it continues to experience ongoing conflict and widespread human displacement. The second observation is that communities and participants lived in rural areas and could be classed as either chronically deprived citizens (as was the case in Darfur) or on the periphery of government support. The problem of poor governance and inability to cope with repeated shocks links all four countries. The third observation is that each geographical location suffered the problems of a short single rainy season and seasonal desiccation of water sources. Burkina Faso, Niger and Sudan are all located in the Sudan-Sahel climatic zone. A distinct feature of countries in this zone is they are subject to low, variable and spatial rainfall. The wet season is typically very short, limited to July to September, and the dry season is long, stretching from October to June. Rural communities suffer from seasonal water insecurity with shallow wells drying up along with ephemeral rivers and wadis. This generally leads to a very poor situation with people migrating to other countries or to wetter regions in the south of their respective countries. The fourth case study site was located in Sierra Leone, a country that receives significantly higher rainfall. Thus the natural environment differs significantly to the other three case study areas. Yet, despite the perception that Sierra Leone is blessed with abundant water resources there are some pressing water problems in the country. Water resources are facing growing pressures and groundwater and surface water sources go unmonitored and unmanaged. In the absence of significant surface water storage or major aquifers, the vast majority of rainfall in Sierra Leone discharges to the Atlantic Ocean unused. A common story across all four localities was the absence of any robust monitoring and management arrangements for water resources. For example, the Encyclopaedia of the Earth (Kundell, 2008) includes this telling comment on the present state of affairs in Sierra Leone: "*As water resources have never been a serious constraint to development in Sierra Leone, no base exists for their management (except for the water supply and sanitation sector).*"

3.3 Summary

This chapter introduced the research countries and case studies, and highlighted the issues that are pertinent to the research topic. This information provides the context within which research was undertaken. The chapter started with a short description of the research countries, followed by a description of the specific case study sites. Following this there was a discussion of the similarities and differences between the research sites, and this is used as supporting information to describe the generalisability of research findings described in Chapter Eight. The next section describes the data collection and analysis methods used to provide insights into CBWRM in fragile states.

4 Research methods and approaches

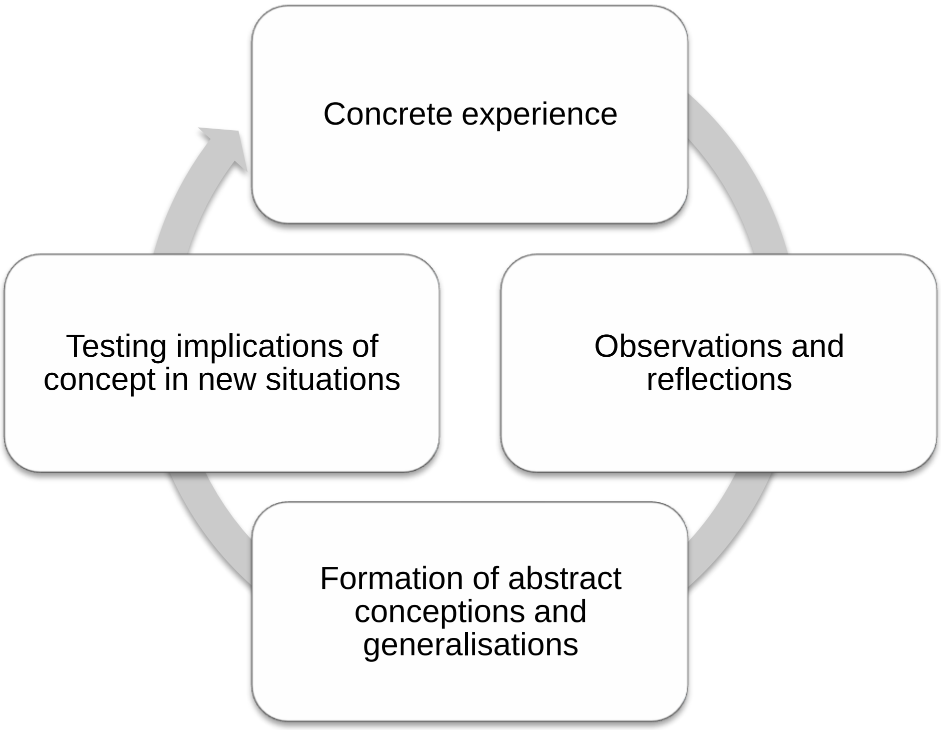
This chapter presents the research methods adopted and applied. Section 4.1 summarises why the author selected AR as the preferred method. Section 4.2 briefly describes the AR process and how the research methods evolved from the literature review. The third section outlines the data collection methods and the ethical issues that were taken into consideration. The fourth section describes the data analysis tools. Section 4.5 describes some important considerations when working in FCAS, before Section 4.6 summarises the chapter.

4.1 AR

AR is used to promote real world change (Robson, 2002). It is carried out in the course of an activity or occupation to improve the methods and approach of those involved. Describing its methodology, Robson (2002) notes that the first stage of AR is to aim to improve current practice, second is the improvement of understanding by its practitioners, and third is the improvement of the situation in which the practice takes place.

There has been increased attention on AR over the past two decades although its origins date back more than 60 years (Reason and Bradbury, 2001). Kurt Lewin first coined the phrase “action research” in 1946 and he is attributed with the phrase *“if you truly want to understand something try to change it.”* (see Lewin, 1946*).* His work is considered foundational because he applied the practice of knowledge production in real life situations. Lewin’s model of exploratory learning is shown in Figure 4-1. The Lewinian model consists of a four stage cyclical process. Two aspects of the model are particularly important. The first is that the model emphasises the importance of real (concrete) practitioner experience as a starting point for research. The second is that problem solving is recognised as being an iterative flexible process that is based on a process of participatory feedback. This study used practitioner experience as the starting point for the study. It also used an iterative process, which builds on Denscombe’s (1998) model of action research (see Figure 4-2 on Page 88). Denscombe's model incorporates a process that is designed to effect change, recognising this is a complex, dynamic, continuous and iterative process. One of the underlying aims of this study was that it should link research and practical experience. For this and other reasons, AR was identified as the most appropriate method for this work because it requires a continuous process of examination and re-examination.

Figure 4-1: The Lewinian experimental learning model



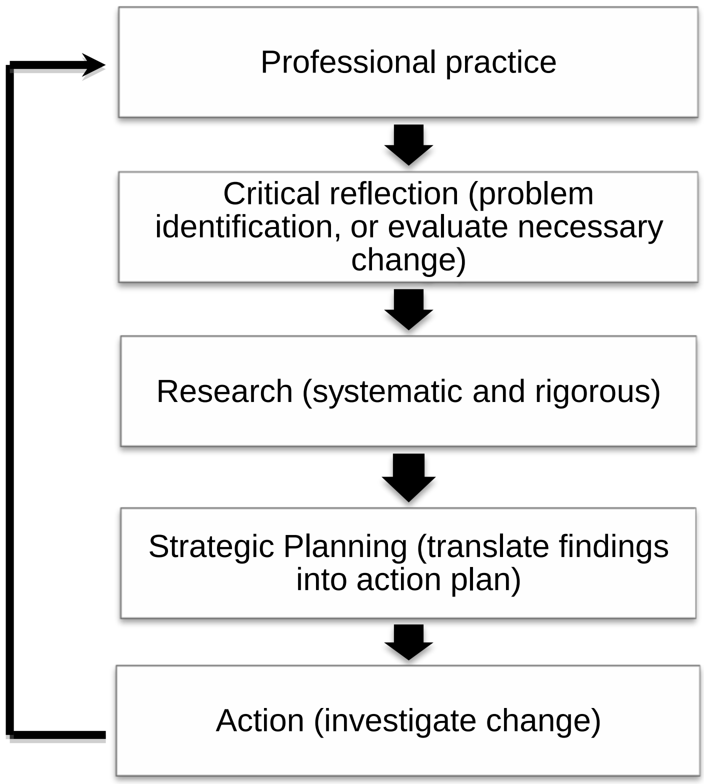
The collaborative and iterative nature of AR contrasts with that of fixed, quantitative design but it is suggested that this perceived weakness is a necessary and acceptable trade-off for an adaptive research design (Reason and Bradbury, 2001). AR resonated with a combined role as practitioner and researcher and the methodological approach reflects the complexity and messiness of development work. When selecting the research methodology it is also necessary to be mindful of previous lessons learnt. Hardin (1968) suggested in his article "The Tragedy of the Commons" the potential over-exploitation and abuse of any natural resources that are common property is a problem for which there is no (purely) technical solution. Hardin maintained the main challenges, when designing effective institutions to manage CPRs, are social and moral[16]. He depicted an irresolvable conflict between the interests of the individual, said to be inherently selfish, and the collective needs of a community interested in the common good. The current literature shows that predictable exploitation of natural resources, as argued by Hardin, is not inevitable. Bromley and Feeny (1992) and Ostrom (1990) have demonstrated that social groups can organise themselves to use resources continually with relatively efficient outcomes. This requires social and moral principles to be adhered to and collective action amongst users to be established. Successful CBWRM intuitively requires collective non-selfish action by individuals within the community. Community members must be able to monitor the resource effectively and apply rules for drawing from the resource and graduated sanctions for rule violators. The ability to communicate with one another, in a transparent manner, with a common goal or long-term perspective is crucial to its success. As a result, this research methodology has leanings towards an ethnographic survey, providing a description of communities, their perspectives, water management customs and rules as well as their relationships with other local water users and the surrounding environment.

AR is not prescriptive about the tools to be used. It is an all-encompassing term that covers multiple quantitative and qualitative approaches. Two key aspects of the AR process deserve closer scrutiny. First, as its title implies, the process is *action orientated* and it aims to influence positive change. Second, and equally important, the AR process is participatory and requires active engagement from its research subjects (Reason and Bradbury, 2001). These two factors are important because the ability for social groups to manage natural resources requires user groups to scrutinise their own social and moral behaviour and moves way beyond preferences for technical solutions or technocratic approaches that are often preferred by some water sector professionals. Tacchi

[16] The term moral refers to moral economy theory, which implies the economy of a small, close knit community is based on gooodness, fairness, transparency and justice. Such an economy is based on the principle of collective action and mutuality – to avoid problems such as water theft.

et al (2003) highlight that ethnographic research is a way of thinking about the relationship between knowledge and action. The role of the researcher is to play the role of facilitator in ensuring active participation and collective action. Thus continuous improvement and involvement are central to the process (Robson, 2002).

Figure 4-2: Denscombe's model of action research



However, it is important not to be dogmatic when selecting research methods and a number of other options were considered – such as Grounded Theory. Glaser and Strauss, who are attributed with introducing Grounded Theory, did so with the aim of addressing the dangers of a researcher beginning with preconceived bias. Yet as an alternative research methodology Grounded Theory was rejected outright for two main reasons. The first is that a pure Grounded Theory approach should have no preconceived ideas or hypothesis (Glaser and Strauss, 1967). Concepts emerge from making comparisons to highlight similarities and differences. Thus theory is developed from the conceptualisation of data rather than from the data *per se*. In many respects this appeared vague and it was felt the methodology did not reflect reality. Clearly it would be difficult for a practitioner to approach an identified problem in an unfocused manner. Organisational support for research would be limited and water users are unlikely to have the time and interest to engage in such a non-specific process. The second consideration is the use of research coding proposed in Grounded Theory methodology. This appeared too abstract and complex. For example, for the study of collective action across comparative sites there is still no agreement on the unit of analysis. What constitutes a user group? Who should act collectively? What is the measurement of successful collective action? These are all unresolved issues, as noted by Poteete and Ostrom (2004).

4.1.1 Critique of AR

AR has been criticised for lacking the methodological rigour and technical validity that is the gold standard of much academic research (Greenwood and Levin, 1998). AR challenges many of the values of traditional social science because the researcher becomes a participant rather than remaining an outside observer. Chambers (1983) warns us that participation by the researcher is empowerment and empowerment of the participants is political. This affects local dynamics because it is increasingly difficult for the researcher to extract themselves from community or local politics. Chambers points out that *"who the outsider is may change but the relation is the same. A stronger person wants to change things for a person who is weaker. From this paternal trap there is no complete escape."* Chambers argues the researcher does not adopt a neutral position and aspects of traditional research design and data collection are lost, because the researcher becomes a collaborator and facilitator – not just an investigator. Hammersley (1996) points out the researcher may inadvertently impose their values upon the research. In mainstream social science the components of research and action tend to take place separately, often with the researcher not involved in follow-up action. AR integrates this approach and there is no distinction. Furthermore, the researcher cum practitioner may also possess specialist expertise and knowledge. Sarantakos (1998) maintains that the personal involvement of the researcher is at the front of the research activity. Participatory Action Research tends to see AR as *“emancipatory practice”* (Herr and Anderson, 2005), and this is because it is often applied in the field of rural development where the researcher is involved with vulnerable and marginalised groups.

The author maintains that influencing local power dynamics is not inherently wrong, but draws upon the work of Fals Borda (1996) who outlined four guiding principles for AR practitioners: First, do not impose or monopolise your knowledge, but ensure your skills complement the knowledge and skills of grassroots communities, treating them as partners and co-researchers. Second, do not trust elitist versions of history and science, which respond to dominant interests, but be receptive to counter narratives and try to recapture them. Third, do not depend solely on your culture to interpret the facts, but recover local values, traits and beliefs. Finally, communicate what you have learnt with the people, in a manner that is wholly understandable and even literary and pleasant; for science should not be a mystery or a monopoly for experts and intellectuals. In order to adhere to this guidance, this research draws on primary data collected in Darfur at the beginning of this study, which revealed communities often have their own indigenous or informal water management arrangements that they practice. Thus the emerging concept of CBWRM should compliment and strengthen extant indigenous practices, wherever possible.

4.2 AR approach

The methodology used in this study draws on the conceptual model for building AR approaches from practitioner experiences and incorporates relevant guidance on building theory from case study research (Eisenhardt, 1989). The methodology draws heavily on the cyclical process of identifying a problem, reconnaissance or fact-finding, planning, action, and evaluation, amending the plan and re-testing. AR was considered a suitable methodology to increase understanding of CBWRM for two main reasons. Firstly, the AR process is suitably flexible to lend itself to the difficulty of doing research in some of the world’s most challenging working environments (as explained in Section 2.1).

Secondly, AR allows a combination of quantitative and qualitative data collection methods to be used. For example, quantitative methods were highly appropriate for determining whether communities could collect rainfall and groundwater level data, while qualitative methods were appropriate for understanding why communities choose to continue collecting data and for understanding how they can understand and use the outcomes of hydrometeorological monitoring. Chapter Two identified the lack of hydrometric monitoring in SSA is a major constraint to sound WRAs.

4.2.1 Overview of methodology

The following step-by-step approach was used in conjunction with both quantitative and qualitative data. For example, quantitative research was collected as part of WRAs, while qualitative research was highly appropriate for understanding the system in which WRAs must operate.

Step 1. Problem identification: The research problem was generated during the Darfur humanitarian crisis in 2007 when the researcher was working as a practitioner. The problem is defined as follows: The onset of genocide across Darfur in February 2003 resulted in the establishment of numerous densely populated IDP camps (Flint and de Waal, 2005). Water was the main problem in many camps, such as Abu Shouk and Al Salaam in North Darfur (see Section 2.2.1). Water points were low yielding or had dried up completely and women had to spend hours each day queuing for water (see Figure 4-3). Other displaced people had to spend three or four hours fetching water every day from local wells located on the outskirts of Al Fasher town. Water access and quantity was a critical problem for the community and their main priority. For international organisations (such as NGOs) the major concern was that groundwater resources were deteriorating in quantity relative to need and a key underlying issue was the absence of any WRM. Annual rainfall in Al Fasher was less than 200mm (Figure 2-5), population density within the camps was growing, no major aquifers were available and the protracted nature of the humanitarian crisis meant that settlements and camps were becoming more permanent with water supplies becoming multiple usage. There were two main drivers for the research. The first was a desire to understand how WRA and WRM could be achieved in FCAS. The second reason was to examine the role of community-based institutions alongside responsible local and central government authorities. The initial research question was: to what extent can community-based institutions monitor and manage water resources alongside or in the absence of effective government support? The research problem was not confined to the issue of threats to water security in Darfur; rather the problem resonated with a broader environmental concern and the perceived lack of virtually any WRM within rural water supply programmes in SSA.

Figure 4-3: Displaced people queuing for water in Al Salaam Camp, Darfur, 2007

Step 2. Literature review: An initial definition of the research objectives (see Chapter One) was made in order to focus the research and collection of data. Although no formal hypotheses were developed for this study, some early assumptions were identified that could be tested at the end of the work: For example, *a localised approach to WRA may be beneficial because it builds the resilience of communities that are exposed to the impacts of climatic extremes.*

It may also enable governments to undertake a transition, the change from one (inferior) situation, where virtually no WRA and WRM is undertaken, to another, better one.

The examination of current literature also helped to identify gaps in research and areas for potential exploitation. Indeed, a review of current literature gave prominence to the common view that IWRM was the dominant water management model to be pursued. This belief was reaffirmed following interviews and discussions between the author and practitioners from the United Nations Environment Programme (UNEP), and visiting academics from UNESCO-IHE Delft[17]. However, as well as finding broader political and technical solutions it was also apparent that local governance issues could not be ignored in such a difficult working environment. For example, the deployment of tribal militia, airstrikes by governments and the influx of firearms meant that people had many grievances towards government (Bromwich, 2015). This knowledge raises the question of how to engage in managing natural resources at various levels when governments are authoritarian and hostile to their own people?

The initial literature review aimed to identify all studies in English published up to the end of 2007 concerned with implementing IWRM in fragile states. The search did not identify any positive examples of all-inclusive IWRM being implemented in such challenging environments. Further background research was undertaken of customary water management practices in Darfur and the Sahel. Initially confidence levels in working directly with displaced communities were low, but practitioners conceded that community participation was vital to any future success. The examination of existing literature helped to identify gaps in current research and in particular the knowledge that IWRM theory has lagged behind its practical application helped shape the initial research design. Constructs identified as potentially important related to the importance of monitoring and managing water resources locally, understanding the process of hydrological monitoring and the areas of support required from the technical

[17] Discussion with Frank Jaspers, Associate Professor of Water and Environmental Law.

wings of government. Power relations and the willingness of government to adopt the principles of meaningful decentralisation and subsidiarity were also identified as potentially significant. Given the integral role of the WASH sector in delivering community water supplies in SSA, the role of NGOs in supporting the evolution of CBWRM was also identified as essential.

Step 3. Selecting case studies: Potential case study sites were selected following a series of discussions with communities, local academics, practitioners (NGOs) and local government technicians. For example, in Darfur this consisted of rural communities in Kabkabiya, as well as representatives from Al Fasher University, Kabkabiya Smallholders Charitable Society, Sudanese Environmental Conservation Society and the Groundwater and Wadis Department. Systematic discussions focused on people's experiences of drought and water management and in particular customary water management arrangements practiced by community-based institutions and the effectiveness of national or regional WRM approaches. Details of the sampling process are discussed in Section 4.3.

Step 4. Crafting instruments and protocols: Following these initial meetings, drafts of the data collection tools and questionnaires were developed or reviewed as appropriate. Data collection methods used included semi-structured interviews, key informant interviews, participatory monitoring, transect walks and participatory hydrological monitoring. The use of transect walks alongside participatory monitoring facilitated the triangulation of data. Hydrological data collection and analysis alongside other academics and practitioners also heightened confidence in the insights found and increased the opportunity for interesting or new insights (Eisenhardt, 1989). This period of work also included translating questionnaires into Arabic, field-testing the tools and working with local translators.

Ethical considerations

AR has been described as *"a research activity with a social change agenda"* (Greenwood and Levin, 1998). As a result, important ethical considerations were incorporated into the research. Four in particular stand out. First, data was collected from communities who had been displaced by violence and hostility in Darfur (as well as communities in Niger, Burkina Faso and Sierra Leone). The author ensured participant confidentiality and anonymity was maintained throughout the course of the research in order to prevent any repercussions. Second, there are serious ethical concerns if vulnerable groups are used just to elicit data. One way to address this issue was to ensure the research problem was of real importance to displaced people. Communities can benefit from data collection if it leads to analysis, improved water management and appropriate follow-up action. This philosophy underpinned the research. Third, one further way to incorporate an ethical approach was to ensure that communities themselves set rules for water usage and management and no decision-making was imposed on them. Lastly, the author also adhered to the Cranfield University ethics committee and the ethical codes of conduct of both Oxfam and Adam Smith International.

Step 5. Fieldwork: In accordance with the AR process data collection and analysis was conducted in a cyclical manner. This was conducted both within and between different case study sites after fieldwork was disrupted on more than one occasion. Field notes were regularly reviewed and reflected upon and field activities were routinely discussed with peers and colleagues. This enabled the researcher to better understand what was and was not working and to make necessary adjustments. For example, it was found that plotting hydrological data (rainfall and groundwater levels) better enabled communities to visualise the relationship between rainfall, surface runoff and fluctuations in groundwater. This analysis allowed the introduction of new data collection methods and more appropriate technology. For example, transect walks were an addition made to the fieldwork in order to validate the participatory mapping exercises and to identify suitable locations for hydrological monitoring by communities. Other research activities were introduced, such as water usage and participant surveys.

Step 6. Data analysis: As mentioned above, data was analysed within and between different phases of research to allow for preliminary insights to be generated that could inform further phases of work. This helped to define a series of activities that could be incorporated into a CBWRM process (see Section 1.5). For example, in-depth analysis included transcribing hydrological data collected by communities followed by plotting information in MS Excel and comparing data between monitoring sites. This helped to identify any gaps in data collection and whether information collected by community members had been recorded accurately or made up. More details of data analysis methods are given in Section 4.4.

Step 7. Reflection and critical reflection: The main purpose of this stage of work was to generate new insights from the research undertaken. Reflection and critical reflection are key components of AR. Both steps are useful in the learning process although they can be difficult to apply. Kemmis and McTaggart (2005) note that participants find it hard to sustain the iterative process associated with AR. However, they maintain the criteria for success is whether researchers have a strong and authentic sense of development and evolution in their practices and the situation in which they practice (Kemmis and McTaggart 2005).

Data from across the case study sites was compared to see if the results and findings were generalisable. Data and the initial insights generated were presented back to both communities and government officials during hydrological monitoring review workshops and community and government feedback meetings. This enabled the researcher to incorporate comments from communities and government officials into ongoing fieldwork.

Step 8. Enfolding literature: Although a preliminary literature review was conducted at the beginning of the study, similar and conflicting literature was reviewed throughout the research period (such as Giordano and Shah, 2013 Oates et al, 2014, Muller, 2015; and GWP and UNICEF, 2014). This was important to reflect on the research findings generated and to assess their generalisability. Furthermore, a more detailed review was conducted once research insights and findings had been identified. A comparison of insights generated with other relevant literature can be found in Chapters Eight and Nine.

Step 9. Reaching closure: Research methodology literature often emphasises the importance of reaching closure or the point of saturation. However, in reality this is rarely achieved due to time and money constraints. Eisenhardt (1989) observes that "reaching closure" or the point of saturation is often not possible as the extent of research possible is often pre-determined in advance. Theoretical saturation was not reached in this study due to time and money constraints and repeated disruptions in the study areas. It was also not possible to examine WRM in detail at village level or on a wider scale, so instead the study primarily focused on WRAs by communities. However, the process of data collection, analysis, reflection and follow-up action for these activities was considered rigorous for a study of its size.

4.3 Data collection methods

4.3.1 Secondary data

Secondary data was collected to triangulate primary data and to provide background records on the research study sites. Background information was collected regarding historical WRM approaches in each study area as substantial effort was made to review historical and current national hydrometric monitoring networks. For example, in Sierra Leone, details of historical rainfall and river gauging monitoring networks were retrieved (see Gregory 1965). As a result of poor records management, disruption to government institutions and sensitivity, it was often difficult to obtain historical data records, although substantial efforts were made to locate and understand past data, including the Sierra Leone hydrological yearbook (1970–1976).

4.3.2 Primary data

Primary data collection consisted of a mixture of quantitative and qualitative data collection. In some respects quantitative and qualitative data is complementary as each approach has a number of viewpoints for assessing the validity of findings. Quantitative research tends to be associated with numbers (data) and analysis and provides a measure of confidence for large-scale studies. In participatory studies, quantitative research has the advantage of trying to establish a causal relationship between two variables – such as monitoring data and decision-making. In this thesis, quantitative methods were used to assess local hydrology (such as rainfall and groundwater levels) and identify collective water usage patterns. Qualitative approaches were used to investigate barriers to community participation and to generate a depth of understanding for motivation and collective action. Poluka et al, (1990) note: *"Qualitative methods allow for analysis of human interaction and make it possible to understand how human behaviour can change due to different factors."* Qualitative data collection can draw upon a broad range of tools to gather and organise information.

In terms of the scale of participation the levels of participation achieved in this research ranged from "consultative participation," during semi-structured and key informant interviews, to "functional participation" (Geilfus, 2008). The higher levels of participation were possible during WRAs where communities in Burkina Faso were actively involved in collecting data, plotting hydrological information and making internal decisions concerning water management. In Sierra Leone communities were primarily involved in collecting hydrometric data and levels of participation were slightly less, as community members were not actively forming water management groups to respond to wider WRM problems within the river basin.

Focus group discussions

Focus group discussions were used in each study site to collect data and information at the village or community level. Participants for the focus group discussions were identified with the support of local key informants so that contributions were relevant to the study area. Single gendered groups were conducted in Darfur, Niger and Burkina Faso, and in all study areas a local NGO and interpreter facilitated the meetings. This ensured the meeting could be conducted in the predominant local language. Focus group discussions were useful because they allowed the author to obtain contextual information as well as background information about people's motives for monitoring and managing water resources. It also demonstrated a broader interest in people's work without disturbing the study results. Although focus group discussions were interesting, not all information could be quantified. In some circumstances feedback from communities concerning their motivation to record rainfall or groundwater level data could be compared to the monitoring records they collected and the number of missing data months (see Chapter Five). However, other feedback, such as their ability to make better management decisions or manage water resources more effectively, could not be quantified. Therefore the study was reliant on people's testimonies. However, focus group discussions were combined with transect walks and observation techniques as a means to review information provided by community members.

Key informant interviews

Over the course of this research period, substantial primary data was collected using key informant and semi-structured interviews. These interviews were conducted with multiple individuals in each study area and details are shown in Appendix A1. Key informant interviews were also conducted with senior academics and professors of climate science in the UK and Africa (see Chapter Seven). The vast majority of interviews were conducted at people's workplace or homestead. In some circumstances interviews were conducted via an interpreter, although this was not always necessary. Invariably the interviews were conducted on a one-to-one basis so the possibility of interference from other community or family members was minimised. The interview structure is summarised in Appendix B. The thematic area of the interviews remained consistent across the four case studies and links directly to the research objectives. A "semi-structured" interview technique was adopted to allow the participant to expand on the thematic area and share a depth of knowledge. Furthermore, given the authors role as researcher and practitioner it is important that participants could also respond and ask questions rather than facing a lengthy structured interview.

Water usage surveys

Household water usage surveys were undertaken in March 2007 in Abu Shouk and El Salaam IDP camps (see Table 4-1 and Appendix F). Data was elicited with the aid of national staff from Oxfam, UNICEF and the Spanish Red Cross; survey forms were completed at households, water points and areas where livelihood activities were taking place (such as brick making). The purpose of the survey was two-fold. First, to understand people's water usage requirements as camps became more permanent. Second, to understand issues of water inequity in the camps as inevitably some households were collecting more water than others, particularly as newly displaced people continued to arrive at the camps. In total 550 survey forms were completed and manually entered using SPSS statistics software.

Table 4-1: Water usage survey statistics, conducted in Darfur 2007

	Household Surveys	Water Point Surveys	Livelihood Point Surveys	Percentage of Female Interviews
Abu Shouk Camp	150	100	50	65%
Al Salaam Camp	100	100	50	76%

Applying large-scale household surveys and questionnaires was time and manpower intensive, as is the data analysis. The results presented in Chapter Seven are thus a synthesis of the most pertinent questions from the surveys. The selective presentation of two water usage surveys undertaken in Darfur returns to a methodological concern – because fieldwork was interrupted. However, selectivity is an aspect of interpretation, and as long as the reasons for the selection are made clear, this does not invalidate the value of the results presented (Gearey, 2005).

Water point mapping survey

Water point mapping is a technique to monitoring the distribution and status of point water sources. It can be used to identify problems with the functionality and seasonality of water points and to inform planning of investments and problems to address. As such as water point mapping survey can help to identify some of the common problems to be addressed and places the spotlight as to whether the WASH sector should be engaged in WRA and WRM activities. In September 2011 the researcher was integrally involved in planning and designing a water point mapping survey for Sierra Leone. This involved engagement with multiple WASH sector organisations and government authorities. From 2011-2012 nearly 29,000 water points were mapped using FLOW software installed on android phones. The evidence that emerged from these surveys was analysed by the World Bank, UNICEF and the researcher and made available to decision-makers and practitioners. It was used to generate dialogue and discussion with WASH sector practitioners.

Participatory mapping

Participatory mapping was a tool used with groups of community members in all four case study areas. The initial aim of the fieldwork was to determine the need and demand amongst communities for improved WRM. This was achieved using participatory mapping, which is an inclusive process that allows literate and illiterate people to take part and share their knowledge. It focused on three key aspects: 1) The ability of communities to identify risks to their water supplies; 2) The opportunity for communities to share their knowledge and wisdom of water management; and, 3) To define the logic for pursuing CBWRM in a particular community. Community-level mapping exercises were carried out on nine separate occasions between 2007 and 2013, over the course of a full day at research sites. Facilitation teams consisted of the author, a translator and members of the relevant project staff. The mapping approach was adopted because it is an easy method for eliciting complex data from communities (Mascarenhas and Kumar, 1991; Shah, 1993). After explaining the principle of the exercise, groups were split between men and women. Basic materials were provided for the mapping exercises and participants were asked to get on with drawing, or forming their maps in the sand, with minimal interference from the facilitation teams. Mapping detail was then presented by community members and discussed to ensure accuracy and consensus amongst participants. Data from the physical maps was then transferred onto a wooden board, so the community can reuse it, and the author transferred the information into PowerPoint.

Transect walks

Transect walks were used to validate primary data following interviews and participatory mapping exercises. Transect walks are a participatory tool to gain information on various sources of information to be found within a community's area of responsibility. They are particularly useful for gaining information on natural resources, community water supplies, farming systems and nearby migration routes. In this study transect walks were used to collect information on functioning and non-functioning water points, local water resources (streams, springs, wadis and groundwater resources). Transect walk observations focused on validating or triangulating information provided during the mapping exercise as well as where monitoring instrumentation could be installed so the transect walks formed part of a fixed plan. A simple checklist was used to record performance issues, such as seasonal wells and non-functioning wells.

Hydrometeorological monitoring

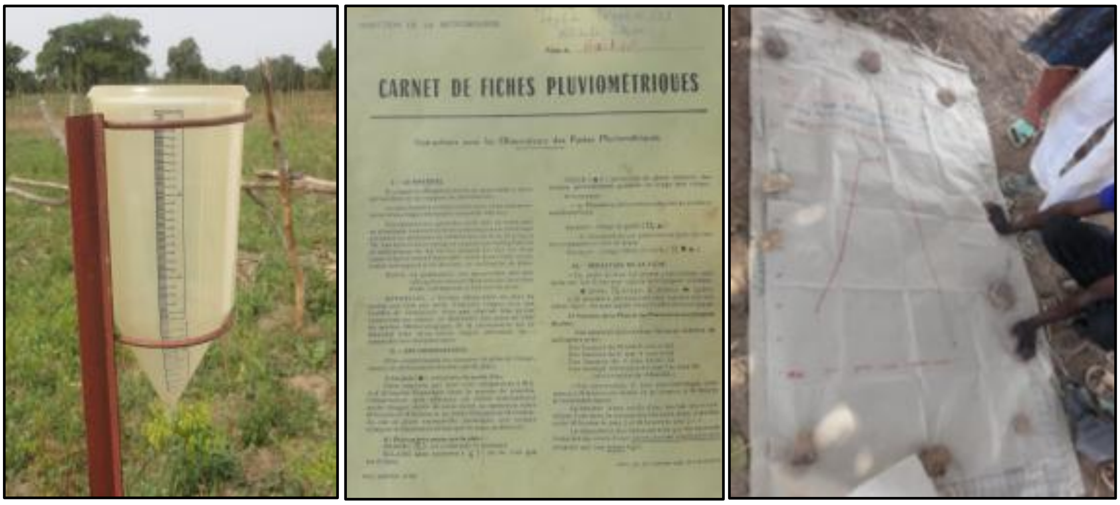
An important component of the field research was the imperative to monitor water resources and in particular water quantity. The justification for this approach is there is currently a lack of hydrological data in many fragile states and, in the absence of scientific data; water management decisions are often based on anecdotes. Following disruption to fieldwork in Darfur and Niger new research sites were established in Burkina Faso and Sierra Leone. Research focused on the following three issues: First, the ability of communities to collect and record data. Second, the development of models of good practice in data collection that could be replicated in a localised and national approach. Third, the ability of government institutions to collect and record data and provide effective external support to community-based institutions engaged in WRAs.

Burkina Faso

Rainfall and groundwater monitoring in Burkina Faso commenced in May 2012 and was conducted across three villages (Kampoaga and Basbedo in Tenkodogo Commune and Sablogo in Lalgaye Commune). These villages lie on a west–east line about 20km long, Kampoaga to the west and Sablogo to the east. Monitoring sites were selected following meetings with communities and local authorities (such as DEIE, DRAH and the Mayor of Tenkodogo). Early discussions focused on the acceptance of community-based monitoring and the instrumentation to be used. For rainfall monitoring, simple plastic raingauges were chosen. The gauges were placed on open ground and fixed to a post at about 1.5m above the ground with the rim of the funnel above the height of the post. Vegetation was cleared around the post and a fence was erected around the raingauge enclosing an area of about 3.5m x 3.5m and about 1.6m high. Volunteer observers (lecteurs) were selected and trained in how to record rainfall (see Figure 4-4). Rainfall was measured around 0900 each day and the reading entered into the record sheet against the date when the reading was taken. During the analysis of the data the values are “thrown back” to the previous day on the assumption that most of the rainfall measured at 0900 fell the previous day. Due to the relatively low rainfall volumes in Burkina Faso and the volume of the raingauge selected there were no concerns that rainfall had overflowed. The community observers plotted rainfall and groundwater data using paper graphs (Figure 4-5).

Figure 4-4: Rainfall observers (lecteurs) in Burkina Faso

Figure 4-5: Raingauge, recording book and community rainfall plot



In each village community members monitored water levels in hand dug wells. Borehole water levels were monitored by DRAH using submerged pressure-transducer water level loggers (In-Situ Rugged Troll 100 total pressure loggers). Manual groundwater levels measured by communities were achieved using a combination of “ploppers” or “whistles” and dip tapes. Ploppers are essentially hollow metal tubes that emit a noise as they reach groundwater. The instruments are only really viable in open hand dug wells. Accurate manual groundwater measurements are important because they provide a means of validation for automated instruments.

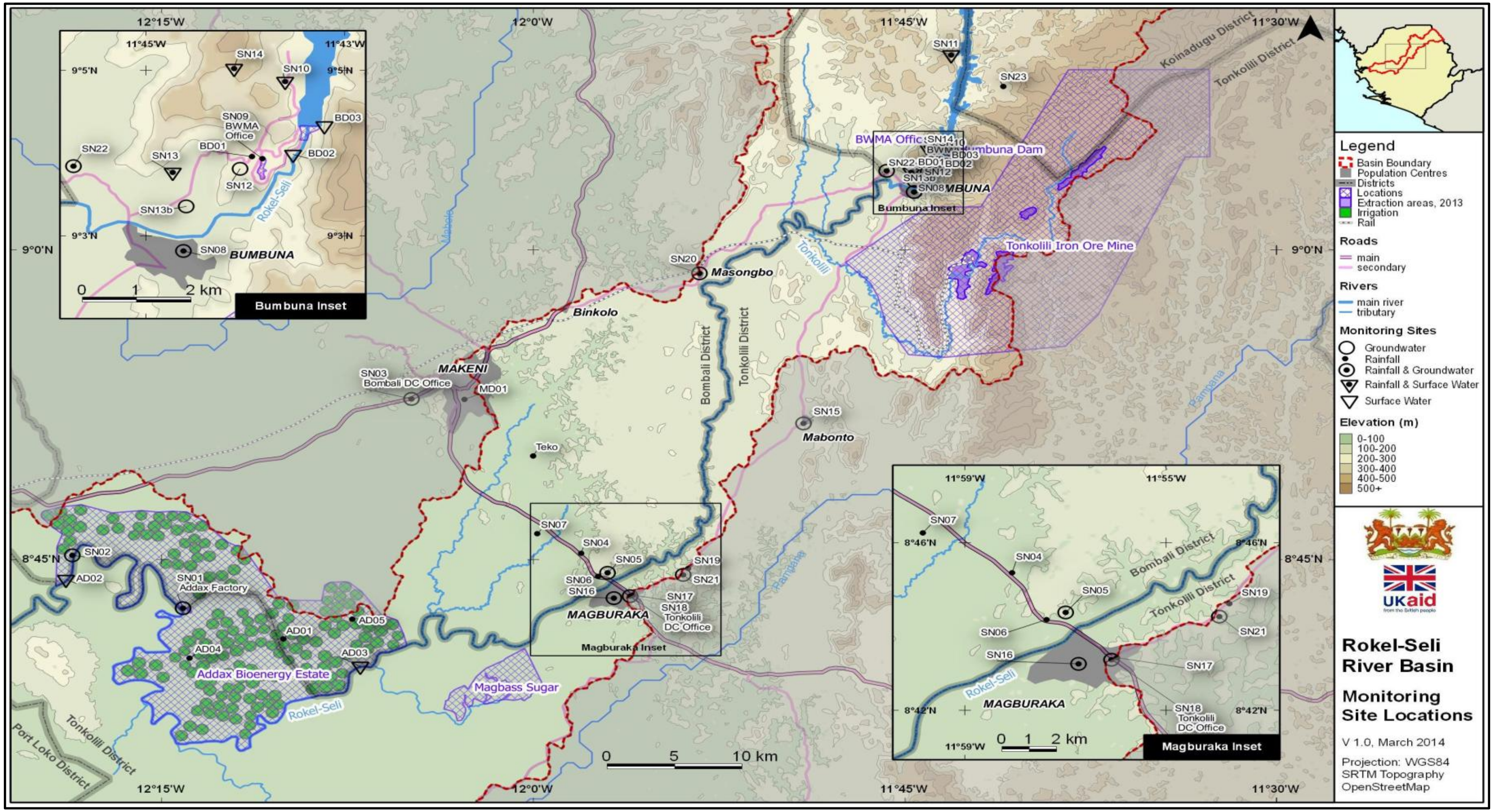
Sierra Leone

Between October 2012 and July 2013 further monitoring sites were established in Sierra Leone. The purpose was two-fold: first, to assess the ability of communities to engage in hydrometric monitoring by comparing the quality of data collected alongside government institutions; and, second, to identify broader problems to be addressed before building a wider monitoring network. The spatial density of monitoring sites in the Rokel-Seli River Basin was greater than necessary for translation into a national monitoring network. However, operating this experimental monitoring network provided many insights into the ability of government to work in support of community-based institutions.

Prior to placement of monitoring instruments, discussions were held with communities, Paramount Chiefs, schools, government authorities and industry. Technical training on the use of monitoring equipment was also provided to government technicians and community members. Focal persons from the Ministry of Water Resources (MWR) and Bumbuna Watershed Management Authority (BWMA) were identified to act as a point of liaison with communities and schools. Monitoring focused on establishing measurements of rainfall, groundwater levels and stream flows, using equipment that was relatively inexpensive and portable. In this study only rainfall and groundwater level data is presented.

Monitoring sites consisted of 11 schools, six community villages, two site investigation boreholes and seven sites within a large agribusiness site, belonging to Addax Bioenergy. A further seven sites were operated and controlled by a mixture of local councils (such as Bombali and Tonkolili District Councils), Sierra Leone Meteorological Department, BWMA and Bumbuna Dam, operated by Salini Construction. Each site was allocated a unique reference number and these are used to reference specific locations in maps and text. Global Positioning System (GPS) coordinates were recorded at all monitoring sites using a combination of GPS devices (Garmin eTrex 10) and an iPhone app (Motion X GPS). The geographical location of all monitoring sites is displayed in Figure 4-6 and a register of all monitoring sites is shown in Appendix C. An example of a rainfall record sheet is shown in Appendix D.

Figure 4-6: Location of hydrological monitoring sites in Sierra Leone



Rainfall

Raingauges were installed at 20 sites with fencing provided at 17 sites, measuring 3.5m x 3.5m x 1.5m high. A 225mm ClimeMET 1016 raingauge that included a 25mm internal cylinder was used for daily measurements by volunteer observers (see Figure 4-7).

Figure 4-7: Installation of a raingauge in Kasokira, Sierra Leone

The procedure for rainfall measurement is described as follows: If all the rainfall was contained in the central graduated measuring cylinder, it was read directly at eye level to the nearest 0.5mm mark on the scale. If rainfall had overflowed into the outer container, then the central graduated cylinder was removed and water poured from this into a separate large storage vessel. To measure the rainfall amount, the graduated cylinder was repeatedly filled to about the 20mm mark and the reading was taken. This process was repeated until all the water had been measured. The totals were then added together. To ensure accuracy, volunteer observers were encouraged to repeat the process until satisfied with the result. If a limited amount of rain had fallen and water had not risen above

0.5mm in the graduated cylinder, observers were asked to record “trace” or “T” on the observers form. If it had rained heavily and the outer (225mm) cylinder had overflowed, observers were asked to record the word “overflow” on rainfall forms. If a reading was missed observers recorded “no data” or “nd.” Figure 4-8 shows school rainfall observers with their raingauge and monitoring guidelines.

Figure 4-8: Installation of raingauge site in Sierra Leone

Daily readings were written onto monthly record sheets by the volunteer observers. Sheets were retrieved monthly by MWR and BWMA. During the West African Ebola outbreak in 2014, monitoring sheets were collected quarterly or whenever possible, as travel restrictions and curfews were imposed in all districts. Once information sheets had been collated, recordings were then typed into MS Excel, although community members did not undertake this work.

Groundwater

Groundwater level monitoring was carried out from nine shallow hand-dug wells and four boreholes distributed throughout the Rokel-Seli River Basin. Because of the number of figures involved, data from only two sites is included in this study. Water levels were recorded at 15-minute intervals using In-Situ Rugged Troll 100 total pressure loggers (see Figure 4-9). BWMA and MWR technicians and communities also recorded manual water levels whenever monitoring data was downloaded and loggers re-programmed. Barometric pressures were recorded at monitoring sites to compensate data from the submerged barologgers.

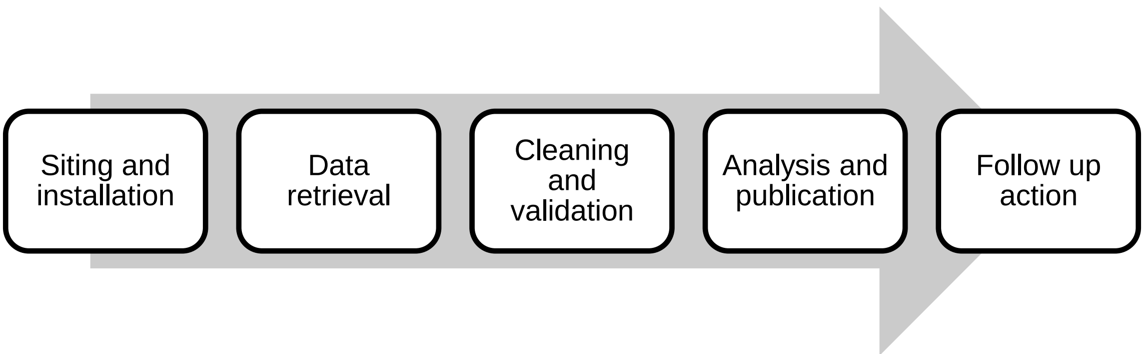
In hand-dug wells, the groundwater loggers were installed inside the top of a 2.5l plastic container that has previously been drilled with 5mm diameter holes and approximately one-third filled with gravel to provide weight and stability while leaving sufficient open depth for the logger. The loggers were secured using Kevlar cord to any convenient point below the well cover, making sure it was safe. If the water level in the well was changing (particularly if the well was in use at the time of the installation) it was necessary to wait until the time the logger starts and re-measure the water level. This was recorded along with the date and time. The well cap was then secured using a padlock where necessary. Figure 4-9 provides an example of a groundwater logger being programmed and installed by government technicians.

Figure 4-9: Programming and installing a water level logger

Scoring methods

For assessing institutional effectiveness in collecting, validating, analysing and publishing hydrological data a three-stage quantitative scoring method was used. The scoring methodology provides a disclosure score, which assesses the level of action taken on hydrological monitoring, evidenced by the institutions past and current practice. As a first step before applying the scoring method the author discussed the core components of a hydrological monitoring process with representatives from the World Meteorological Organisation and senior academics. This provided insight into the critical components of a basic hydrometeorological monitoring system (see Figure 4-10).

Figure 4-10: Components of a hydrometeorological monitoring system



Next, during subsequent meetings and key informant interviews with government institutions in Burkina Faso and Sierra Leone, participants were then asked to describe the hydrological monitoring work they routinely conduct. Participants were also asked to share examples of the hydrological data collected and to explain the process used to clean, validate, analyse and publish data. Scoring of the institutions was completed following further discussions with colleagues, who were aware of the scoring criteria devised and had attended all relevant interviews. Lastly, in order to minimise any potential errors, separate interviews and meetings took place in Tenkodogo, Burkina Faso and Makeni, Sierra Leone, with regional representatives from national hydrometeorological agencies who are responsible for collecting information and those organisations responsible for emergency planning (such as the Office of National Security [ONS] in Sierra Leone). These additional meetings confirmed whether once raw monitoring data has been shared with national offices if there was any subsequent feedback or publication of the data. The use of a scoring method was not ideal, in the sense that it can be subjective. However, due to time and resource constraints it was not feasible to trace the entire process of turning raw data into analysed and published hydrological information. Discussing the scores allocated with colleagues and peers also reduced any possible subjectivity. The outcomes of the scoring method were also compared to current literature that described other researcher experiences in Sierra Leone and Malawi (see Oates et al, 2014).

4.4 Data analysis methods

Hydrological data analysis

Community members recorded daily hydrological data using simple paper-based forms. These forms were collected on a monthly basis either by the author, or a technically trained person, who could identify any obvious problems and raise appropriate questions with the volunteer observer. The paper-based forms were then copied and transcribed into MS Excel format and retained in a safe and organised manner. Once the data was entered into a spreadsheet or other software package it was checked and corrected for any internal inconsistencies or obvious errors. This process is known as data cleaning. There is no formula for doing this – rather it requires common sense and knowledge of the likely ranges of different data values. This was achieved by comparing daily data with neighbouring monitoring sites and historical data that had been retrieved by the author. Any obvious anomalies and outliers were questioned with the observers just in case they were not correct. For the purpose of this study, data has been stored in MS Excel format.

Groundwater data was also analysed by comparing manual measurements with automated instruments and overlaying the data with daily rainfall data. Similarly, daily rainfall data was plotted using cumulative verses average cumulative rainfall. The visualisation of the data combined provided a basis for observing any obvious errors or deviation from nearby monitoring sites. A further key component of the monitoring process was that data was made publically available to all interested parties. An important question that arose during this study is which data should be disseminated – raw data, cleaned data or analysed data. Following initial discussions in Darfur and Niger, it became evident that both communities and government institutions often have limited experience in processing data. In most cases data collected was plotted by communities and government technicians with external support by the researcher or facilitators in order to help people visualise the relationship between rainfall and fluctuating groundwater levels. At community level, data was plotted on large-scale graph paper so that observers could describe the data to other community members.

Reflection

As described in Section 4.2.1 (steps 5–7), data collection and analysis was conducted as part of a cyclical process in accordance with the AR methodology. During data collection field research notes from each activity (such as semi-structured interviews, key informant interviews, participatory mapping, and transect walks) were discussed by the researcher with practitioners and academics together as soon as possible after the research activity. These discussions enabled the researcher's notes to be reviewed and updated as necessary to ensure that emerging themes could be captured and investigated. At the end of each field visit research notes were transcribed into a short report to ensure all information was compiled accurately and could be stored securely. Field notes and transcribed information were read repeatedly to ensure familiarisation with the data collected. This process provided an opportunity to reflect on what "does and does not" work. In-depth analysis was also undertaken when field research was disrupted, and the enforced break between case studies inadvertently provided an opportunity to reflect on the data collected and the evolving approach of CBWRM. Further details of the process used to analyse information collected are outlined in the following sections.

Critical reflection

In November 2012 the researcher joined an international evaluation team to assess some early learning experiences of CBWRM being implemented in Burkina Faso. Reviews were undertaken at three separate geographical locations over a five-day period. The evaluation identified some possible challenges with CBWRM. Three in particular stood out: The first concerned the need to ensure continued, extended support so communities can assimilate, analyse, interpret and act upon monitoring data. Second, the evaluation identified the need to ensure that monitoring equipment (technology) remains appropriate for community-level monitoring. Third, it was evident the standard of data collected by communities must be robust so that it is recognised and respected by local and central government authorities. These important insights were used to inform the CBWRM design process further. Such steps were important because the concept of CBWRM was laid bare to wider scrutiny.

Peer review

The author also presented interim research findings at a number of national and international conferences. This enabled scrutiny of the CBWRM concept and discussions with expert academics and practitioners. The author used these conferences to subject the idea of community-based approaches in fragile states to further peer reviews through a series of public presentations. The key events where presentations were given are shown in Table 4-2 and an example of events organised by the researcher at the ICE is shown in Appendix E.

Table 4-2: Key presentations made by the author between 2009 and 2014

Presentation Title	Location and Date
Moving IWRM from Policy to Practice. A series of four separate presentations followed by a book launch by Sir Crispin Tickell.	The Institution of Civil Engineers (15 December 2009 - 08 November 2011)
Water For All, Forever: Launch of Managing Water Locally: an essential dimension of community water development.	Newcastle University (02 July 2012)
Managing Water Locally: the role of community-based institutions in the management of water resources.	Oxford University Water Security Conference (17 April 2012)
Monitoring and Managing Water Locally for Water Security. Joint presentation with MWR Sierra Leone and WaterAid UK.	Stockholm World Water Week (05 September 2013)
Managing Water Variability and Competing Demands in Complex River Basins: Presentation on the Rokel-Seli River Basin in Sierra Leone.	Stockholm World Water Week (01 September 2014)

4.5 Research methods in fragile states

Working in FCAS presents major challenges and obstacles to rigorous field research and this study was disrupted on multiple occasions. On the 4th March 2009 several international organisations were expelled from Darfur after the President of Sudan became the first serving head of state to face an international arrest warrant for war crimes and crimes against humanity. The operations of 16 aid organisations, including Oxfam and Medicine Sans Frontiers, were shut down immediately with assets confiscated. This decision followed a sustained period of pressure on aid workers with increased intimidation and restricted movement. Inevitably, it also impacted directly on this research and the researcher was forced to look for new study areas. A new study area was set up in Niger in May 2009, also with Oxfam GB. In September

2010 access to field sites in Niger became increasingly difficult following increased activity by groups aligned to al-Qaeda in North Africa. This followed the kidnapping of foreign workers from uranium mines in Niger. The Arab Spring in December 2010 led to further regional unrest and regretfully field research was halted for a second time in January 2011 following the deaths of two French citizens who had been kidnapped in Niamey.

Despite these unforeseen problems, the researcher had been implementing a research plan, collecting and analysing data and communicating the early results with WaterAid who had country programmes in neighbouring Burkina Faso and Mali. The early results and research methodology were shared with WaterAid at two separate learning workshops in September 2009 and October 2010. This enabled field research to continue and the next step in the research plan was to secure additional funding so research could be undertaken elsewhere in West Africa away from conflict hotspots. The disruptions to fieldwork, although unhelpful, did provide an enforced opportunity to diagnose, implement and monitor stages of this research. In recognition of the difficulties, the researcher attempted to develop a systematic approach to research. For example, the research objectives were specified in a clear unambiguous form and they aimed to provide focus to work that could be applied in either emergency or development contexts. This meant the research objectives were not confined to a single context. The literature review was also extensive and included studies that had broad relevance to both emergency and development programmes. The development of a conceptual framework (see Figure 1-3) also enabled complex research activities to be distilled into a few core elements. Working effectively in fragile states requires flexibility, innovation and tenacity. To quote Weinberg (1975): *“If we want to learn anything, we mustn’t try to learn everything.”* Consequently this study focused primarily on WRAs and much less on WRM activities.

4.6 Summary

This chapter described the AR methodology used as the foundation to this research. It also outlined the step-by-step process used in this research and the ethical considerations that were taken into consideration. In doing so the chapter described how the research methodology selection was informed by the extensive literature review. Following this there was a description of the data collection and analysis methods used to generate the data sets shown in Chapters Five, Six and Seven.

5 The role of communities in WRA

This chapter presents interpretation of the data collected in relation to the first of the three research objectives. The purpose of this chapter is to assess the potential ability of rural communities to engage in WRAs. Section 5.1 of this chapter outlines the requirement for participatory monitoring by community-based institutions in fragile states. Section 5.2 presents the results of participatory mapping and monitoring activities from the case study sites. Section 5.3 examines how hydrometric data can potentially lead to better WRM if communities understand monitoring outcomes. The last interpretive section identifies the external support communities require.

5.1 Why community-based monitoring in fragile states?

When discussing participatory monitoring, much hinges on why communities need to be involved in WRAs. After all, some scholars suggest water resource benefits can be achieved by having no stakeholder participation (see Giordano and Shah, 2013; Coleman, 2013). This section provides a succinct explanation as to the situation in fragile states.

The oft-repeated saying is that “you can’t manage what you do not measure (or monitor).” In trying to assess how hydrometric monitoring can be achieved in fragile states, this study argues that participatory monitoring is beneficial because the technical ability of government institutions in fragile states may be modest. For remote rural communities that are dependent on point water sources, participatory monitoring will likely be the only viable approach in the short to medium term. Chapter Two mentioned that water resources in SSA face multiple pressures. However, the direction and magnitude of change is difficult to determine and huge uncertainty exists regarding impacts on groundwater resources (see Descroix et al, 2009). As mentioned in Section 2.2.5, despite growing anxiety over climate change, GCMs are of limited use for local-level adaptation planning. Furthermore, hydrometric monitoring networks are often absent in SSA (Grey, 2012). This combination of unfavourable factors spells trouble for assessing water resource availability. Scholars and practitioners have called for new and better hydrometric monitoring networks to be established. At a minimum, all countries require national monitoring networks for rainfall, surface water and groundwater. However, government institutions in developing countries typically struggle to sustain monitoring networks or fail to make use of the data collected (see Oates et al, 2014). How do these problems affect rural communities and what can they do in the meantime? As mentioned in Chapter Two, there are many examples of self-activated WRM that have been used by populations to exploit surface water and groundwater to satisfy their needs. A related line of argument is that community-based institutions should engage in localised WRAs to strengthen their own resilience, particularly as government reforms require lengthy transitions (Andrews, 2013). The line of reasoning is that a badly governed country, undergoing difficult reforms, may not necessarily generate convincing solutions to the water management problems communities face. For example, IWRM has been widely promoted and for many it is seen as *the only game in town*. However, many scholars (such as Biswas, 2004; Giordano and Shah, 2013) have argued the adoption of foreign blueprints has unintentionally created problems, evidenced by the slow rate of implementation.

Rural communities remain on the periphery of government assistance in many fragile states. These communities will be reliant on point water sources far beyond 2030 (Carter, 2015). Point sources typically consist of wells and boreholes fitted with handpumps drawing from shallow groundwater sources (<60m depth). However, the capacity of shallow groundwater sources to buffer inter-annual rainfall variability is expected to be less than deeper aquifer formations because of low replenishment rates (see Pavelic et al, 2012; Villholth, 2013). Past debate has argued that groundwater use for irrigation would have a negative impact on community water supplies, wetlands and other groundwater-dependant ecosystems (Giordano and Villholth, 2007; MacDonald et al, 2009). More recent studies have proposed that shallow groundwater sources represent a neglected opportunity for intensification of agriculture in SSA. They argue that concerns over aquifer transmissivity, low yields and aquifer vulnerability are exaggerated (see Gowing et al, 2016; Villholth, 2013).

Recent studies highlight governments; donors and NGOs are gradually promoting groundwater irrigation by smallholder farmers in SSA (Gowing et al, 2016). Farmers are also pursuing groundwater irrigation opportunities, driven by low cost technologies and new market opportunities for produce (Villholth, 2013). However, groundwater resources are not evenly distributed (Calow et al, 2010). So it is essential to improve understanding of groundwater availability whether stored groundwater is renewable or non-renewable (Edmunds, 2012). It is clearly the case that without WRAs there would be no controlled abstraction. So the importance of citizen participation in collecting hydrometric data is receiving growing attention (see Gowing et al, 2016). There are three particularly important considerations. The first is the ability of communities to monitor key hydrological parameters. The second consideration is how communities use the data recorded. The third relates to the areas of ongoing government support communities will require. If participatory monitoring is viable then perhaps it can compliment wider government initiatives and help build community resilience.

5.2 Identifying the ability of communities to monitor water resources

A first step in an empirical investigation of participatory monitoring is a clear and workable definition of the phenomenon. This study defines community-based WRAs as repetitive measurements by community members of one or more element of the environment to enable assessments of the current state of water quantity and quality and their variability in space and time. Thus, this study considered three issues: the ability of communities to identify risk, measure water resources and interpret the outcomes of hydrometric monitoring. The following sections of this chapter describe the empirical research undertaken to investigate the first research objective.

To better understand these issues, fieldwork, using semi-structured and key informant interviews, was undertaken in Darfur, Niger and Burkina Faso. In discussing the water situation in the case study areas key informants highlighted the problem of a short rainy season followed by a long dry season over many months. As a result communities have often developed their own informal arrangements to assess water availability. Some insights from Darfur are provided here:

"*We observe rainfall periods or Wadi flows so we can try to determine 'good' or 'bad' rainfall years." [KI-15D]*

"We undertake observations of water levels in open wells based on the number or length of coils of rope left in our hands when hauling water." [KI-22D]

"We mark inside 'brick lined' wells to compare water levels between dry and rainy seasons." [KI-26D]

The principal drivers for customary water management arrangements were two-fold: first, so that communities could organise themselves more effectively; and, second, because they had little confidence in receiving adequate support from government: "*Any help will come from God, but not from government,*" remarked one community leader from Kabkabiya [KI-27D].

Participatory mapping

To better understand risks to water resources a series of participatory mapping exercises were conducted (see methodology in Chapter Four). Community members in Darfur, Niger and Burkina Faso mapped important physical features in their respective villages: such as, land depressions where seasonal ponds form, areas where gardening and irrigation takes place and the locations of functioning and non-functioning water points. Access to safe and adequate water resources differs considerably between wet and dry seasons and it was important to identify seasonal variances during mapping exercises. Community members in the case study areas typically engage in activities such as farming, agriculture or rearing livestock. As a result, water is a productive input into their livelihood activities and great importance is placed on its use. Figure 5-1 illustrates the village level maps produced in Niger and transect walks undertaken. Figure 5-2 shows an example of the village maps produced in Burkina Faso.

Figure 5-1: Participatory mapping and measuring groundwater levels in Banibangou, Niger

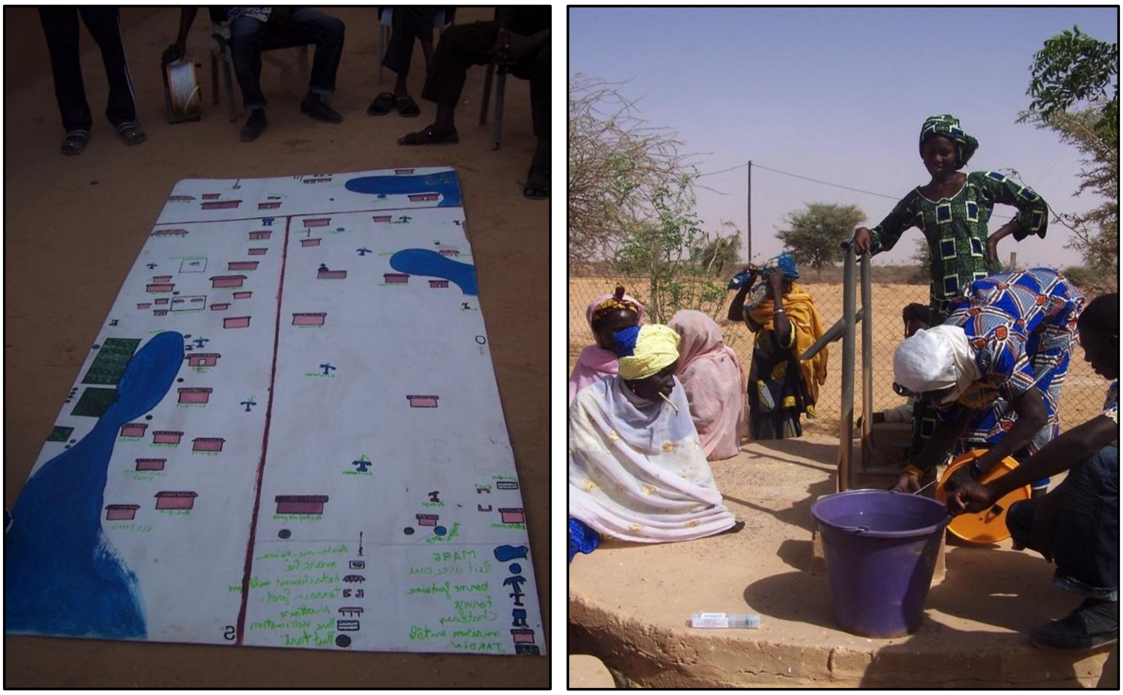
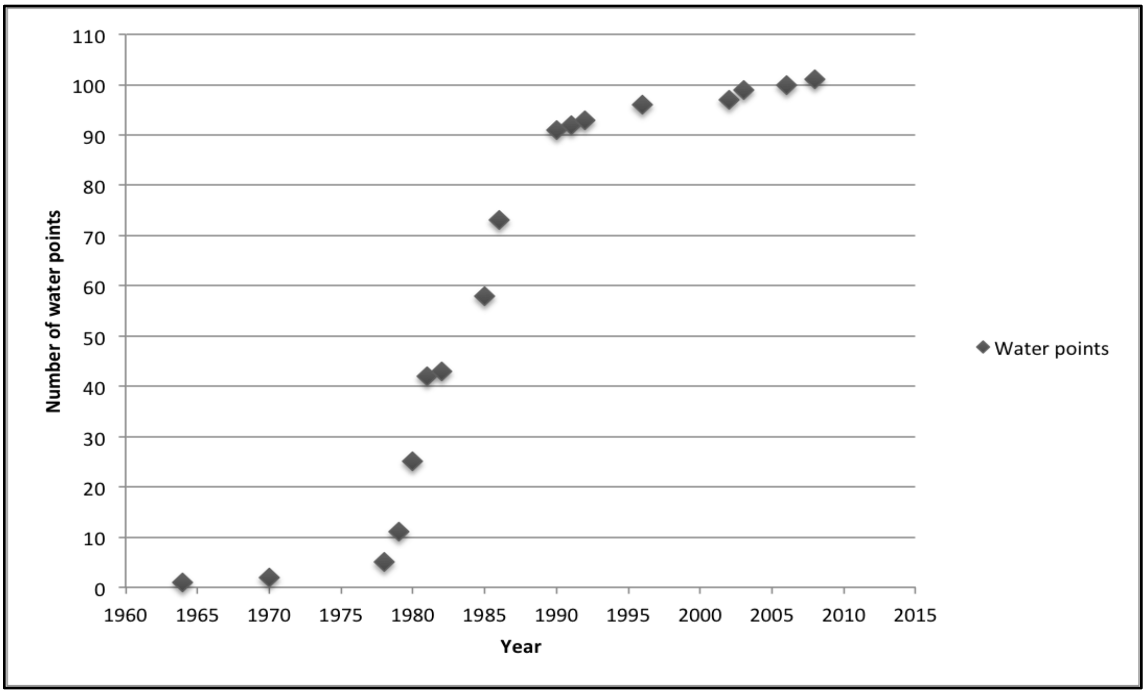


Figure 5-2: Participatory mapping in Basbedo, Burkina Faso

During these participatory sessions the researcher also discussed the question of water point development with older community members. For example, Figure 5-3 shows the relative development of water points in Banibangou, Niger since 1960. Although population growth rates for Banibangou were not available, there is clearly a substantial increase in the number of water points constructed in the 1980s. This was attributed to dozens of shallow hand dug wells being built by an international NGO. The Women's Gardening Committee in Banibangou uses these shallow wells for irrigation, but reported they dry out each year. Follow-up transect walks were used to validate mapped information in all case study sites and the problem of shallow wells running dry was evident.

Figure 5-3: Historical development of water points in Banibangou, Niger



Findings from the various community mapping exercises and transect walks were distilled. The resultant logic was an attempt to generate analysis of the problems rural communities in arid environments face. Box 1 provides an example for Basbedo village in Burkina Faso and attempts to generate a better understanding of why communities may be interested in engaging in WRAs. Following the participatory mapping exercises, transect walks were undertaken to validate the mapped information. A further outcome of the transect walks was the identification of hydrological monitoring sites in the case study areas and combining this information helps to form the agenda of the community.

Box 1: Basbedo village Burkina Faso: an example of the data collected

- The village has 3 Boreholes that function year round. Some mechanical issues but these have been addressed.
- The village has multiple shallow hand-dug wells. Community concerns that uncontrolled abstractions will cause wells to dry up prematurely in the dry season.
- Evidence of water disputes at water points away from the bas-fond.
- A sand dam is located near the village but the body of sand build up is unlikely to have any effect on water resources.

The term bas-fonds refer to inland valleys in Burkina Faso.

A sand dam is a simple low cost water conservation measure that is designed to retain surface runoff and recharge groundwater.

As mentioned in Chapter Three, the context of the case study sites in Sierra Leone differed to those in Darfur, Niger and Burkina Faso. The two major reasons were: first, localities in Sierra Leone receive significantly higher volumes of rainfall (<2,500mm); second, communities are located within a larger river basin that involves major water abstractors. In the Sierra Leone river basin stakeholders undertook a two-day workshop to discuss the water management issues that matter to them. Two questions were posed to workshop participants: What does water security look like? How might the achievement of your water security affect the water security of others? Table 5-1 provides an indication of the different interests and concerns various stakeholders highlighted regarding water resources (quantity and quality) as the basis for supply, or as the recipient of discharges.

Table 5-1: Stakeholder water security discussions in Sierra Leone 2012

Stakeholders	Issues Raised
Rural communities – unserved by improved water supplies	Expressed concerns about seasonality of quantity and quality of (self-supply) water sources (mainly springs and streams).
Rural communities – served by an improved water supply	Cannot take the reliability of their engineered sources for granted.
Energy producers (GoSL and operators of hydroelectric dams)	Concerned to maximise energy production while assuring dam safety. Together these legitimate preoccupations can affect both upstream and downstream communities and entities, which are affected by reservoir water levels or dam releases.
Regulator (GoSL and BWMA)	Concerned about the environmental and social impacts of large-scale reservoir storage, both on lakeside communities and for water users downstream of major impoundments.
Major water abstractors drawing water from rivers	Concerned about quantity and predictability of flows, as well as water quality (depending on the purpose for which water is to be used).
Industry and other entities, which discharge effluent into surface or groundwater	Not adequately concerned about: (a) meeting acceptable standards of effluent quality whether imposed by a regulator or not; and, (b) avoiding potential bad publicity which may arise from failure to observe the highest professional environmental and social standards.

Together Box 1 and Table 5-1 provide an indication of the issues that matter to communities, even in dissimilar contexts. According to community members in all case study areas seasonality of point sources is a major concern. Even in wetter countries, like Sierra Leone, the main observation from communities was: how to manage collective water demand during the dry season period and prevent contamination of water sources from non-regulated discharges. Based on these insights, participatory WRAs were proposed and investigated as a rational first step to address these concerns. For the purpose of this study, the researcher focused on monitoring rainfall and groundwater levels, and how communities can use the data recorded.

Participatory monitoring

This section presents hydrological data sets collected by community members in Burkina Faso and Sierra Leone. Prior to installing simple monitoring instruments, the suitability of raingauges, dip tapes and pressure transducers was discussed between the author and relevant government authorities. In such situations, where negligible hydrometric monitoring is taking place, it would not be surprising if some officials rejected the concept of participatory monitoring, because ordinary people should not engage in scientific work. For example, in a discussion with local council representatives in Tonkolili, Sierra Leone in May 2013 it was suggested that: *"communities will have little willingness and ability to undertake hydrological monitoring"* (KI-15SL). There are many ways an official may reconcile this belief: communities degrade natural resources, water resources should be vested in state control, and community members are illiterate. Furthermore, because government technicians often receive bonuses (per diems) for collecting monitoring data, officials may be reluctant to relinquish monitoring duties to volunteer observers.

Burkina Faso

The data from Burkina Faso is taken from three villages, namely: Basbedo, Sablogo and Kampoaga. Although the data is small in scale it provides a measurable indicator of communities' ability to record hydrometric data. Participatory monitoring began at the end of 2011 and replaced a long tradition where community observations of rainfall and groundwater fluctuations were informal. It is important to introduce the distinction between data collection independently achieved by communities and data presented in this study by the researcher. Volunteer observers recorded measurements on rainfall and groundwater levels using monitoring forms provided to them (see Figure 5-4). Community members have subsequently plotted this information so they can interpret and visualise the changes occurring (see Figures 5-5 and 5-14). However, for the purpose of clarity and analysis the raw data collected by communities has been replicated in this study by the researcher using MS Excel (for example in Figure 5-6 and 5-7).

Figure 5-4: Example of monthly groundwater levels and rainfall recorded by community observers

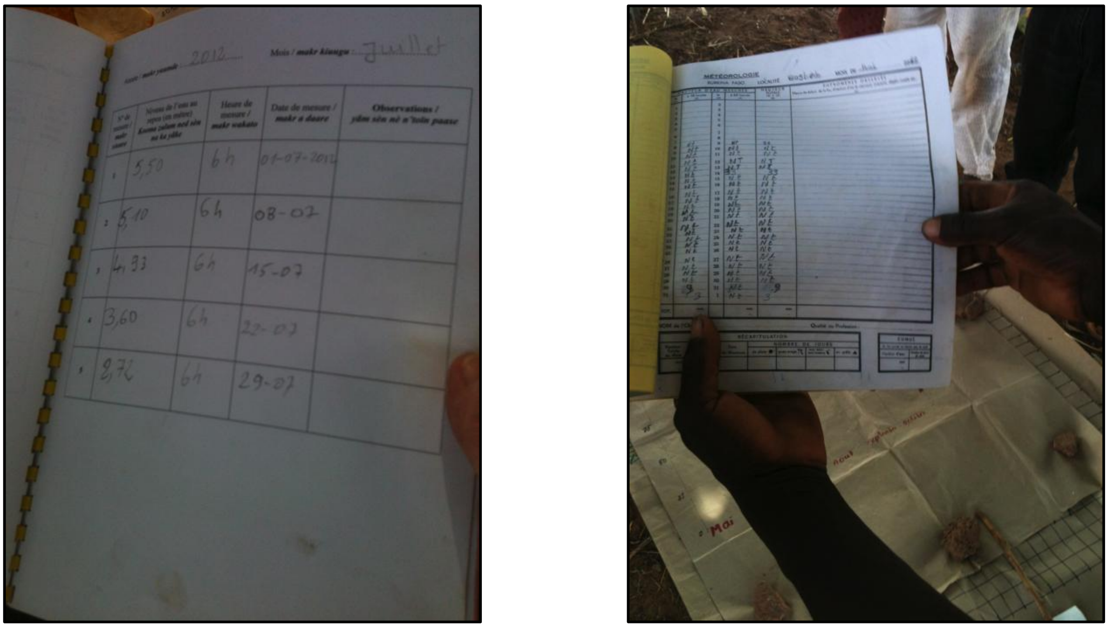
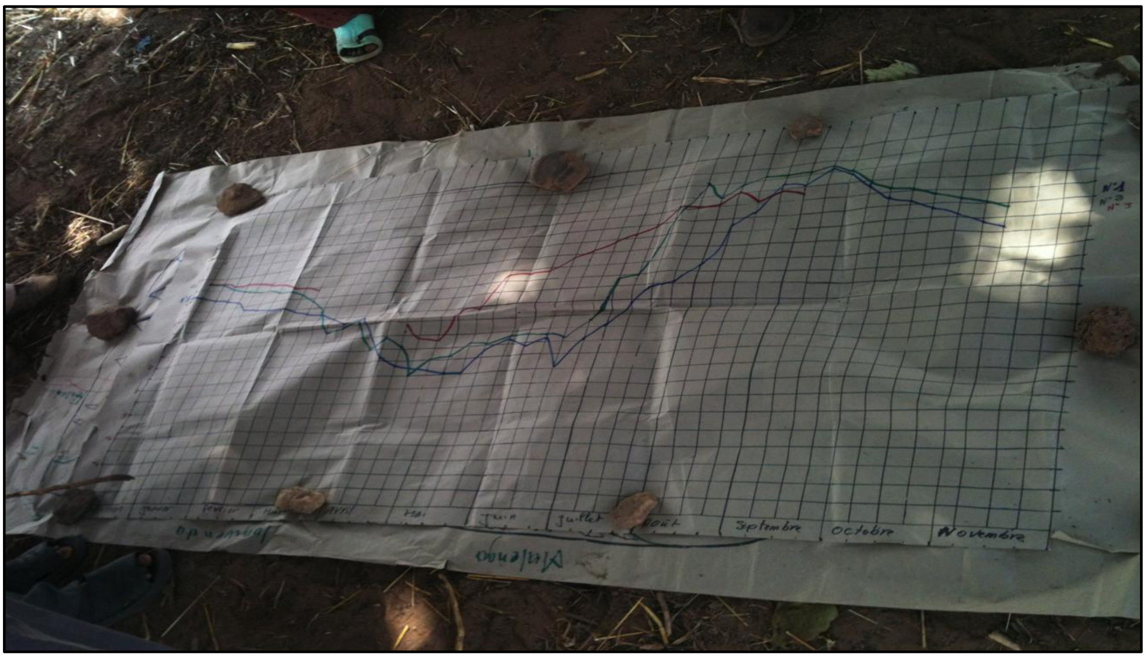
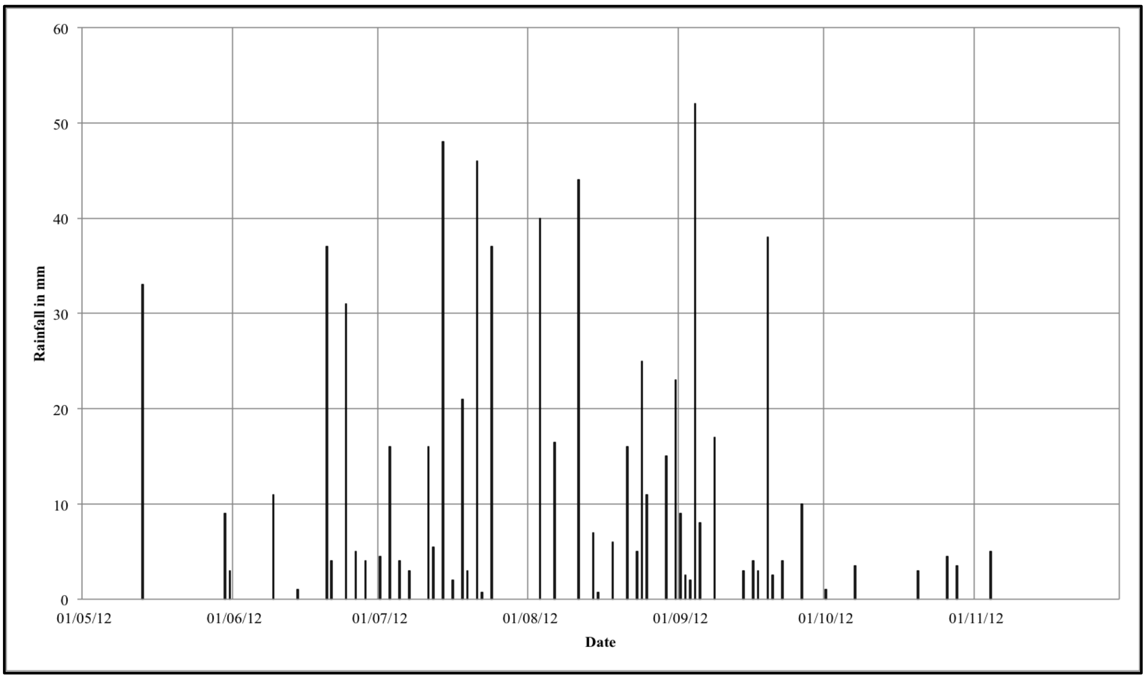


Figure 5-5: Example of groundwater data plotted by community members



The data presented in this study covers the period from November 2011 to December 2012. Figure 5-6 provides an example of rainfall data collected in Basbedo village, with other data sets for Sablogo and Kampoaga shown in Appendix G1 and G2 respectively. Data was collected on a daily basis and it shows that more than 50 separate rainfall events occurred during the 12-month period.

Figure 5-6: Basbedo daily rainfall data, 2012



Selected rainfall statistics (see Table 5-2) show the contrast in rainfall from across Basbedo, Sablogo and Kampoaga villages. The straight-line distance from Kampoaga to Basbedo is 9.7km and the distance from Basbedo to Sablogo, 7.1km. Although well-documented spatial variances in rainfall were evident in Burkina Faso there appears to be a good (plausible) correlation between monitoring sites and the variables shown.

Table 5-2: Selected rainfall statistics: Kampoaga, Basbedo and Sablogo

Variable	Kampoaga	Basbedo	Sablogo
Total rainfall May–October	826mm	730mm	827mm
August rainfall as a total of percentage	25%	29%	24%
Number of rain days (non-zero)	46	54	40
Number of rain days with at least 5mm rainfall	32	28	32
Number of days on which all three stations received some rain			20

Rainfall and groundwater data recorded in Burkina Faso is presented through a series of three figures and supplementary narrative. Once again raw data has been collected by volunteer observers and transcribed and plotted by the researcher. Data combining seven-day rainfall totals (P-7) and groundwater levels for Basbedo, Sablogo and Kampoaga villages is illustrated in Figures 5-7, 5-8 and 5-9 respectively. For the purpose of analysis it is useful to combine rainfall and groundwater data. This helps to show how groundwater levels respond to rainfall, which approximate to reality. Thus the overlays enable people to see the inter-relationships between rainfall and groundwater. The three data sets show that groundwater levels recede steadily in the dry season over a range of 2.5–5.0m before rising again quickly at the onset of the rains in May or June. Data shows that all three of the shallow wells in Basbedo village (Figure 5-7) run dry in the period of March and April (there is a period of missing data for Basbedo 3, but a downward water level trend can be observed). Groundwater levels respond rapidly to rainfall at the start of the rainy season in mid-May and the correlation between rainfall and groundwater fluctuations is apparent. Water level depths do not fall as sharply in Sablogo (Figure 5-8) and the groundwater response to rainfall occurs slightly later in mid-June when compared to Basbedo. In Kampoaga there is a single well (Kampoaga 1).

Groundwater levels in Kampoaga (Figure 5-9) show a continuous recession from December to April before recovery occurs in June. The period of missing data covers the period when the well runs dry completely. Data recorded by community members shows that a number of wells run dry completely and only a small number of wells maintain a usable water level year round. This links back to the original project logic (see Box 1). The rainfall and groundwater level correlations presented in Figures 5-7, 5-8 and 5-9 do not imply that sound WRM is actually taking place. However, they provide confidence in the ability of communities to collect hydrometric data.

Figure 5-7: Basbedo 7-day rainfall totals and groundwater levels (2011–2012)

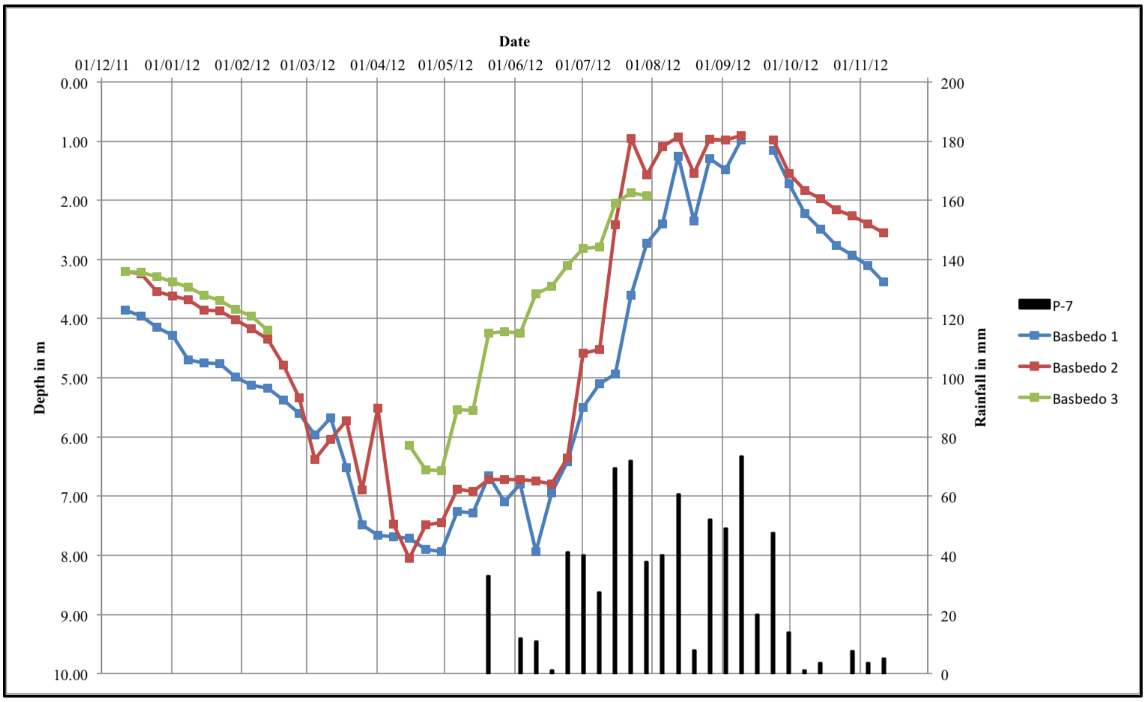


Figure 5-8: Sablogo 7-day rainfall data and groundwater levels (2011–2012)

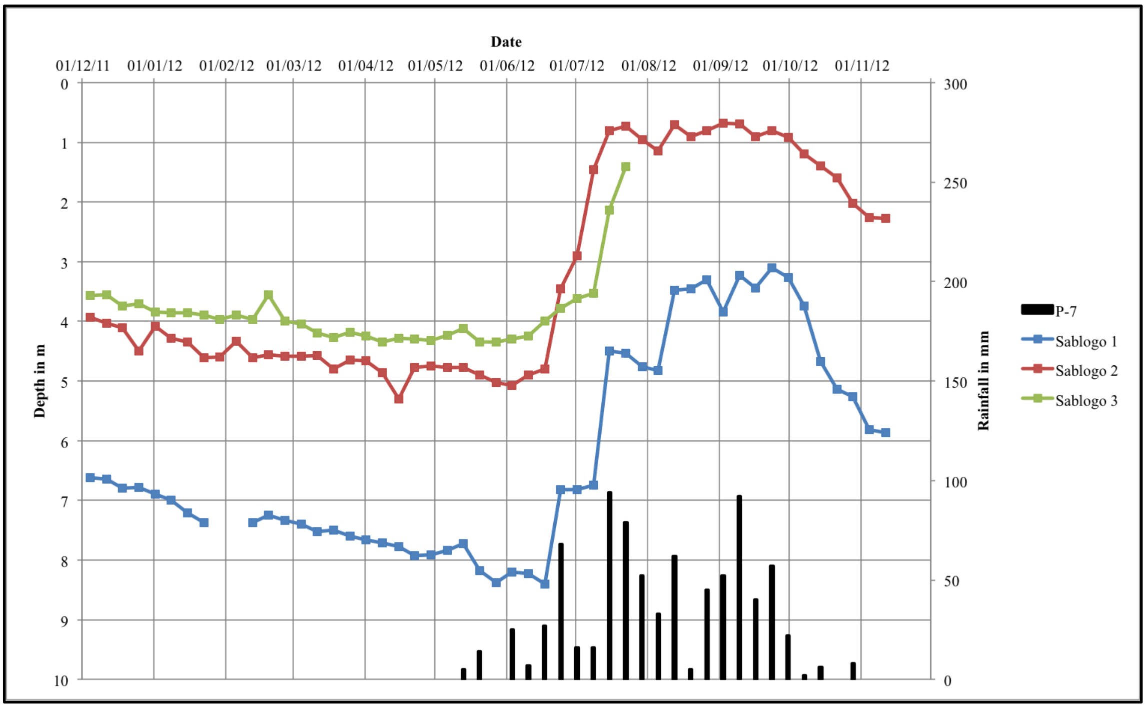
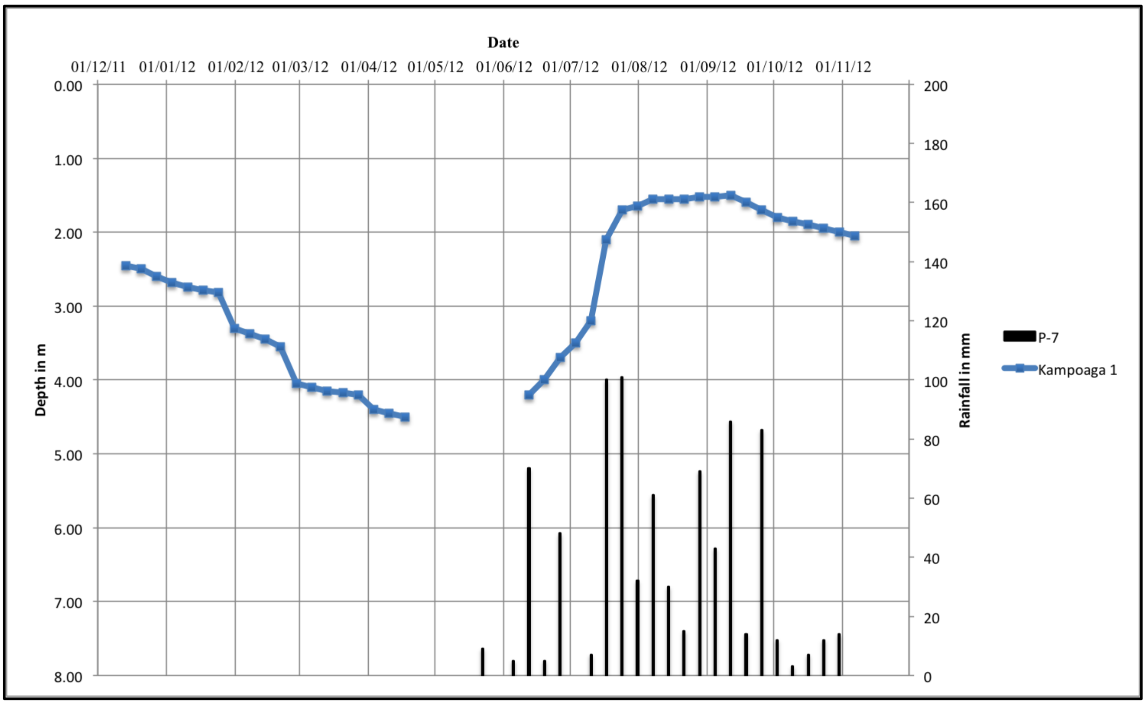


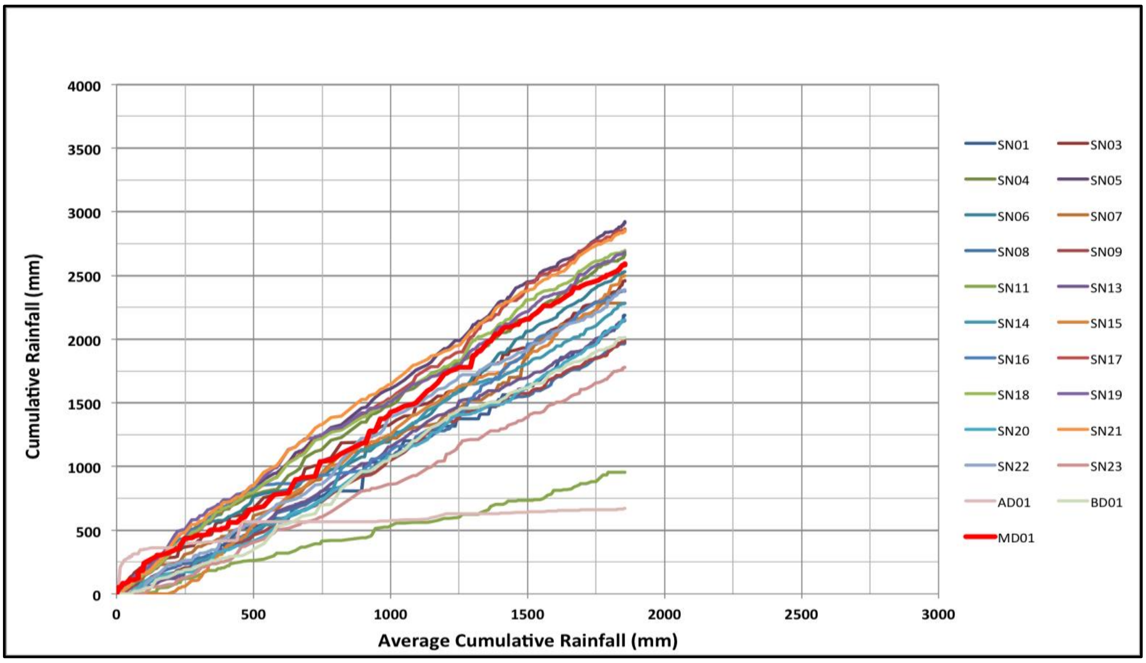
Figure 5-9: Kampoaga 7-day rainfall totals and groundwater levels (2011–2012)



Sierra Leone

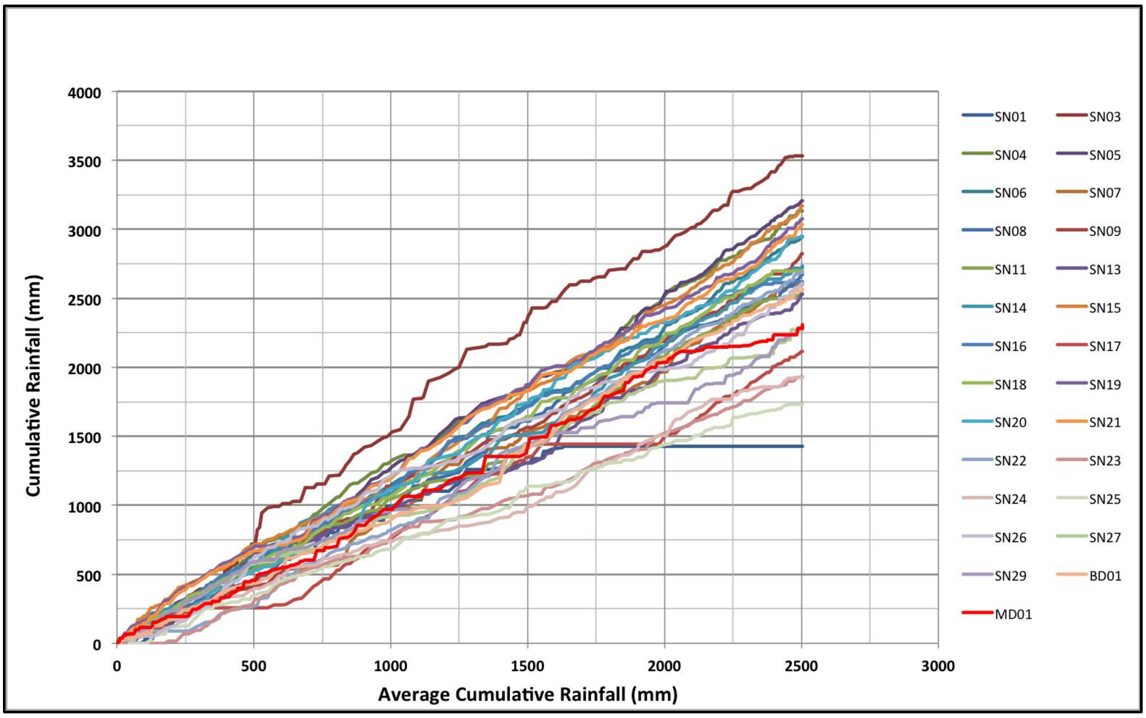
Participatory monitoring was also undertaken in Sierra Leone. A substantial number of daily rainfall records were recorded during this period across multiple sites. Complete records of rainfall data collected by communities and government technicians for the period 2013 to 2015 are shown in Appendix H and these have been replicated by the researcher using MS Excel. As previously mentioned, the ability of communities to engage in WRAs was often the central debate in this study and community involvement in participatory monitoring was not without its critics. Because data was collected at river basin scale, involving both volunteer observers and government technicians, it was helpful to test the data collected by communities for robustness. Evaluation of trends in time-series, such as precipitation or groundwater levels, is an essential element in hydrologic evaluations. The theory behind the Cumulative Rainfall Departure (CRD) method is to understand the temporal correlation of rainfall between monitoring sites, since it is useful as a general indicator of short-term rainfall trends. However, care must be taken not to extend the CRD method over lengthy time periods as it may lead to erroneous results (Weber and Stewart, 2004). Once again the researcher transcribed raw data collected by observers and the graphs were plotted using MS Excel. The theory applied in this study is that if rainfall trends deviated above or below the average over a relatively small geographical area it may indicate erroneous results, because of imprecise or missed readings. Analysis of 2013 data, illustrated in Figure 5-10, shows two monitoring sites with significantly less rainfall then other locations – namely Kakutan village (SN11) and Addax's Automated Weather Station (AD01). It can be observed that the other rainfall monitoring sites maintain a much closer grouping. Kakutan village (SN11) differed from other results because of consistently low readings being taken. This was as a result of problems with measuring rainfall when the inner measuring cylinder had overflowed (see Chapter Four). In follow-up meetings the Addax station was also found to be providing surprisingly low readings when compared to adjacent monitoring sites. The data plot virtually flat-lines, which indicates multiple days when “zero” or very little rainfall was being recorded.

Figure 5-10: Comparison of 2013 rainfall data across monitoring sites using the CRD method



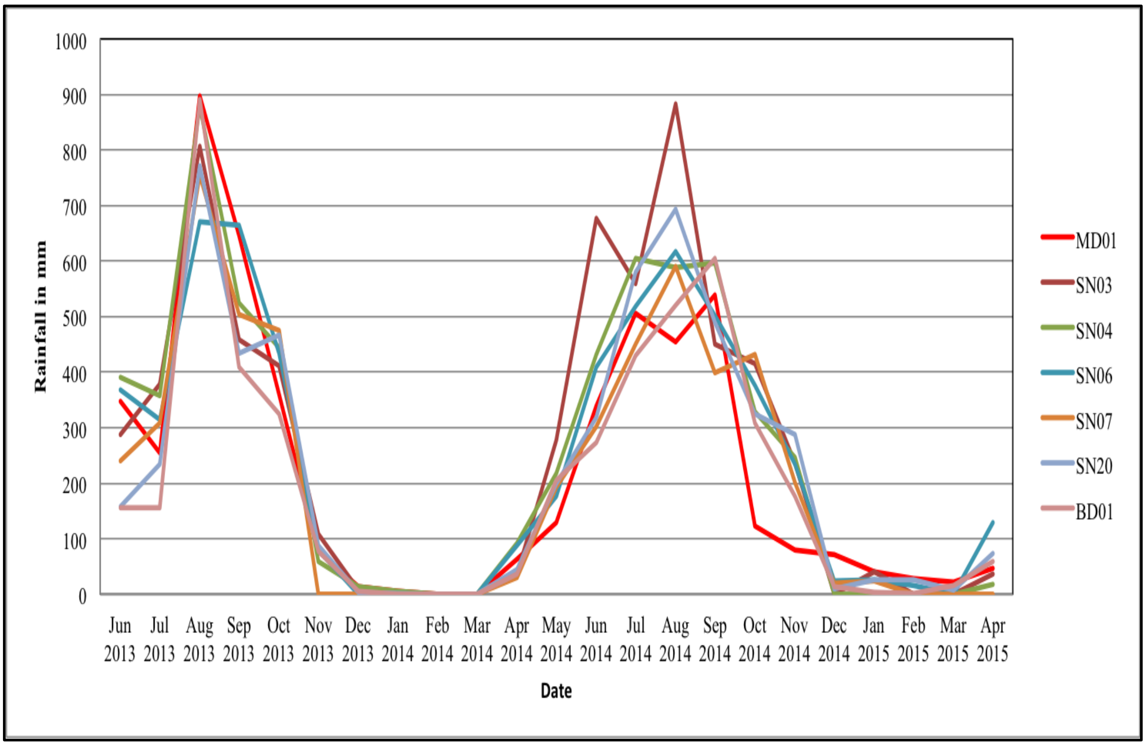
Similarly, Figure 5-11 shows the pattern of rainfall trends in 2014 is more varied. For example, Makeni weather station (MD01), which is operated by the Sierra Leone Meteorological Department, shows a decrease in rainfall, while Bombali Local Council Office (SN03) shows a significant increase (more than 1,000mm), although the sites are less then 5km apart. The monitoring site (SN01) at Addax Estate ceased recording data. Missed readings or misapplication can lead to significant departures from mean rainfall and confuse our understanding of the hydrological system.

Figure 5-11: Cumulative verses average cumulative rainfall 2014



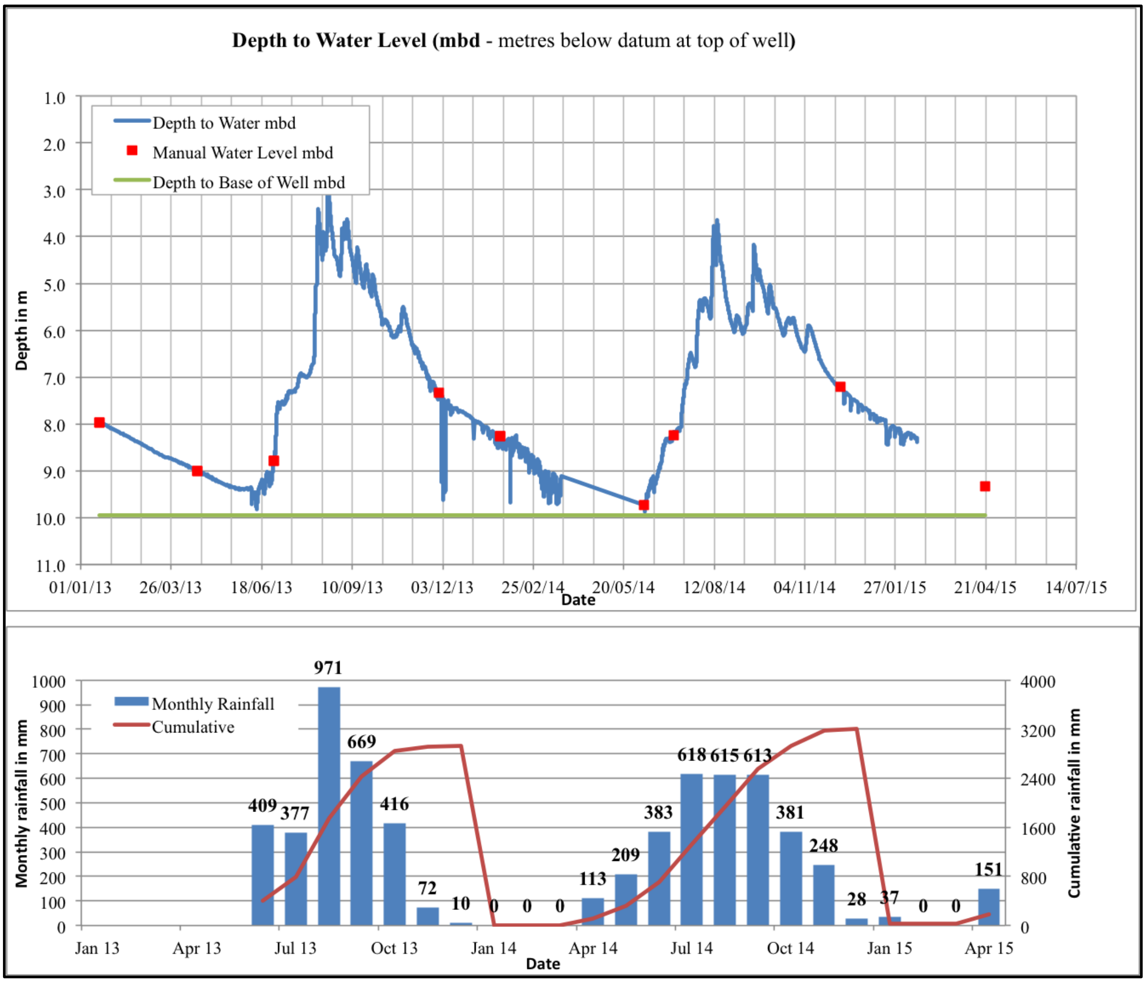
Although it is difficult to determine fully, data presented using the CRD method suggests volunteer community observers record rainfall data with reasonable degrees of accuracy. This proposition can be investigated further by looking at selected monitoring sites in and around Makeni. Figure 5-12 shows the results of cumulative rainfall at selected sites. It shows significant variation in rainfall measurements between Makeni weather station (MD01) and Bombali District Council Office (BD01). Follow-up field visits in 2015 suggest the observed reduction in rainfall at Makeni weather station was primarily due to a number of days of missed readings in August 2014 when the assigned rainfall observer changed. In contrast, data from nearby community sites looks more reliable, largely because there is a much tighter alignment across monitoring sites. So is participatory monitoring a viable approach? For the Sierra Leone data sets presented, two important conclusions can be drawn. The first is that data collection by volunteer observers has continued across multiple sites over a two-year period. This is significant, most remarkably because it covered the time period when Sierra Leone was devastated by the West African EVD outbreak. Second, daily rainfall measurements appear accurate, more so than data collected by national government institutions, including the Sierra Leone Meteorological Department.

Figure 5-12: Daily rainfall data at Makeni Meteorological Station and nearby community sites: June 2013–March 2015



Combined rainfall and groundwater data collected at community sites (e.g. Mayawlaw Primary School) shows a good relationship between daily rainfall measurements and manual and automated groundwater levels. This is illustrated in Figure 5-13. Point sources in Sierra Leone experience rapid direct recharge and groundwater responses to rainfall can be observed almost immediately. Water depths in wells rise quickly before falling sharply in August, once the peak rainfall events have passed. A number of shallow wells do not provide usable water into the dry season, and a similar pattern was observed in a number of monitored wells. This data does imply that groundwater storage in Sierra Leone is extremely limited and usable water levels end in the dry season months of March to May. Despite significantly higher rainfall volumes, shallow groundwater wells in Sierra Leone exhibit similar behaviour to community wells in Burkina Faso.

Figure 5-13: Mayawlaw Primary School: Groundwater and rainfall data



5.3 How does data collection support better WRM?

If community members have engaged in participatory monitoring, it is important that data is analysed and used effectively, otherwise it will serve little useful purpose. This raises a question: What is the role of communities in data analysis? By and large, there are three possible options for analysing data. At one end of the spectrum government institutions may take sole responsibility for sorting, validating and analysing information. However, the potential risk is that data may not be shared with communities and their role is reduced to that of "bookkeepers." At the other end of the spectrum, communities themselves may be expected to analyse and interpret data with minimal assistance. This may be aspirational but not realistic. Another possibility is that data is analysed alongside communities with support from either government institutions or, in the short term, NGOs.

This study had limited resources and limited duration, thus research focused on how communities and government officials could potentially use the data collected. The opportunities in this study focused on two important issues: first, how can communities understand the data collected; and, second, what impact does this ostensibly have on WRM. Having successfully recorded data over many months, community members in Burkina Faso were supported to draw the relationship between rainfall and groundwater levels. The method used was to plot data so it can be visualised to help people understand the relationship between rainfall and groundwater levels (Ziemkiewicz et al, 2011). Value versus time was plotted on large-scale graph paper involving community members, and facilitators from WaterAid (see Figures 5-5 and 5-14). Once the data had been plotted, community members were encouraged to discuss the seasonal trends occurring. During visits to Sablogo, Basbedo and Kampoaga in November 2012, community members were able to clearly describe the relationship between rainfall and groundwater levels. This process enabled community members to picture groundwater fluctuations and the relationship with rainfall. Although the description of groundwater recharge and decline was relatively unsophisticated, the visualisation of data enabled people to better understand the links between rainfall and groundwater levels.

Figure 5-14: Community members in Burkina Faso discussing groundwater data they have recorded

Although understanding the resource is necessary, it is not sufficient to guarantee sustainable WRM (Gowing et al, 2016). A series of semi-structured interviews with volunteer observers and water user associations was held to examine how communities use the monitoring data. Although it was not possible to see improved water management in practice, the researcher used these interviews to obtain the views of male and female community members. According to members of the Basbedo Water User Association the water situation in the village, prior to monitoring, was difficult:

"Water usage was disorderly and people would collect water as and when they needed it." [KI-15BF]

"Shallow water points ran dry and water was collected randomly, with no management systems in place." [KI-16BF]

"No discussions were taking place regarding receding groundwater levels and community water user committees only met when water points ran dry." [KI-17BF]

"Different water user groups would compete for access to water and at times disputes and arguments broke out." [KI-18BF]

The introduction of hydrological monitoring and the visualisation of hydrological data have seemingly led to a departure from these informal arrangements. During focus group discussion participants spoke of a number of key principles being introduced post the WRAs, such as:

"More importance is placed on water. People see the relationship between rainfall and groundwater levels and this encourages discussion on water management." [KI-21BF]

"Communities have established rules for water usage. People are better organised and structured (distinct roles for men and women); and fines are imposed for rule violations." [KI-22BF]

"Water is prioritised between domestic and productive usage. For example limits are set on water usage (5–6 buckets per household)." [KI-19BF]

"Point sources have been separated for domestic and productive use." [KI-17BF]

"Water management problems have reduced and wells last longer during the dry season." [KI-22BF]

In reality these statements alone cannot be used to determine if sound water management is actually taking place. Yet it is important to consider the changes that are apparent. The initial engagement between communities and government authorities encourages both parties to commit to solving real water management problems. Whether this is sustained will depend on the capacity and credibility of both groups. Risk assessments were undertaken, whereby communities map perceived threats to their water resources. Far from being an extractive process where information is only collected from communities, the community members themselves faced the task through problem solving. In reality the mapping exercise will not produce complete information and invariably the actual relationship between rainfall and groundwater movement at this stage is unknown. The communities then set out to monitor the resource with the specific aim of using the data to improve their own knowledge. Intuitively, community members already know the dry season is a difficult period, but previously different water users were seemingly free to abstract water without formal rules or checks being applied, until it was too late. The introduction of monitoring has encouraged community members to discuss water management. The evidence suggests that visualisations help people see things that were not obvious to them before. Patterns regarding groundwater recession and recharge can be observed and it conveys information in a simple manner that can be understood by literate and illiterate people alike. It also encourages people to discuss water management and share ideas. In defining rules for water management, the community is encouraged to reach agreement on the internal WRM actions that can be taken. This is achieved through a participatory process of dialogue (see Figure 5-15) and agreements can be reached to prioritise or ration water usage, and apply graduated sanctions. Importantly, the information problem is overcome because communities have significantly more information on which to base their decisions. Participatory monitoring is voluntary; however, the offer of small incentives also helps to ensure people are committed to the monitoring process. An advantage of this activity is that communities are monitoring the resource over a period of time, rather than simply being presented with data from an external organisation. Thus, the monitoring effort of communities represents an ongoing part of their mitigation measures.

Although limited in scope, the principles adopted by communities in Burkina Faso have connection to the operating principles identified by Ostrom (2008). Current arrangements observed in Burkina Faso include monitoring the resource, setting rules for resource usage and applying graduated sanctions for rule violations. There was less evidence that principles, such as proportionality, were being adhered to, with rationing of water to 5–6 buckets per household per day, regardless of family size. However, it is commonly recognised that the principle of proportionality rarely exists unless the principle of uniformity is also present (Trawick, 2001b). However, this may be difficult to achieve because people are using water for multiple activities and all users are not necessarily engaged in a single activity such as irrigation.

Figure 5-15: Community members in Basbedo, Burkina Faso discussing water management arrangements

Despite promising community feedback, it should be borne in mind it was not possible to determine sound WRM. Analysis of hydrometeorological data and abstraction records would need to undertaken to determine the direct correlation between changing human activities and the water balance. An important question to answer in future research is whether local communities really determine a safe water yield in accordance with the natural rate of recharge.

In Sierra Leone, aspects of WRM were less advanced. Instead, this study looked at people's willingness to engage in monitoring and managing water resources. Community members were asked: *What messages would you have for other communities who were interested in monitoring and managing water resources?* The rationale for this approach is that it provides an indication of the perceptions of volunteer observers. The responses have been grouped and ordered according to the number of times they were stated. When organised in a frequency distribution the important issues raised by communities become more apparent. In statistics theory frequency distributions are visual displays that present frequency counts so that information can be interpreted more easily. Issues commonly raised were:

"To have the spirit of volunteerism and be serious in your work." [11 times]

To safeguard the environment and reduce destruction." [9 times]

"To work with community leaders to establish byelaws for WRM." [9 times]

"To train others to engage in WRA." [8 times]

"To demonstrate the benefits of the work by having a better understanding of hydrology." [5 times]

Although it is important for communities to expand their role, in this study analysis is confined to the important subject of the part that WRAs may play in promoting CBWRM. While it would not be legitimate to extrapolate from this study that communities can manage water resource efficiently, some of the initial criticisms of communities appear misplaced. The value added by communities as partners in WRAs is clear in three respects. First, communities appear highly interested in collecting hydrometric data. This is evidenced by the feedback received. Second, because monitoring collects real scientific data and encourages dialogue on water stewardship, it increases the possibility that communities can build resilience and adapt to local pressures on water resources. Third, being volunteer observers implies that community participation helps to reduce recurrent monitoring costs. This is important because the problem of limited recurrent budgets in government institutions is well documented (see Oates et al, 2014) and is discussed in Chapter Six.

Although the data on participatory monitoring is taken from just two case study sites, some important comparisons can be drawn. One is to compare whether communities would continue to collect hydrometric data in the absence of external support. This is illustrated in Tables 5-3 and 5-4, which shows the number of months of data for each community site and the percentage missing for each parameter. Site by site, the number of months where communities in Sierra Leone and Burkina Faso have recorded rainfall data is encouraging. In summary, 100% of the sites in Burkina Faso had a full record, compared to 76% in Sierra Leone. Volunteer observers appear willing to record data with minimal external support. For example, during the West African EVD outbreak government technicians were unable to visit the community sites on a routine monthly basis. Yet data collection continued relatively unaffected. The author attempted to answer this question by asking the volunteer observers: What is your willingness to monitor and manage water resources? Comparing the responses from the volunteer observers a number of common themes are evident. Once again, the responses have been grouped into answers and ordered according to the number of times they were stated:

"It enables communities and schools to learn and build capacity on rainfall monitoring and water management." [19 volunteer observers]

"The work is interesting, educative but challenging." [14 volunteer observers]

"The work provides us with a better understanding of local rainfall and hydrology." [12 volunteer observers]

"The training and workshops are valuable." [11 volunteer observers]

"The provision of incentives and prize giving is rewarding." [11 volunteer observers]

“The learning process with other communities and schools is useful.” [6 volunteer observers]

Comparing the responses of the volunteer observers provides a believable account of people’s interest. Empirical research provides a good indication that observers will continue to collect data if there is genuine interest, supplemented by small incentives. It is also interesting to consider whether this is atypical of communities elsewhere. During an evaluation of CBWRM work in Burkina Faso in December 2012, one issue that was discussed between the author and peer reviewers is whether communities appear to be active participants in water management simply because it is an issue being discussed – the so-called Hawthorne (observer) effect. This concern can never be fully dispelled, however Table 5-4 shows data collection in the three case study villages in Burkina Faso has been impressive and communities continue to collect data, right up until the time of writing (March 2016) without the presence of the author.

Table 5-3: Percentage of months with complete hydrometric data for all monitoring sites in Sierra Leone

Site number	Monitoring site	Monitoring duration: (months)	Percentage of months with full data
Sierra Leone: June 2013 – December 2014			
SN01	Addax Estate	19	79%
SN03	Bombali District Council	19	100%
SN04	Mayagba CHMS	19	100%
SN05	Mayawlaw PS	19	100%
SN06	Mayawlaw SDAS	19	100%
SN07	Rosinth WCSL	19	100%
SN08	Bumbuna Boyo MBS	19	100%
SN09	BWMA Office	19	100%
SN11	Kakutan	19	95%
SN13	Kamathor 2	19	100%
SN14	Kasokira	19	100%
SN15	Mabonto TDCS	19	100%
SN16	Magburaka BSS	19	95%
SN17	Magburaka NCSS	19	89%
SN18	Magburaka TDC	19	95%
SN19	Maraka SLMBS	19	100%
SN20	Masongbo	19	100%
SN21	Mathora RCPS	19	100%
SN22	Kathombo RCPS	19	100%
SN23	Waia	19	100%
AD01	Addax AWS	19	63%

Table 5-4: Percentage of months with complete hydrometric data for all monitoring sites in Burkina Faso

Site number	Monitoring site	Monitoring duration: (months)	Percentage of months with full data
Burkina Faso: January 2012 – December 2012			
BF01	Basbedo	12	100%
BF02	Sablogo	12	100%
BF03	Kampoaga	12	100%

5.4 Limitations of community-based monitoring and areas for external support

If participatory monitoring is useful to community groups it is helpful to understand what external support from government is required. This section identifies areas for necessary support from government institutions. Superficially, it might appear that communities should be responsible for all aspects of the monitoring process. However, experiences from the operation and maintenance of handpumps show that this can have unfair consequences for community groups. There is a distinction between the roles that can be performed by community members and responsible government authorities (WaterAid, 2011). For the purpose of WRAs it is important to define the boundary clearly so mandates and capacity building activities can be clearly defined. The dividing line between the responsibilities of communities and government will be context specific but the questions of who collects and records information, which organisation validates, analyses and publishes data and pays recurrent monitoring costs are particularly important if participatory monitoring is to be institutionalised.

This study identified a number of areas where external support is required because technical and management problems will likely arise that exceed community member capacities. The first concerns the replacement of damaged or missing monitoring equipment. With rare exceptions, it is unlikely community groups will be able and willing to replace equipment directly. The second concern is that data analysis by communities was relatively unsophisticated. Since community members are not hydrogeologists or hydrologists this is to be expected. Similarly, communities are not likely to be experienced in processing large amounts of data. The third big issue is support to villages in engaging with other stakeholders. Engagement with neighbouring communities and major water abstractors (such as mining companies) is likely to severely challenge communities. So these are areas for government support.

However, the lack of institutional capacity for WRA and WRM, particularly at local and community level remains a major problem (Oates et al, 2014). Many governments in developing countries remain dysfunctional despite substantial institutional reforms (Andrews, 2013). Interviews and training sessions were held with relevant authorities in Burkina Faso and Sierra Leone. Based on these discussions and practical sessions, the technical wings of government were scored to identify their ability to provide external support to communities (see Table 5-5). The arrangements for data collection, validation and analysis were observed from 2012 to 2014. The methods used are described in Section 4.3 and the results are shown below. The methodology is used to explore the ability of government institutions to collate, validate, clean, analyse and publish data. The researcher argues that even if hydrological monitoring networks exist, the analysis, publication and sharing of data remains problematic.

The key elements of a monitoring system were scored as follows: 4 points for a clear demonstration that each element of hydrological monitoring is institutionalised and adequately resourced; 2 points for a correct answer that shows knowledge and appreciation of the monitoring element, even if human and budget resources are constrained; 0 points for an incorrect response or little evidence of an ability to undertake hydrological monitoring. The scoring method is subjective (see Chapter Four). A key issue, therefore, is how this affects the objectivity of the research. Qualitative methodology recognises that subjectivity of the researcher can be a problem if they are intimately involved in the research (Ratner, 2002). However, the researcher argues this scoring method has not distorted the research because several other methods were used to understand the ability of government institutions to process hydrometric data. The scoring system was discussed with colleagues and peers before finalising, and separate one-day workshops were held in December 2013 to understand how institutions collect and process data.

Table 5-5: Review of institutional ability to process monitoring data in Sierra Leone

Component	Ministry of Water Resources	Bumbuna Watershed Management Authority	Environmental Protection Agency
Placement and installation	4	4	2
Data retrieval	4	4	2
Cleaning and validation	2	2	0
Analysis and publication	0	0	0
Follow-up action	0	0	0
Total	10	10	4

Table 5-5 highlights variation in the ability of government institutions to undertake all components of a monitoring process. It should also be borne in mind that placement and installation of monitoring instruments and data retrieval has only been possible in Sierra Leone after substantial external technical assistance was provided. Although a rigid scoring system was not applied to government institutions in Burkina Faso, the pattern that emerged during interviews corroborates experiences in Sierra Leone. For example, the government has established 54 groundwater-monitoring sites across Burkina Faso. Groundwater monitoring started in the 1990s and water levels are reportedly measured on a weekly basis using manual dip tapes (termed sondes). Data is stored on a website: www.eauburkina.org and covers the period 2009–2012. However, there was no evidence during meetings with Plan d'Action pour la Gestion Intégrée des Ressources en Eau (PAGIRE) in December 2012 that information is routinely published and shared with communities. Common problems cited by government technicians included difficulties in maintaining monitoring networks and ensuring analysed information leads to appropriate follow-up action.

5.5 Summary

This chapter introduced the potential role of rural communities in participatory monitoring. Through the course of this chapter the ability of communities to map and monitor their water resources was examined in detail. If participatory monitoring builds the resilience of rural communities in fragile states and contributes to local WRAs, it is reasonable to expect the practice to be supported by responsible government institutions. Based on the evidence presented, this study argues the principles of subsidiarity and modularity should be introduced into the monitoring process, so the potential benefits of WRAs for remote rural communities are not solely dependent on the actions of central government. The next chapter builds on these findings and explores potential bottlenecks to community participation.

6 Identifying barriers to community participation

This chapter covers the second of the three research objectives and explores barriers to community participation in WRM. Section 6.1 highlights why external support from government institutions is necessary to bridge external communities. The next section discusses the importance of meaningful decentralisation and adherence to the principle of subsidiarity. It includes experiences of decentralisation in the case study areas and provides evidence of unwillingness of central authorities to cede power to local-level institutions. This will help to identify some of the main bottlenecks that hinder meaningful decentralisation and engagement with “lower” level institutions. Section 6.3 contemplates what risks must be overcome to strengthen community-based approaches. This chapter is important because it provides an analytic review of the downstream aspects that hinder community participation. The brief insights provided in this section provide a narrative of common problems that exist in FCAS and help to make sense of the problems that hinder community participation. Additionally it yields some explanation of the problems that should be addressed if local level WRM problems are to be addressed. In this chapter I seek to judge barriers to community participation as a term closely bound up with “subsidiarity” which is central to many government decentralisation efforts. The issue of whether central government is willing to decentralise resources and clarify institutional roles and responsibilities is accepted as an important component of subsidiarity. This is because lower level institutions and citizens know what is expected of them and have the resources to perform their roles effectively. As this chapter shows, there are a number of obstacles to community participation that need to be addressed if governments are going to monitor and manage water resources locally.

6.1 Why examine the role of government?

The need for effective support for community management structures has become pervasive in current literature and thus demands attention (see WaterAid, 2011). As outlined in Chapter Five, it is unrealistic to expect community-based institutions to undertake WRAs without any external support from government. A sophisticated interpretation of monitoring data, replacement of damaged monitoring equipment, or engagement with major water abstractors are all likely to challenge communities, which makes support essential.

The role of government in managing natural resources is fundamental. In developed nations, governments regularly have custodial rights of water resources for their citizens. Government must manage water resources in their custody, in such a way so they maximise their value to citizens (Collier and Venables, 2008). In fragile states these arrangements are often ambiguous. However, the very act of rebuilding nations affected by conflict and war confers rights on their citizens – especially the poor (Collier, 2009). Their interests should not be dismissed as governments undergo lengthy transitions, which include a commitment to decentralise. Thus, the goal of external support should be fostering adaptive capacity through ongoing incremental improvements (Andrews, 2013). This requires government to have professional institutions. Nonetheless, Chapter Five highlighted that the technical wings of government require considerable support to professionalise. This requires adjustments in institutions, which Andrews (2013) argues are stubborn and difficult to change. This raises questions concerning how much institutional change one should expect in fragile states.

6.2 Characteristics of government institutions in fragile states

A sound appreciation of government institutions in fragile states is necessary to fully understand the bottlenecks that need to be overcome in order to address the principal–agent problem. This refers to an agency or institution that makes decisions which adversely impact on other groups. Significant problems in the case study areas were evident. Authoritarian states have a poor record of environmental stewardship and accountability to their citizens (Giddens, 2009). The credibility problem is likely to be important because mutual trust must exist between government and citizens. Data collected in this study showed the potential benefits of working in partnership with government are not always obvious to remote communities that feel excluded. In all cases the delivery of safe, adequate and affordable community water supplies has been frustratingly slow for communities. This can easily lead to a sense of apathy and deep frustration towards government:

"Government has done nothing for us." [KI-12N]

"Any change will come from God, but not from government." [KI-27D]

Communities in the case study areas believed that WRM should have a socially useful function, because government reforms take time. This concern is borne out from responses received during interviews with key informants in Ghana and Sierra Leone:

"It has taken ten years for Ghana to establish its first river basin board, after the Water Resources Commission was established." [KI-1G].

"Sierra Leone has a roadmap for implementing IWRM, which was developed in 2004. However, since then we have been unable to start the process." [KI-12SL]

"Sierra Leone has been drafting a new water resources law. This process began in September 2011 and as of March 2016 it is yet to be officially passed by cabinet." [KI-11SL].

Furthermore, Sierra Leone failed to achieve its National Water and Sanitation Policy targets (set in 2010) by some considerable distance, which should have been realised by the end of 2015. Thus, despite good intentions the rate of implementation and engagement with communities has been slow. Data illustrates that the communities are frustrated by these delays because they want real water management problems to be resolved in a timely manner. However, one of the main reasons for community scepticism during any reform process was because people felt rules and laws imposed from afar might undermine existing local management arrangements:

"Community members must be fully involved in managing water resources and establishing local byelaws." [KI-24SL].

In Darfur scepticism of government intentions was more pronounced and local stakeholders often spoke of the historical problems that had been created by government in Khartoum:

"The talaig[18] *was a historical agreement between nomadic tribes and settled farmers regarding access to fertile rain-fed lands. In the 1990s central government fixed the time for the talaig, which provided much less flexibility if the onset of rains was late and the harvest was delayed. Previously the system had worked well through a process of local dialogue and negotiated access to land and water"* (Key informant: KI-7D).

The institutional problem

Sound WRM requires integration across a number of previously separate functions (see Haigh et al, 2010). The institutional problem arises because fragile states may have experienced years of conflict, chaos and under-investment. Government institutions are inevitably affected because normal development activities are essentially suspended. The skills and knowledge of government technicians may be sidelined as authorities struggle to cope with large-scale human displacement and the destruction of water infrastructure. The role of institutions is also shaped by politics and society. Some communities may mistrust government institutions, informal institutions may emerge during periods of anarchy and in the aftermath of conflict institutions, and communities may need to reconnect so trust can be re-established.

From the outside looking in, it can be difficult to determine what the specific capacity constraints of institutions are. It is important to understand what obstacles must be overcome if institutions are to provide effective external support to communities. Data in Table 6-1 shows that as of 2012 institutional roles and responsibilities in Sierra Leone for managing water resources was shared across nine separate central institutions and there is wide disparity over responsibilities that continues today despite the establishment of a standalone

[18] The term talaig refers to migration and grazing by livestock.

MWR in 2013. A related concern is that institutional activities are not coordinated and information is not adequately shared. Consequently, the decisions and actions of one institution may take precedence over and constrain the work of another.

Table 6-1: Institutional roles and responsibilities identified in Sierra Leone

Ministry or Agency	**Responsibilities**
Ministry of Energy and Water Resources	Domestic water supply, including oversight of two national water utilities – Guma Valley Water Company and Sierra Leone Water Company. Water quality testing at water points (handpumps, boreholes, springs and tapstands). Allocation of water for hydroelectric power and assessing energy potential based on available river flows.
Ministry of Health and Sanitation	Safe drinking water quality at household level.
Ministry of Agriculture, Forestry and Food Security	Provision of water for agribusiness, farmers and growers (such as coco plantations) and issuing water abstraction permits.
Ministry of Mines and Mineral Resources	Awarding water rights, abstraction licences and regulating mining activities (such as gold and iron ore mining).
Ministries of Fisheries and Marine Resources	Safeguarding water quality in coastal waters, estuaries and inland lakes.
Ministry of Lands and Country Planning	Land management and oversight for changes in land use. In Sierra Leone land is managed and allocated in agreement with administrative boundaries, not river basin boundaries.
Environmental Protection Agency	Mitigating and regulating air, water and land pollution. Ensuring compliance with Environmental Impact Assessments.

Meteorological Department	Meteorological data collection and weather forecasting.
Office of National Security	Planning for floods and drought and water-related disasters.

For example, field visits to Makeni in August 2013 revealed regional staff at the ONS had no knowledge of a meteorological station installed in Makeni decades previously and still functioning to this day. The ONS in Sierra Leone is responsible for planning for floods, drought and national emergencies. An understanding of roles and responsibilities has partially improved since 2013 following the creation of a separate MWR. However, inter-ministerial cooperation remains weak, evidenced by the fact that no national coordination meetings on WRM have been held since 2013.

The decentralisation problem

Sound WRM requires government to adopt the principle of subsidiarity. This principle is established in Article 5 of the Treaty on European Union and is fundamental to the functioning of the EU and more specifically to European decision-making, which influences much WRM policy in SSA. In summary, it emphasises the importance of decisions being taken near to citizen level and the maxim is essentially: Whatever communities are willing and able to do, they should do. For example, the principle of subsidiarity has been central to Rwanda’s decentralisation effort, notably in fostering relationships between government and citizens. Andrews (2013) highlights the process of decentralisation takes time, must be incremental, requires a localised focus on problems and contextual realities, and requires the formation, through bricolage, of hybrid institutions.

The act in which central government cedes power to actors and institutions at “lower” levels is referred to as decentralisation. Many international organisations (such as the International Monetary Fund and the World Bank) support decentralisation because the approach aims to address the shortcomings of a centralised state (Ribot, 2002). There is not a single African country where some form of local government is not in operation; for example, Ethiopia, Ghana, Mali, Namibia, Nigeria, Senegal, Sierra Leone, South Africa and Uganda have constitutions that are explicitly pro-decentralisation and formally recognise the existence of local government (UNCDF, 2000; Therkildsen, 1993). Thus decentralisation aims to increase local empowerment, reduce poverty, increase administrative capacity, reduce corruption and improve efficiency (Ribot, 2002).

Many fragile states are encouraged to decentralise as a response to government failure and as a means to make government service delivery more efficient, responsive and accountable (Kim, 2008 in Ryan and Woods, 2015). A key argument is that if a government is closer to the people it serves, people will be more accepting of government authority (White, 2011). As Chapter Two mentioned, the implementation of IWRM is seen as requiring more centralised policy and development, with the risk that institutions are slower and more bureaucratic (Pahl-Wostl et al, 2007). This model reflects the centralisation of water management that occurred in Europe, as control of water resources shifted from communities to the state (Bakker, 2003). Some scholars have proposed that polycentric governance systems with appropriate levels of central and local institutional responsibility provide the best opportunity for success in managing natural resources (Ostrom, 2012). This is because the government has responsibility to ensure local stakeholders are part of a single coherent system (Green, 2012). However, in some circumstances (such as China) it has also been argued that stakeholder participation in decision-making is not necessary in WRM (Giordano and Shah, 2013).

There are various dimensions of decentralisation, which include: fiscal, administrative and political. In summary, meaningful fiscal decentralisation demands that local government expenditures are proportionate of total revenues and local government have necessary decision-making and revenue-generation powers. Administrative decentralisation focuses on giving local government the right administrative controls, such as transferring managerial responsibility with the necessary resources. Finally, political decentralisation focuses on the ways political activities in a region or district are conducted at the local level, as opposed to the national level. Decentralisation in WRM has often been viewed positively because it encourages water management problems to be resolved locally, with local institutions able to devise and enforce rules. For example, the Local Government Act (2004) provided the legislative framework governing decentralisation in Sierra Leone. Qualitative data collected in Sierra Leone shows government reforms have remained excessively centralised, despite the establishment of a national Decentralisation Secretariat[19]. During meetings with the Decentralisation Secretariat it was suggested:

"The performance of individual ministries to decentralise has been mixed, and there are serious questions concerning willingness to decentralise." [KI-14SL]

A key finding in their evaluation work is that the MWR[20] has consistently performed badly with regards to surrendering roles to local councils. A common argument put forward by central government is that local councils "*lack capacity*." The pattern that commonly emerged at coordination meetings and annual Sector Performance Reviews was to look at the shortcomings of local councils, rather than how local capacities can be strengthened. A possible reason for this is the struggle for limited financial resources. Other problems cited include:

"Central government staff members are reluctant to work at local council level, because promotion opportunities are restricted and career ceilings are imposed." [KI-2SL]

"Staff payroll remains centralised and the centre claims local government cannot manage their own payroll." [KI-1SL].

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[19] The Decentralisation Secretariat was formed after Sierra Leone's civil war ended in 2002 under the Institutional Reform and Capacity Building Project funded by the World Bank.

[20] The Ministry of Energy and Water Resources split in 2013 to form separate ministries for energy and water resoures respectively.

Human resource capacity at state level is also often constrained. Table 6-2 depicts the changes in staffing levels of technicians at the MWR at central and local level from 2011–2015. During this period, staffing at local council level was re-organised and the number of middle-grade staff increased. However, specialised capacity for WRM has remained largely stagnant, evidenced by the fact that no hydrologists or hydrogeologists have been recruited. Furthermore "*local government budgets currently exclude funding for WRM"* [KI-2SL].

Table 6-2: Changes in MWR staffing levels 2011–2015

Department	Changes in central level staff (2011–2015)	
	2011	**2015**
Water Resources Management Unit	1	2
Policy Unit	0	1
Urban Water Supply Unit	1	1
Rural Water Supply Unit	1	1
Monitoring and Evaluation Unit	0	1
Water Information Mapping Unit	0	0
Number of technical staff deployed to local councils (district engineer, district supervisor, mapping engineer)	14	36
Total	17	42

The finance problem

Chapter Two mentioned how with growing concerns over climate change more attention is now being paid to stewardship of water and land resources. The ideal system is that countries would be incentivised to manage water and land resources thereby reducing the risk of deterioration. However, developing countries are often excluded from funding mechanisms because of the difficulty in enforcing and validating agreements (Collier and Venables 2008). A well-motivated country that is concerned about water management problems may reasonably take the view to increase expenditure to protect water resources. However, evidence from Sierra Leone suggests expenditure on water resources remains limited, even after the creation of a standalone national ministry. Table 6-3 displays the annual budgets for the Water Resources Unit (based at MWR) and the anticipated National Water Resources Management Agency (NWRMA) budget. During the period 2013 to 2015 annual budgets have steadily increased but do not exceed £55,000 per annum. Funding has been set aside for the establishment of the NWRMA, but remains limited.

Table 6-3: Annual and projected operational budgets for WRM provided by the Ministry of Finance and Economic Development 2013–2017

	Past and current funding			**Projected funding**	
Year	2013	2014	2015	2016	2017
Ministry of Water Resources	£30,770	£42,000	£51,755	£58,215	£65,492
National Water Resources Management Agency			£57,230	£64,385	£72,430

Data in Table 6-4 is taken from the Sierra Leone Agenda for Prosperity (A4P). The domestic and foreign funding figures show that both GoSL and its development partners have committed to increasing funding for the sector. Water and sanitation financing for the period is projected to increase from a baseline of about £3.4 million in 2013 to an average of about £18.9 million during the four years 2014–2017[21]. However, despite more than a five-fold increase, funding for the protection of water resources remains limited, compared to investment on WASH infrastructure. In comparison, the Scottish Environment Protection Agency (SEPA), which also covers a relatively small and "wet" country of a similar size to Sierra Leone, has an annual operating budget of £75.5 million[22].

Table 6-4: Sierra Leone A4P estimates (in millions GBP) 2013–2017

	2013	**2014**	**2015**	**2016**	**2017**
Water and Sanitation	3.37	13.22	20.63	22.41	19.18
Water Resources Protection	0.02	0.13	0.13	0.26	0.13

Interviews with the MWR[23] staff revealed that funding for WRM in Sierra Leone is principally reliant on foreign donors. Respondents in government stated the lack of funding creates two additional problems:

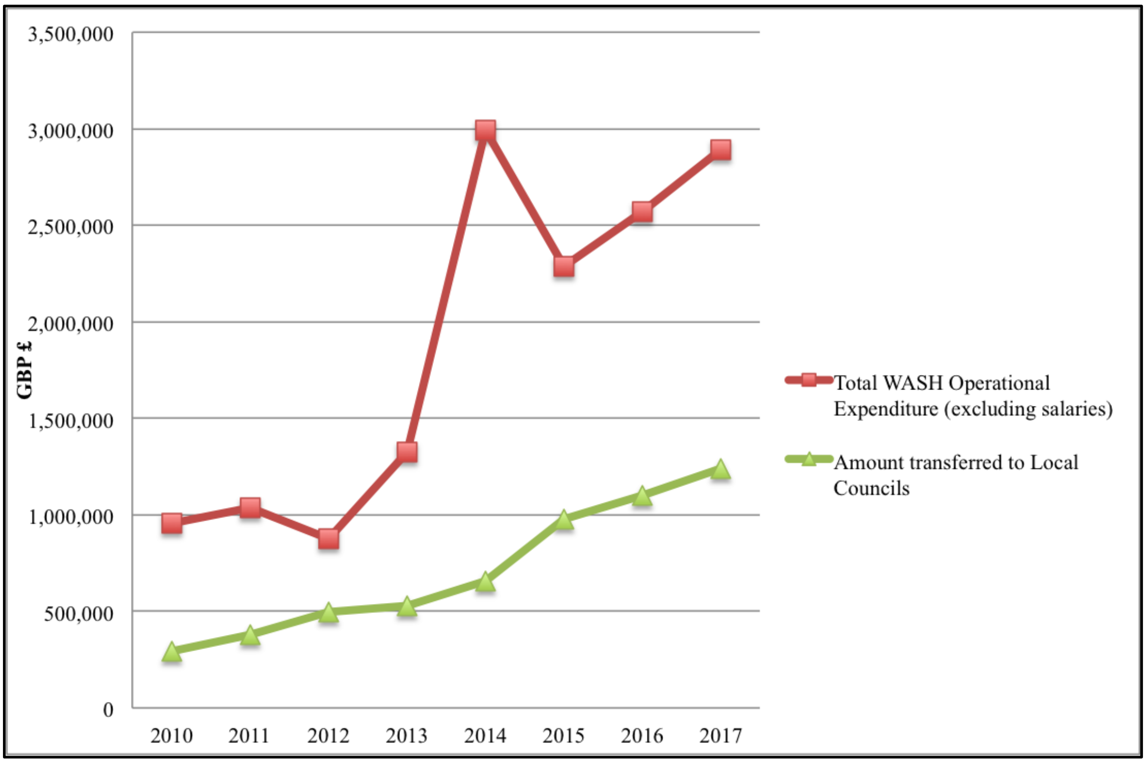
"When new funding becomes available there is a tendency for national ministries to act in a territorial manner and compete for finances." [KI-11SL]

"Competition leads to a belief that water resources should be vested solely in state control; consequently, discussions and actions focus on not wanting to cede control to other ministries or local institutions." [KI-12SL]

Data in Figure 6-1 shows the division of domestic funding for WASH between central and local government. The increased funding in 2014, as a result of the Ebola crisis, shows a big swing towards central ministries, rather than local councils, when funding become available.

[21] It should be borne in mind these projections were made prior to the 2014 West African EVD outbreak.
[22] www.sepa.org.uk/media
[23] Water Directorate, Ministry of Water Resources, interviewed in March 2012.

Figure 6-1: Comparison of total WASH operational expenditure and amount dispersed to local councils in Sierra Leone: 2010–2017



The experience problem

As a result of conflict and violence it is common that infrastructure is destroyed in FCAS. For example, Sierra Leone's water resources monitoring infrastructure was destroyed during its decade-long civil war. In the aftermath of violence the emphasis of humanitarian work is on the provision of emergency water supplies. A resultant complication is that water resources are exploited, and education and guidance on how to monitor and manage water resources is overlooked. This has potent capacity implications for the capability of government institutions in monitoring and managing water resources. At a workshop[24] in September 2012, there was common agreement that communities have a role to play in managing water resources. With the use of a questionnaire and semi-structured interviews 26 local government representatives were asked: *What should be the role of community-based*

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[24] Local council training workshop, Freetown Peninsular, September 2012.

institutions in managing water resources? Once again, the responses have been grouped into issues raised and ordered according to the number of times they were stated (see Table 6-5).

Table 6-5: Perceptions on the roles of communities in WRM

What should be the role of communities based institutions in managing water resources?	
Number of times identified	**Issues raised by government staff**
17 Times	Communities should be responsible for routine operation and maintenance of water points (referring to handpumps and boreholes)
15 Times	Communities should be responsible for establishing and enforcing local byelaws related to water usage, water management and hygiene at water points
12 Times	Communities should collect user contribution fees for maintaining water points
9 Times	Communities should be responsible for environmental stewardship
6 Times	Communities should be responsible for safeguarding water quality, including preventing open defecation at or near water points
1 Time	Communities should be involved in mapping of water points
1 Time	Communities should help coordinate rural water supply activities to prevent duplication by implementing agencies

Government technicians must have knowledge and ability of WRAs and WRM and to recognise what could potentially be achieved through community-based institutions. In its simplest form, WRAs require ability to assess risk to water resources. Technicians must also have an ability to assess the availability of the resource with reasonable degrees of accuracy and know what institutional measures are required to sustain the resource. Technicians also need to know how water resources can be allocated based on a bargaining process that has agreed principles for sharing the resource (Perry, 2008). Practical training sessions in August and December 2013 were used to assess local government capacity. Analysis focused on four key components of WRM, shown in Box 2 and Table 6-6. Once again a simple scoring mechanism was applied for each element of the training:

Box 2: Scoring system for assessing government capability

1 point was awarded for a general understanding of the objective as well as an appreciation of the reasons why it is important.

2 points for a clear demonstration of an understanding of how the objective can be achieved, in addition to a general understanding and appreciation.

3 points if the objective could be achieved independently or under supervision, or for experience of relevant techniques and functions to guide others.

4 points for a demonstration of an ability to carry out the objective without supervision and to potentially supervise others.

As mentioned in Chapter Four, scoring methods are subjective, however the values scored were arrived at following a three-day workshop and extensive consultation with colleagues. The scores were then openly discussed with workshop participants to see if these were a fair representation of institutional capabilities. Data in Table 6-6 illustrates government technicians had knowledge of the risks to water resources and a basic understanding of hydrological monitoring. However, there was less understanding of how to assess water availability, calculate the water balance or principles for water allocation. There was also a marked decrease in participants with practical experience of WRM with such limited field activity having taken place.

Consequently it should be borne in mind that many government technicians have never actually seen or engaged in any form of practical WRA or WRM.

Table 6-6: Assessing capabilities of government staff in Sierra Leone to engage in WRM

Water resources management component	Observation	Score
Understanding of risks to water resources	Local council staff possesses appreciation and knowledge of risks to water resources. People commonly referred to issues such as population growth, increased water demand, and changes in land use, and had the ability to cite local examples.	2
Practical experience of hydrological monitoring	Limited experience of hydrological monitoring (such as rainfall, groundwater levels and stream flows). No practical experience of hydrological monitoring.	2
Ability to assess water availability	Limited capacity to assess water availability. Limited knowledge of assessing the water balance and hydrologically effective rainfall.	1
Principles for allocating water	No experience of allocating water through a bargaining process or ensuring water availability is consistent with demand.	1

6.3 Is it possible to overcome institutional problems in government?

Analysing the ability of government institutions to support communities was difficult, because institutions are often in denial regarding the problems they face. The evidence presented in the previous section is not final, but it does provide a strong indication of common problems that exist. Despite extensive institutional reform efforts over many years – such as Sierra Leone Decentralised Service Delivery Programme, supported by the World Bank – evidence from previous sections suggests government improvements have been limited. Reforms often focus on improving government capacity, but it is unclear whether this translates into increased capability. As Andrews (2013) observes: *“the form of government changes but functionality does not.”*

There are many different dimensions of water management to consider. Evidence suggests a real willingness to decentralise resources is lacking and government institutions may have limited experience and expertise in monitoring and managing water resources. For example, local government budgets in Sierra Leone exclude funds for any aspect of WRM. Furthermore, data in Table 6-5 showed few government technicians could identify activities pertinent to monitoring and managing water resources. It is perhaps puzzling why institutional reforms do not have a more positive impact.

What is evident from the previous sections is that central governments must undertake multiple lengthy institutional reforms in order to become fit for purpose before their country can embark on ambitious national or transboundary WRM plans. As previously mentioned unfortunately many institutions remain dysfunctional despite lengthy reforms. This beggars the questions: how reform processes can yield better results but also what positive change can be introduced at a local level during the transition process? This study argues the basic picture is that: real water management problems should be resolved locally as government institutions build capacity in an incremental manner. This process should occur simultaneously. But an overreliance on central government in FCAS may not necessarily lead to real water management problems being addressed.

6.4 Summary

In this chapter the complex nature of fragile states and the typical problems encountered in weak national institutions were explored. Data collection and analysis highlighted the potential roles community-based institutions can play in WRAs may not always be recognised. Community members are recognised as being key to operating and maintaining water points (infrastructure), but their role in monitoring water resources was less clear. One of the key factors influencing this problem is that government technicians have limited experience in practical WRA and WRM. The evidence suggests this is because funding for water resources lags behind the extension of water supply systems and roles and responsibilities remain blurred across central ministries. This limits the potential role of communities in WRA and WRM. The next chapter explores the role of NGOs and the potential influence the WASH sector could have in promoting CBWRM.

7 Exploring the place of WRM within WASH programming

The aim of this final results chapter is to explore obstacles linking WRM and rural water supply in the WASH sector. In particular, this chapter picks up on issues highlighted in Chapter Two and the previous two results chapters regarding WRA and the capability of governments in FCAS. The key argument put forward is that despite the proliferation of toolkits and guidance, such as WASH Climate Resilient Development (GWP and UNICEF, 2014), the WASH sector has ostensibly engaged relatively little in WRM. This study argues given the lengthy and difficult transitions fragile states need to undertake NGOs are in a strong position whereby they could support both community-based institutions and government authorities. After all, this is the approach the WASH sector adopts in the provision of rural water and sanitation services (WaterAid, 2011). To that end, Section 7.1 examines the role of NGOs in delivering rural water and sanitation services and in doing so argues that environmental factors should not be overlooked. Section 7.2 examines the water usage requirements of communities, problems with point source seasonality and the current attitudes and practice in the WASH sector with a particular focus on WRM and climate change adaptation. Based on the data collected, the second section promulgates the argument and Section 7.3 asks whether the WASH sector should engage in WRM in fragile states.

7.1 The role of NGOs in delivering and sustaining rural water supplies

As mentioned in Chapter One, community water supplies can only be sustained if environmental factors are considered. If groundwater abstraction exceeds recharge or a sanitation system is polluting the environment then it cannot be environmentally safe or sustainable (WaterAid, 2011). From the outset this implies two inter-related environmental issues need to be considered by NGOs working in the WASH sector. The first concerns stewardship of water resources, from both a quantity and quality point of view. The second is the way in which the sanitation system is conceptualised so that excreta is treated and exposed of safely (WaterAid, 2011).

Chapter Two emphasised that water resources in SSA face multiple pressures. Population is growing at significant rates, land degradation is widespread and this is often taking place in regions with high rainfall variability. These factors combined are placing constant and continuous pressures on water supply infrastructure and natural resources. In the past it was assumed the community water supplies are not constrained by water resource limitations (see Cairncross, 2003). Yet, relatively recent studies (for example Robins et al, 2013b) have highlighted concerns regarding groundwater sources. Chapter Two also highlighted concerns over the high failure rate of rural water supply systems. Pinpointing the exact causes of failure intuitively requires an understanding of groundwater resources, siting, design and construction, amongst other things (Bonsor et al, 2015). Chapter Six demonstrated government institutional capacity is not ideal. Essentially they lack skills, knowledge and resources to monitor and manage water resources successfully. Governments are also wrestling with other development challenges such as sustaining WASH service delivery, increasing access to irrigation and improving energy distribution through the development of hydroelectric power plants – all of which require professional institutions and hydrometric information. This knowledge has implications for the wider role of WASH agencies.

NGOs carry out service delivery on a relatively small scale. Their work has a direct impact for the people they serve; however, their service delivery work must also be novel for at least two reasons. First, it maintains professional credibility when engaging in policy and strategy debates. Second, it should be innovative, so it can help guide, support and educate weaker government institutions (WaterAid, 2011). So unless there are strong efforts to sustain rural water supplies, build community resilience and strengthen government institutions, NGOs will tend to be viewed as makeshift solutions. In the last few years the importance of a large amount of data (often termed *big data*) and communications has been seen as a fundamental way to improve water management (Grey, 2012). The author is somewhat sceptical of this approach because unless government institutions can use the data collected it will serve little useful purpose. However, the use of hydrometric data in planning, designing and adapting rural water supplies has always been hopelessly inadequate. Clearly factual knowledge of constant and continuous environmental change taking place needs to advance.

This chapter explores four factors that drive the argument for NGO engagement in WRA and WRM. The first is whether communities demand water for both domestic and productive water use. The second concerns the wider problem of water point functionality and seasonality drawing on a water point survey from Sierra Leone. The third factor concerns the experiences of a number of senior WASH practitioners that have been recorded through semi-structured interviews and survey responses. Lastly, perceptions as to whether GCMs can be used for local-level adaptation planning are examined from the perspective of WASH practitioners. These factors combined are used to illustrate why NGOs should not overlook WRA and WRM.

7.2 Investigating rural water supply approaches in the WASH sector

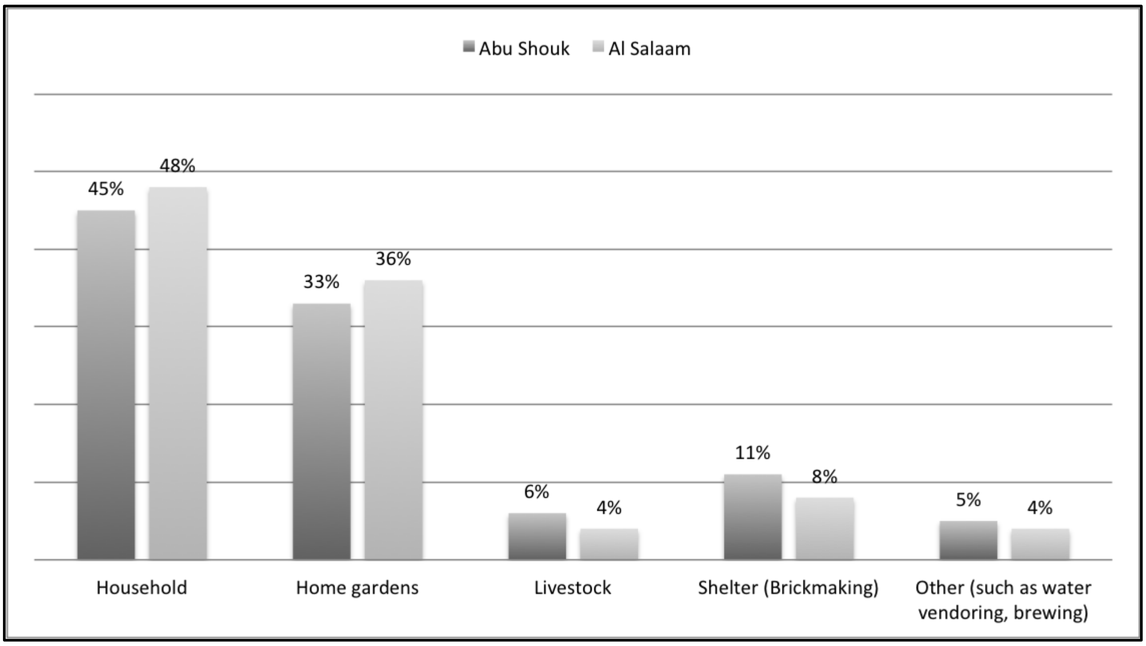
A good appreciation of community's water usage requirements is necessary to understand the potential demands on point water sources. In extreme humanitarian conditions it is often assumed people simply require water for basic human needs only; however, important differences were evident in IDP camps in Darfur in 2007, as a result of the protracted nature of the humanitarian crisis.

7.2.1 Productive water usage

Water supply in the WASH sector is often artificially compartmentalised between domestic and productive usage. WASH practitioners often assume that point sources (such as wells and boreholes) should be used for domestic or household use only, with people requiring 20l of potable water per day. This is because there is a strong preoccupation in the WASH sector with improving people's health. However, people do not demand small quantities of potable water (Moriarty, 2011). In reality households and communities use water for a variety of purposes that include irrigation, home gardens, livestock, brick making, laundry and countless others. The compartmentalisation of water usage inadvertently has a number of negative consequences. First, simply focusing attention on small quantities of domestic water means people's real water needs and requirements may not be adequately addressed. Second, men, cattle, and women compete for water at point sources, with the obvious risk that water points get damaged or contaminated. Third, as water demand grows, the volume of water abstracted increases, along with the risk of localised depletion at or near the point source (van Koppen and Smits, 2012). This problem is discussed further in Section 7.2.2. Lastly, if people do not receive water for productive use (livelihoods) there may be less possibility they can actually afford to pay for the upkeep of services.

The most efficient way to understand people's water usage requirements was to undertake a household water usage survey. The data presented here is taken from two field surveys conducted in North Darfur in 2007 (see survey questions in Appendix F). Data in Figure 7-1 shows that a significant percentage of water collected by communities (>50%) is used for productive needs, such as livestock watering, brick making and home gardens. Home gardens were used to improve household food security. Space is often at a premium in densely populated IDP and refugee camps and vegetable production takes place at household level. Brick making is used to improve basic shelters as plastic sheeting degrades over time, and it becomes a livelihood activity for male youths. Brick making has an impact on both water resources and local forestry as firewood is collected to fuel kilns.

Figure 7-1: Water usage by volume in Abu Shouk and Al Salaam Camps, Darfur, 2007



As IDP camps become more permanent the water needs of communities evolves beyond basic human requirements (5l of clean water). As a result, water demand on groundwater sources increases. Point sources, such as boreholes fitted with handpumps, become low yielding or dry out, which leads to increased collection times, tension at water points or women having to walk to alternative, distant sources. The survey data shows that even in extreme environments (such as protracted humanitarian crisis) people require easily accessible and reliable multi-purpose water usage.

Perhaps the biggest impact of productive usage is the demand it places on groundwater sources. The water supply in Abu Shouk and Al Salaam camps was heavily dependent on handpumps. During the period 2005–2008, 12–15 handpumps ran dry or became low yielding (UNEP, 2008). As a result of the power imbalance in humanitarian emergencies, displaced people are often classed as beneficiaries of aid by NGOs. In many respects displaced groups lose control of their traditional management arrangements as humanitarian aid is provided to them. Community members interviewed stated: *"People are more likely to use the water provided by NGOs, because there is a sense of ongoing* *support with all humanitarian items provided for free"* [KI-17D]. Initially communities were less concerned about having to develop new water sources themselves; however, as levels of water supply deteriorated it became the most pressing issue in Abu Shouk and Al Salaam IDP camps.

7.2.2 Water point seasonality

The aim of rural water supply programmes is to provide access to safe, adequate, reliable and affordable water supplies year round. However, this target can be significantly threatened if point sources are non-functioning or seasonal. A good appreciation of the way in which groundwater and surface water responds to rainfall is necessary to fully understand whether the use of shallow groundwater for productive water usage is feasible. Concerns have been raised regarding over-exploitation and falling water tables (see Robins and Fergusson, 2014) but to date there has been no widespread study to gather evidence to assess the effect of falling groundwater tables and sporadic groundwater recharge to rural water source failure (Bonsor et al, 2015). However, problems of increased demand on water sources and drought (see Calow, et al 2009), low and variable rainfall patterns, competing water demands in the dry season and complex aquifer conditions are all other possible contributing reasons for water point failure (Bonsor et al, 2015).

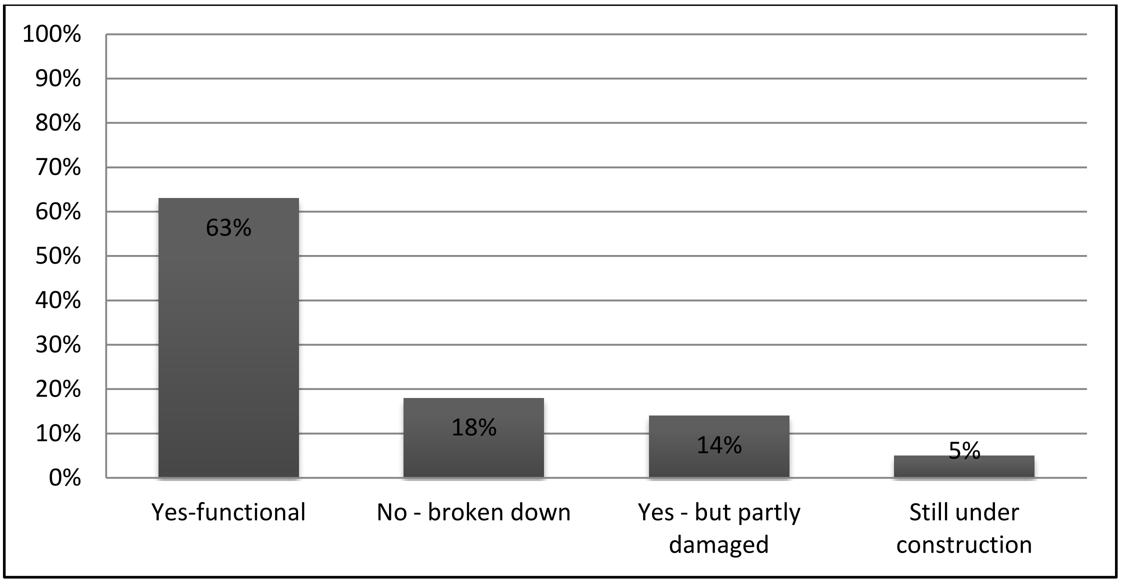
Typically handpumps do not exert large pressures on groundwater resources over large geographical areas. Nevertheless, localised depletion may occur if drawn from limited pockets of groundwater where transmissivity is low. Where more intense mechanised abstraction occurs (>1 litre per second) there is a greater risk on the resource. This may occur if groundwater is used for productive uses, such as irrigation water or livestock water. Chapter Three highlighted, how the case study areas, and large parts of Africa, are underlain by basement complex aquifers, which are low yielding and highly vulnerable to depletion, particularly where there is low connectivity between fissures and limited groundwater movement. Table 7-1 highlights the relative vulnerability to depletion of different groundwater types across SSA.

Table 7-1: Example of aquifer types and relative vulnerability to depletion (source Institution of Civil Engineers et al, 2011)

Aquifer type	Deep sandstone basin	Volcanic rocks	Alluvial	Basement complex
Groundwater potential	Moderate–high	Moderate	Moderate–high	Low
Typical borehole yield (l/s)	1–10	0.5–5	1–10	0.1–1
Typical water table depth (m)	30–110	No data	2–10	15–55
Typical borehole depth (m)	200–350	50	10–40	30–75
Relative aquifer storage capacity	Very high	Moderate	Moderate–high	Low
Relative vulnerability to depletion	Very low	High	Low–moderate	High

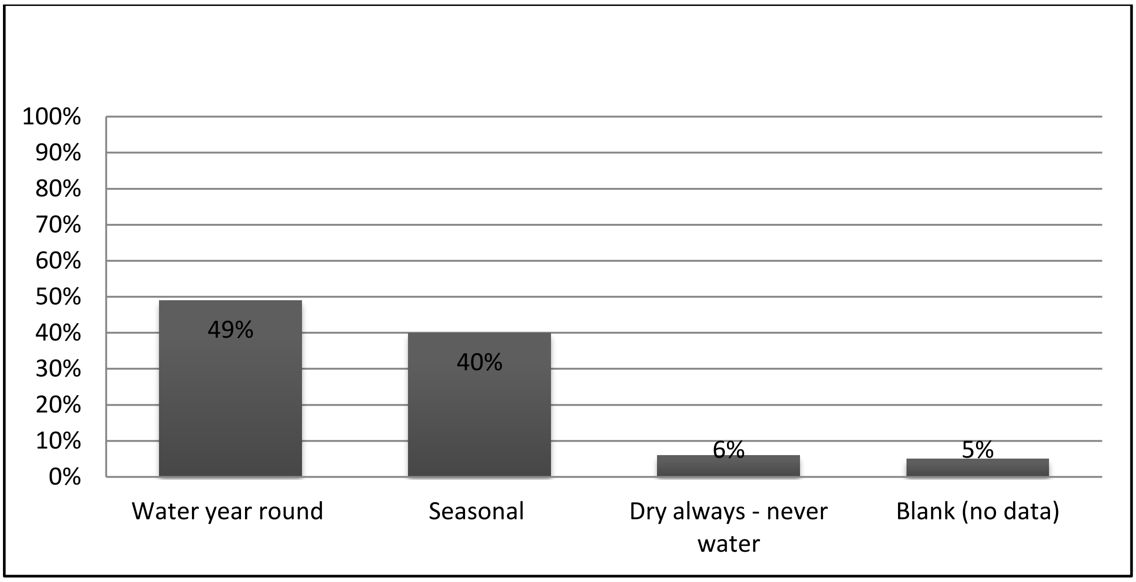
The water point mapping data below further illustrates the widespread problem of seasonality, even in countries like Sierra Leone that are perceived as being blessed with abundant water resources. Evidence shown in Figure 7-2 suggests the problem of non-functioning water points is a major issue in Sierra Leone, as it is elsewhere in SSA, with only 63% of water points recorded as functioning.

Figure 7-2: Percentage of functioning water points in Sierra Leone in 2012 (n=28,845)



The causes of water point failure are multiple and complex and as yet no formal system exists in Sierra Leone to document (*black box*) the reasons for breakdown. However, data presented in Figure 7-3 suggests point source seasonality is a major problem with less than 50% of 18,172 functioning water points providing water year round. Seasonal water points means that community members (normally women) are required to haul water from distant, unprotected water sources. A lack of supervision during well or borehole construction, or simply installing water points at the wrong time of year, was said to be a particular constraint by practitioners in the WASH sector in Sierra Leone.

Figure 7-3: Percentage of functioning improved water points in Sierra Leone in 2012 providing water year round



Water point data in Table 7-2 shows a significant difference in well seasonality between hand-dug wells fitted with handpumps and those without. Nearly half of hand-dug wells fitted with handpumps are shown to be seasonal. It is likely this is because handpump cylinders are set at the nearest multiple of 3m (the length of a rising main/pump rod), rather than cutting and rethreading the components to set the pump as deep as possible in the well. The vast majority of "seasonal" water points are sealed with a concrete apron to prevent groundwater contamination. However, this also prevents groundwater levels from being measured unless modifications to the handpump are made. As shown in Table 7-2, seasonality of boreholes is also disturbingly high with one-third of constructed boreholes affected.

Table 7-2: Seasonality and water point type from Sierra Leone water point summary

Water point type	Percentage of all mapped water point sources	Seasonality rate
Hand-dug well with handpump	35%	48%
Protected hand-dug well (no handpump)	29%	42%
Borehole	7%	33%

During a series of follow-up semi-structured interviews, the lack of knowledge regarding groundwater recovery and recession was shown to be a major constraint. In multiple cases practitioners had never seen visualisations of rainfall and groundwater levels for Sierra Leone, which has implications for both the construction of water points and the design of latrines:

"I don't believe I have seen any long-term hydrological monitoring in Sierra Leone. I have seen data on water level, quality and usage, however this is linked to a particular project so it is only monitored prior to and immediately after project completion" [Survey respondent 7].

"Abstraction quantities and water quality are standard measures, but organizations typically do not manage or monitor broader water resources" [Survey respondent 9].

The problem of groundwater seasonality was further analysed by monitoring rainfall and groundwater levels. This information was used to: a) interrogate the causes of seasonality identified in the water point mapping survey; and, b) synthesise the research findings. The relationship between groundwater and rainfall respectively is illustrated in Figures 7-4 and 7-5.

Figure 7-4: Bombali local council: Groundwater monitoring from 2013–2015

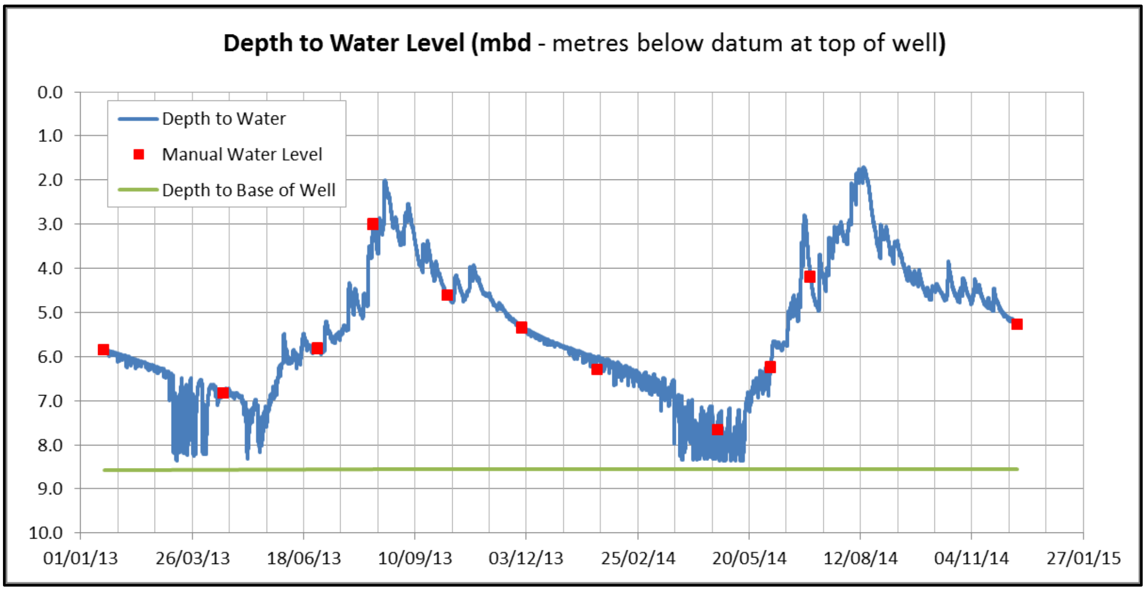


Figure 7-5: Bombali local council: Rainfall monitoring from 2013–2014

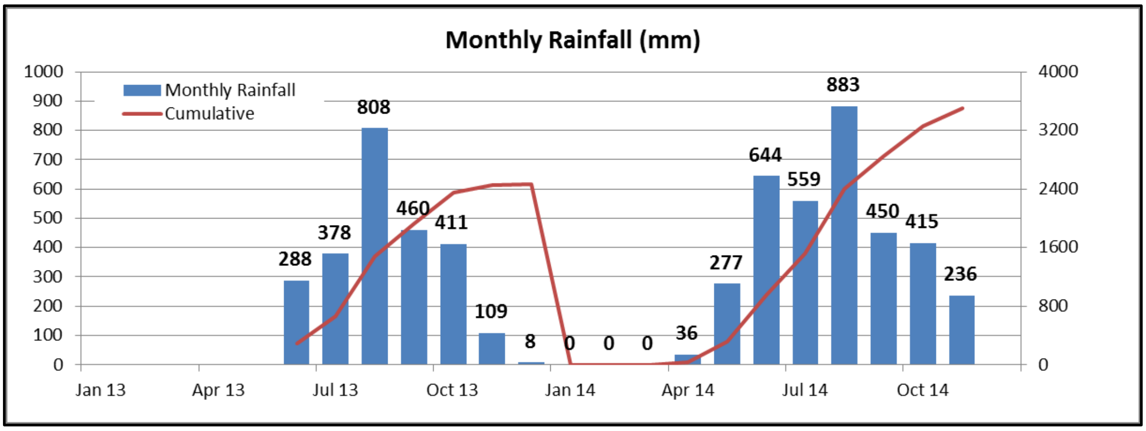


Figure 7-4 illustrates groundwater response to rainfall in Sierra Leone is very fast – within days of rainfall starting. This suggests rainfall moves to the water table through rapid vertical flow paths, which has implications for water quality and when groundwater levels may rise after the dry season. It can also be observed that groundwater levels recede quickly at the end of August, which implies there is little natural storage in the shallow aquifer and it is highly seasonal. Groundwater data collected across multiple monitoring sites (see Chapter Four) shows groundwater levels in Sierra Leone typically fluctuate across a range of 5m to 8m depending on the location and time of well construction. It should be stressed the seasonal range of groundwater level variation in Sierra Leone was not known before this study was undertaken because no monitoring was taking place.

7.2.3 Perception on engagement in WRM

Using a combination of semi-structured interviews and surveys WASH practitioners were asked about their perceptions on risks to water resources in SSA. The author introduced the research in detail and explained the focus countries identified in SSA. Practitioners were asked whether they felt community water supplies were under threat from pressures on water resources, as described in Chapter Two. Figure 7-6 illustrates that 93% of 26 respondents identified that community water supplies were perceived as being under continuous pressure. However, the vast majority of respondents (73%) felt that the conventional community management model does not routinely include consideration for managing groundwater and surface water resources (see Figure 7-7).

Figure 7-6: Summary of survey responses: Perceptions on risks to water resources

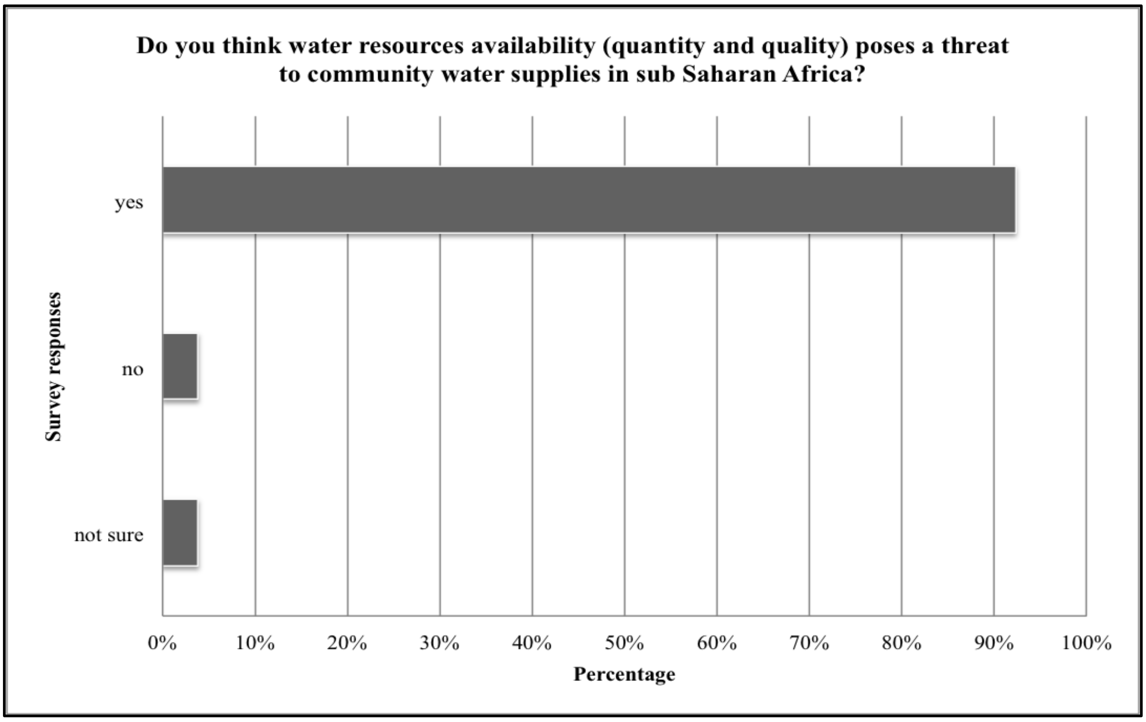
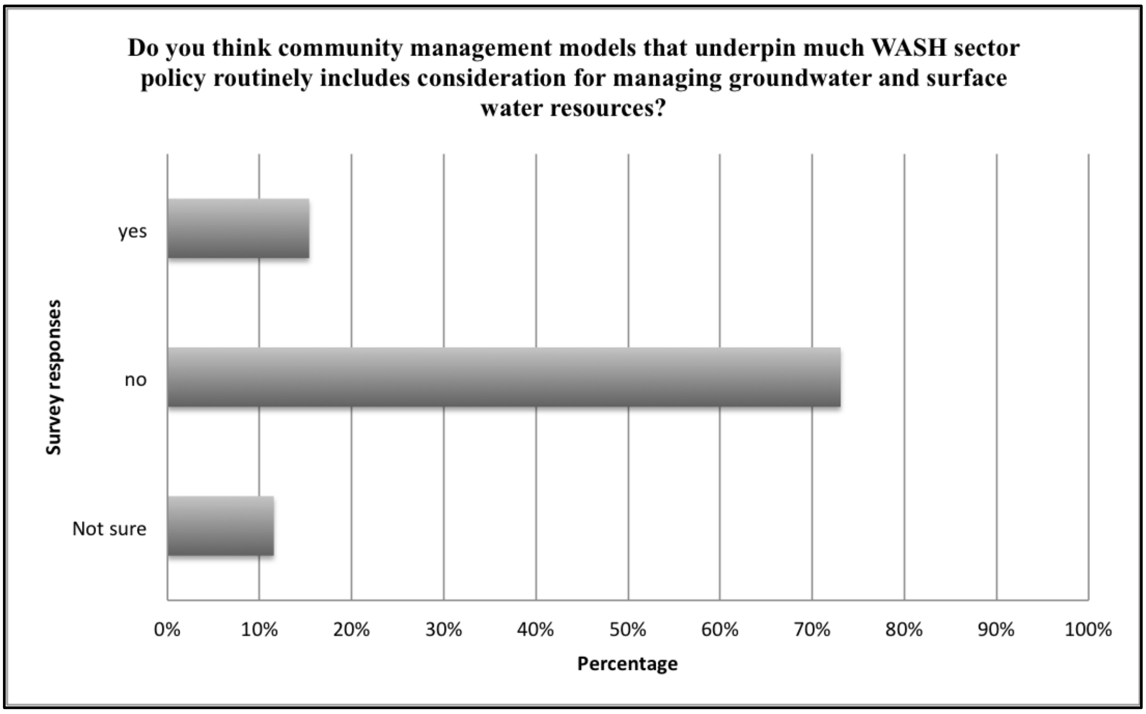


Figure 7-7: Summary of survey responses: Perceptions of WRM in WASH



Data presented in Figures 7-6 and 7-7 is contradictory and indicates that practitioners may well believe WRAs and WRM should be a component of WASH programmes, but this is rarely achieved for a variety of reasons. It is important to understand why the uptake of WRA and WRM has been so low and what the constraints are:

"The WASH sector is constrained by a focus on water supply assets (hardware) with inadequate capacity to assess the water balance of an area. Drinking and domestic water use are viewed as only requiring small quantities of water, compared to agriculture, so limited efforts are made to genuinely assess water availability beyond doing a pumping test on boreholes or monitoring spring flow the year before construction of a gravity scheme" [Survey respondent 2].

"In rural water supply financial and personnel resources are limited so the focus is primarily on providing water for domestic use. Water resources management requires longer-term commitment, and the impacts of it are not seen in the short term, this makes it less attractive both politically and to the NGO sector" [Survey respondent 7].

"*Practitioners find it difficult to integrate water resources management with usual WASH practice and they lack capacity, expertise and access to scientific data" [Survey respondent 4].*

"The lack of understanding of the water cycle, which includes rainfall distribution, natural environment and land use change hinders participation, but also limited understanding of the diverse inter-sectoral needs of water resources management" [Survey respondent 13].

"The main challenge associated with initiating hydrological monitoring is convincing people within the organisation (and partners) of its importance and the significance of hydrological data. Although many WASH practitioners may be engineers, hydrology and hydrogeology are very different disciplines which require additional understanding" [Survey respondent 2].

"Practitioners lack motivation because they are not accustomed to thinking about how the hydrological cycle works and why water resources management is important. Capacity and funding is also constrained by donors" [Survey respondent 12].

"Getting organisations and implementing partners to see the importance of water resources management in the context of water security underpinning water supply is a major problem. Institutional capacity at central and local government levels is also lacking to provide the necessary direction to implementing partners" [Survey respondent 15].

Lack of perceived need was not a barrier to practitioners wanting to engage in WRAs. Only one practitioner interviewed suggested that WRM is much wider than rural water supply service delivery and consequently they did not regard them as necessary:

"The link between water resources management and the local impact is too small. Linking water resources management and WASH reduces the water management issues to a smaller issue than it deserves. Consequently water

resources management should only be undertaken where drought and flooding are perceived to be a major risk" [Survey respondent 5].

One practitioner drew attention to the fact that indigenous knowledge is often overlooked:

"The views of local communities on water resource management are usually not incorporated into water service delivery. WASH projects are usually short-term and do not therefore include water resource management in their programmes" [Survey respondent 6].

Although limited in size, empirical research collected in this study indicates the links between WASH and WRM are incomplete. Two conclusions relevant for the research aim can be drawn from the data so far. First, community water supplies are threatened by growing pressures (as described in Chapter Two) but constant and continuous change to water resources is not routinely monitored. Second, the process of WRM is often perceived as being beyond the scope of rural water supply programmes and NGO activities. While all-inclusive IWRM and WSP approaches are in all likelihood beyond the scope of individual WASH programmes (see Chapter Two), it may be argued this represents a contradictory approach by the WASH sector because growing obsession with climate change demands evolution into new territories.

7.2.4 Why examine climate change adaptation?

International WASH organisations are often engaged in helping communities build resilience and adapt to the impacts of climate change by integrating climate considerations into planning activities at national and local levels. This is often referred to as "climate proofing" and the process requires an assessment of risk posed by climate change. Thus it reflects a desire to reduce the vulnerability of physical infrastructure. The German NGO, GIZ, who are credited with introducing the climate proofing concept, state: "*by viewing development through a climate change lens, appropriate steps can be taken to reduce vulnerability and ensure programmes factor in environmental change"* (GIZ, 2011).

Section 2.2.5 described how climate change models provide a poor lookout for planning community-based approaches, such as CBWRM. When making climate change impact assessments a "cascade" of uncertainty arises, making it difficult to make reliable predictions (Heath et al, 2010). The researcher would argue that that GCMs have severe limitations for localised adaptation planning, and that much remains to be done to in terms of relating this information to WASH practitioners. The purpose of this section is to explore the problem in terms of two issues. The first of these is to reaffirm the limitations of climate change models drawing on examples from Niger and Sierra Leone. Second, the misconceptions of WASH practitioners should also be recognised. By highlighting a current dichotomy in WASH sector approaches this study stresses the need for climate change to be seen as one of multiple risks, and hydrological information must be used to build resilience and adaptation strategies.

Modelling data collected by the author in December 2009, with the assistance of Oxford University and African Center for Meteorological Application for Development shows climate change projections for Niger. In summary the IPCC has developed a range of possible emissions scenarios (known as SRES scenarios). Three benchmark scenarios – A2, A1B and B1 – were taken to represent a wide range of future development and emission scenarios (see Table 7-3).

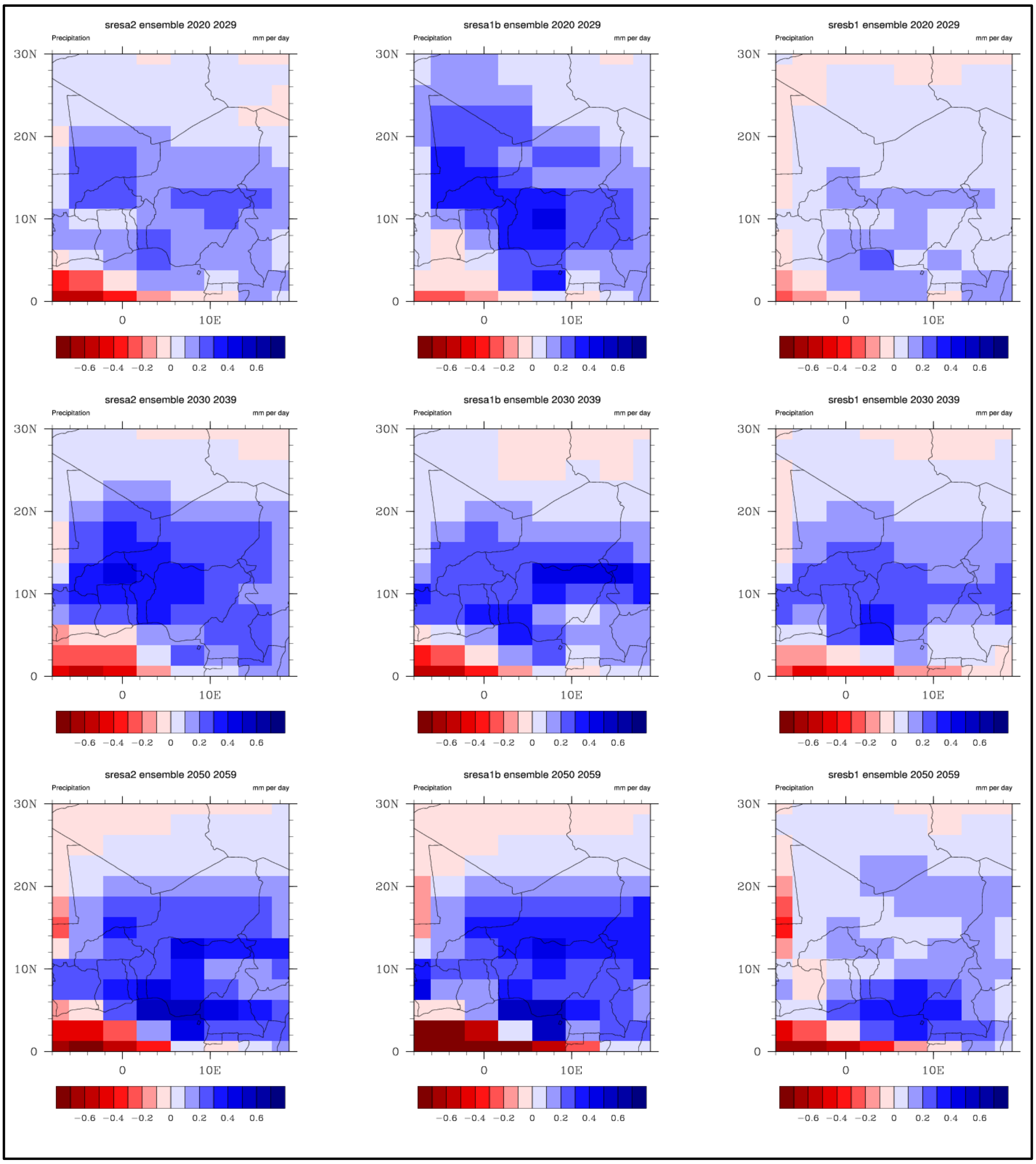
Table 7-3: Outline of the main SRES scenarios (Source: Washington, 2009)

1) SRESA2 – a medium–high future emissions scenario that results in a best estimate temperature change of ~3.4°C by 2100.
2) SRESA1B – a more middle-of-the-road future emissions scenario ~2.8°C by 2100.
3) SRESB1 – a low future emissions scenario ~1.8°C by 2100.

Figure 7-8 displays the projected July to September rainfall change (mm/day) from the 1961–1990 mean for the 9 IPCC AR4 GCM. This is shown for the

2020s (top), 2030s (middle) and 2050s (bottom) for medium–high scenario (left), medium scenario (centre) and medium–low scenario (right). The climate dynamics of the Sahel and West Africa are difficult for climate models to simulate, and very few models have a realistic climatology of these regions (Washington, 2009). Temperature has increased since the 1960s but trends for rainfall are less clear and it is difficult to separate long-term trends from natural climate variability. Projections to 2060 suggest an increased rise in temperatures (not shown) but do not indicate significant changes in future average annual rainfall. Data suggests there may be a heightened risk of extreme rainfall events that may lead to increased flooding. Chapter Two described the propagation of uncertainty and the difficulty in assessing resultant impact on groundwater resources. This is of critical importance because 80% of rural water supplies in SSA are thought to be reliant on groundwater sources (Calow et al, 2011).

Figure 7-8: Projected July–September rainfall change (in mm per day) from the 1961–1990 mean for 9 IPCC AR4 global climate models (Source: Washington, 2009)



Difficulties in assessing climate change impacts are not restricted to the Sahel region. Climate change modelling data for Sierra Leone from McSweeney et al (2010), and summarised by Oates et al (2014), is presented in Table 7-4. It also illustrates that climate models do not agree on the direction of change for future rainfall and major uncertainties exist. In summary, climate change is expected to alter hydrological regimes and patterns of freshwater quality and availability. Rainfall events may become more intensive, dry seasons may extend and the possibility of point sources drying up may increase (Calow et al, 2011). However, the direction and magnitude of change cannot be easily determined. Typically groundwater sources may respond more slowly to changes in climate, but the direction of change is also unspecified. A key conclusion from this study, which reinforces current literature, is that even if a single climate model and future emissions scenario was selected, the timing, duration and intensity of rainfall remain uncertain. Thus GCMs are of limited use for a CBWRM approach other than indicating if rainfall will increase or decrease.

Table 7-4: Climate trends and projections for Sierra Leone (Source: Oates et al, 2014)

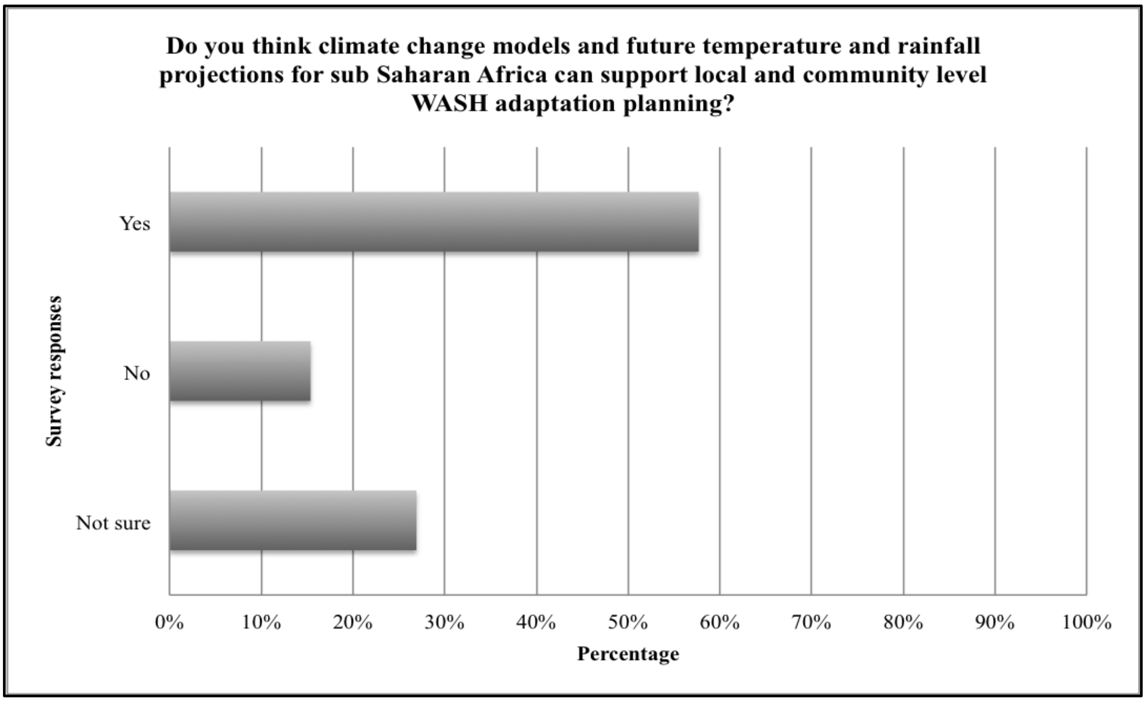
Climate trends (1960–2006)	Mean annual temperature rise	0.8^{O} C
	Annual rainfall trends	Mean has decreased since 1960s but hard to distinguish from variability
	% Rain in heavy events	Insufficient data
Climate projections (by 2060s)	Mean annual temperature rise	1.0 – 2.6^{O} C
	Mean rainfall	Models disagree but tend towards increases
	Seasonal rainfall trends	Clear increase in late wet season (August–October)
	Trends in % of rain falling in heavy events	Tends towards increases especially in late wet season
	Increases 1 and 5 day rainfall maxima	Tends towards increases especially in late wet season

An appreciation of practitioner understanding of climate change models is necessary to understand current problems in the WASH sector. Important differences between practitioner knowledge and scientific advice were evident. Qualitative data from forty-one WASH practitioners was collected through the use of a survey. The author asked a number of experienced international WASH specialists, working for major international organisations:

Do you think climate change models and future rainfall and temperature projections for sub-Saharan Africa can support local and community-level WASH adaptation planning?

Data illustrated in Figure 7-9 showed the vast majority of respondents (57%) were of the opinion that climate data derived from GCMs could meaningfully support localised adaptation activities. Only 15% of respondents identified that GCMs are of limited value for local and community-level planning, while 27% of respondents were uncertain.

Figure 7-9: Survey of current perceptions on the usefulness of climate change models for local-level adaptation planning



The question arises about where WASH practitioners obtain meaningful information to help plan and design climate change adaptation activities, and three possible answers exist. The first is that major challenges exist for downscaling of climate models and in reality models provide limited information for climate proofing and designing community-level adaptation activities. Criticisms can be made of the models and practitioners should be aware of model limitations. As mentioned in Chapter Two, how rainfall divides between surface runoff, infiltration, evapotranspiration and recharge is compounded further by changes in soil properties, and vegetation cover is not factored into current GCM simulations. The second is that climate change should be seen as one of multiple pressures, and other factors such as population growth and changes in land use should not be ignored. The third is that, given the longevity of climatic variability and seasonality in many countries, adaptation to existing climatic variability offers by far the most fruitful inroad to the climate change problem for many countries. However, as explained in Chapter Six, government institutions in FCAS have limited capability to operate and manage hydrological monitoring networks.

7.3 Should the WASH sector be concerned about WRM?

Data presented through previous sections of this chapter reaffirms that the WASH sector has engaged relatively little in monitoring and managing water resources. This section discusses whether WASH practitioners are correctly ignoring WRM because there is no substantial connection, or whether WASH agencies are mistakenly ignoring significant links to strengthening community resilience and building institutional capacity in failed states.

The data reviewed in Section 7.2.2 indicate that WRA and WRM is a neglected component of rural water supply service delivery. With regards to practitioner feedback the responses reflect the need for environmental considerations to be factored into WASH service delivery. However, a more controversial issue is the high rate of point source failure and seasonality (shown in Figure 7-3). This discrepancy should be considered in three perspectives. First, it has been argued that end users require water for productive use, which includes protracted humanitarian emergencies like Darfur. Empirical research shows that people use water for multiple uses (such as irrigation, home gardens, livestock watering and brick making) that extends way beyond simple household use. This would imply that multiple-use water services should be factored into rural water supply approaches, which in turn impacts on localised groundwater demand (van Koppen and Smits, 2012). Second, the climate in many parts of SSA is much more dynamic than in northern Europe. It is less predictable, typically rainfall volumes may be much less and the discrepancy between rainy and dry seasons is much greater. The climatic system is referred to, as "non-equilibrium," meaning there is a high coefficient of rainfall variability and demand for water increases as river flows and groundwater levels decline. Modular and localised approaches for river basin management are often proposed in such variable climates (Institution of Civil Engineers et al, 2011). Third, a number of international development organisations have committed to addressing the impacts of climate change through adaptation programmes. This chapter identified that the limitations of GCMs are not widely understood by WASH practitioners. This creates a dichotomy whereby GCMs provide a poor lookout for defining future adaptation requirements; however, the ongoing impacts of population growth, land degradation and increased water demand is not monitored. This begs the questions: What data is being used by NGOs to inform adaptation planning? Where does it come from and who is collecting it?

These findings have implications for evolving current community management models (described in Section 2.4). There is significant omission of WRA and WRM in the WASH sector as a whole. There is also minimal consideration for how community-based institutions can engage in WRAs and how this can be incorporated within conventional community management and IWRM models. As a result, the WASH sector can offer little guidance on strengthening the wider institutional arrangements for WRM. Despite this the survey results indicate a general consensus amongst a small number of practitioners that water resource issues should be factored into rural water supply programmes. Arguably, the main drivers pushing the linking of water supply and WRM within the WASH sector appears to be the growing demand to deliver sustainable water supply sources. The global commitment to help people adapt to the potential impacts of climate change further highlights the requirement to monitor continuous change and to use scientific evidence to inform decision-making.

7.4 Summary

This chapter contemplated WRM within the WASH sector. It reaffirmed that the WASH sector have engaged relatively little in WRA and WRM with the exception of water quality monitoring. Central to the insights and observations discussed in this chapter was the limited rainfall and groundwater monitoring conducted in rural water supply programmes even though water source seasonality is known to be a major issue. Even when there is a desire to adapt to the impacts of climate change, the limitations of climate models are not widely known amongst WASH practitioners, who do not necessarily facilitate engagement in monitoring and managing water resources.

8 The place of CBWRM within a failed state

The research topic was investigated initially in Darfur, Niger and finally in Burkina Faso and Sierra Leone. The case study areas were large-scale IDP camps and remote rural communities, where people experience a short rainy season followed by a long dry season. Three of the case study areas are characterised as receiving low rainfall (typically 200–500mm annually); however, communities in Sierra Leone receive significantly higher amounts of rainfall (>2,500mm). This variation in context enabled a deeper understanding of the factors that affect the role of communities in monitoring water resources.

As mentioned in Chapter Two, communities in the case study areas are experiencing many of the factors that threaten water resources. Yet, despite more than two decades of widespread promotion, there are few signs that governments can implement IWRM policy and strategy. There are those communities that have a keen interest in stewardship of water resources and continue to wait for government to establish effective methods. Chapter Five revealed that participatory monitoring plays a key role in helping people understand risks and the relationship between rainfall and groundwater levels. However, community-based approaches are constrained by weak government institutions and reluctance to decentralise resources (Chapter Six). In a fragile state context it might be expected that organisations working in the WASH sector engage in CBWRM in order to sustain point water sources and support the technical wings of government to build capacity (Chapter Seven).

Through the course of this chapter the rationale for CBWRM is argued based on insights from Chapters Five to Seven (inclusive). The requirement for meaningful external support from government is explored and consideration is given to the opportunities presented by the WASH sector to shape CBWRM approaches. The second section discusses the tension between micro-and macro-scale WRM if community-based approaches evolve beyond the village to include catchments and river basins. The third section highlights some limitations of the research in relation to repeat disruptions. It also discusses how well attuned the research methods are to uncovering CBWRM.

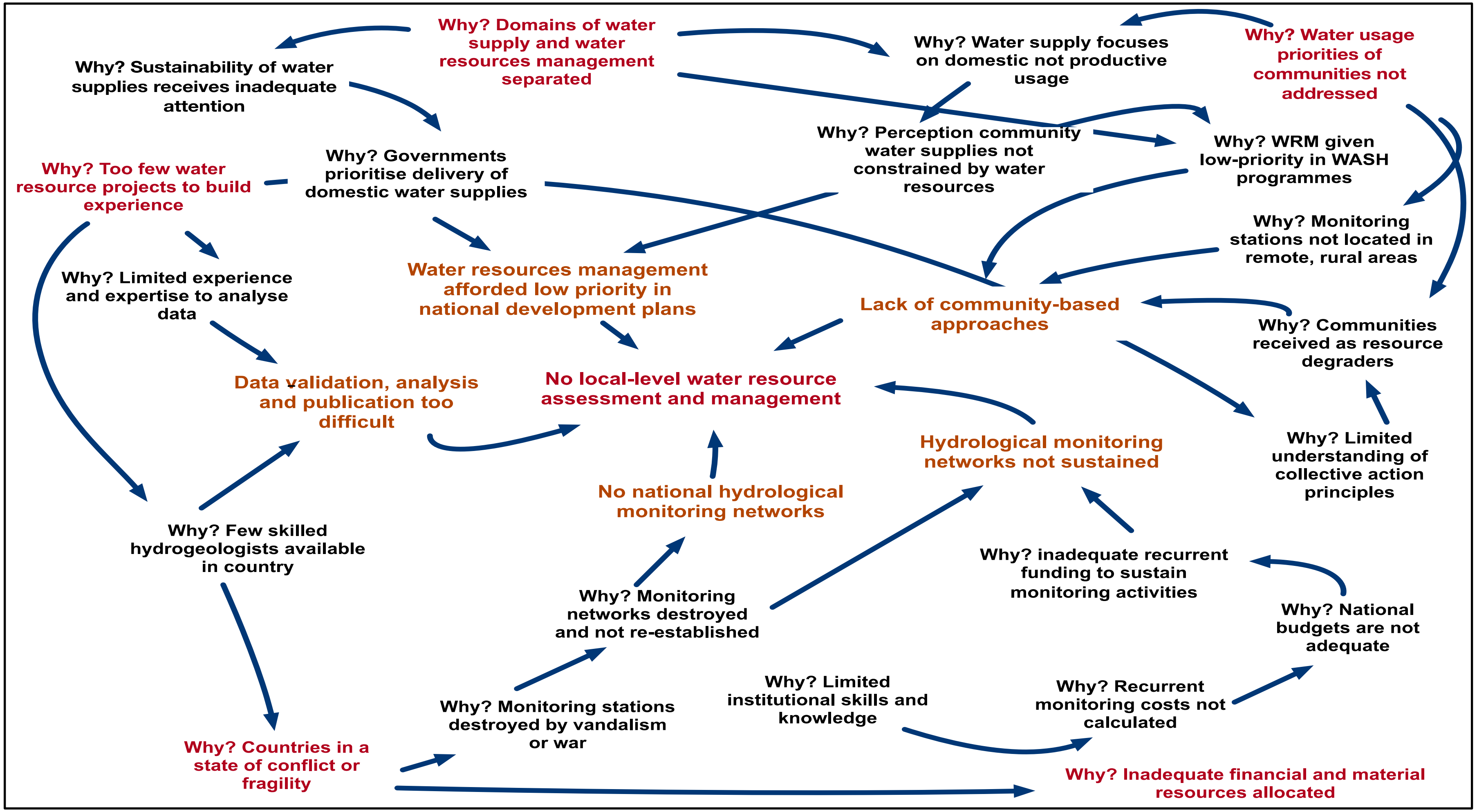
8.1 The emerging theory of CBWRM

8.1.1 Towards a CBWRM model

Philosophically, this study is about how and why communities should be engaged in monitoring and managing water resources in fragile states. As mentioned in Chapter Two, the lesson from the past two decades is not that IWRM is bad, but rather it is particularly difficult to implement in a fragile state context and more realistic solutions are required (see Biswas, 2004; Moriarty et al, 2004). Chapter One provided a detailed overview of the CBWRM process. In summary, the approach in a fragile state context is two-fold: First, it is a set of activities and relationships designed to improve the monitoring and management of water resources and so improve local water security (WaterAid, 2012a). These are activities that can be carried out as part of regular WASH programming. This is important because CBWRM directly helps to address problems that already exist – such as water point seasonality. Second, it also aspires to help lay the foundations for local and national water resources planning by building institutional capacity.

Empirical research in Chapter Five suggests small community groups are willing to play their role in collaborating to monitor water resources and to use the monitoring data to improve management arrangements. However, they also require external support from government. The particular problem of WRAs in fragile states typically hinges on three issues: the absence of hydrological monitoring networks; the lack of skills, knowledge and resources within government institutions to collect and interpret data (as shown in Chapter Five); and the peculiar separation of water supply and WRM (see Chapter Seven). This means governments have limited hydrological data for planning purposes and the role of community-based institutions is afforded inadequate attention. Use of a cause and effect diagram (Figure 8-1) provides insight into the wider problems that exist.

Figure 8-1: Concept diagram of the main cause and effects relating to local-level WRA and WRM



In order to get some feel of the different problems that exist in fragile states it is useful to think of the different causes and effects. Figure 8-1 illustrates that the central risk is the absence of virtually any water resources monitoring or management at local levels. The primary causes are: a lack of hydrometric monitoring networks, difficulty in processing data, a lack of community-based approaches and a lack of WRAs in national planning activities. What else matters? Knowledge of collective action by community-based institutions matters because communities often have their own customary water management arrangements. The role of NGOs working in the WASH sector matters because water points face problems with seasonality and poor yields. Also, in a fragile state trust and cooperation between communities and government may not arise naturally (see Chapter Six). This implies communities may require interim support from NGOs because communities *"can't do it all by themselves"* (Schouten and Moriarty, 2004).

The root of the problem for CBWRM clearly lies in the ability of government institutions to provide effective external support (see Chapter Six). Government institutional capability needs to be developed at intermediate level to backstop communities in both governance and delivery functions (Schouten and Moriarty, 2004). Appropriate external support for CBWRM in a failed state has a number of characteristics: Line ministries must provide devolved offices, along with increased technical skills and financial resources (Moriarty et al, 2004). In turn, insights from this study highlight that local government should have the capacity to: help replace community monitoring equipment, analyse and interpret hydrometric data, provide support to engage with major water abstractors, provide autonomy to community-based institutions and ensure appropriate follow-up action is undertaken. Developing this intermediate capacity adequately and quickly is a major challenge.

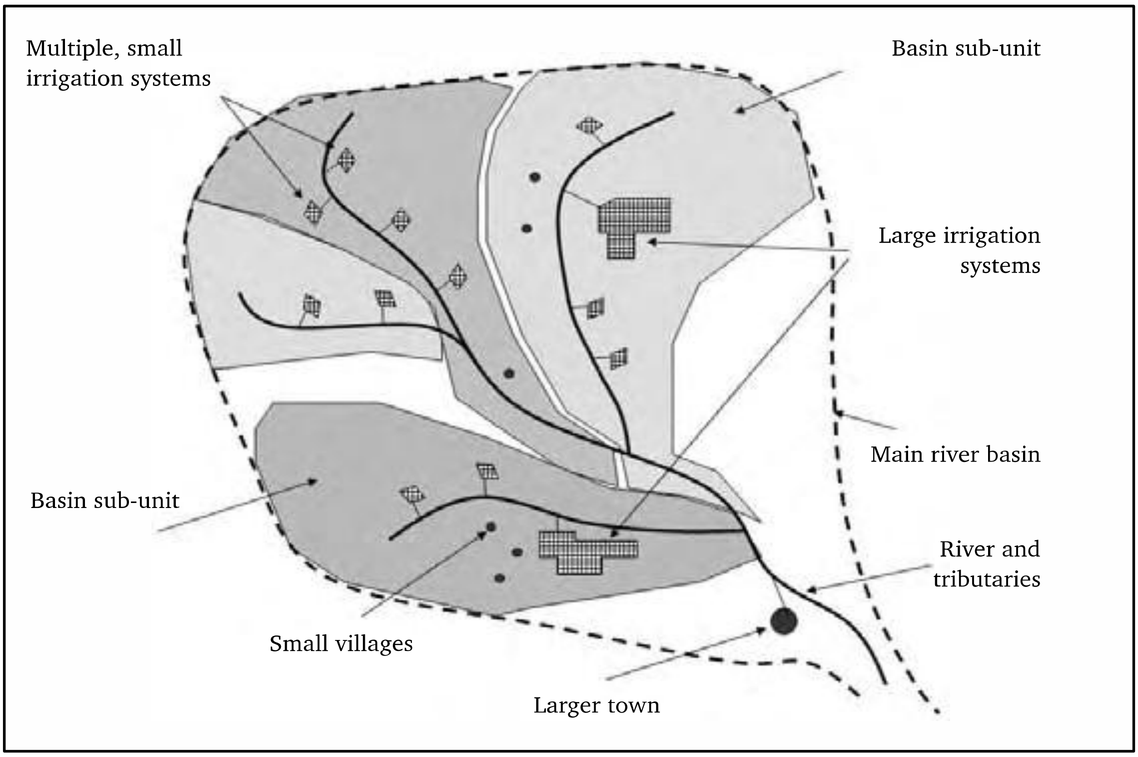
As mentioned in Chapter One, CBWRM is not a direct replacement for IWRM – which has a much wider range of activities. There are, however, very powerful arguments for pursuing alternative solutions. For example, "light IWRM" has been proposed by scholars (see Moriarty et al, 2004) as a method to overcome the inaction of “full IWRM.” It is intended to be less rigid, more pragmatic, problem focused and adaptive. It also has advantages in that it can be applied in situations where the overarching legal and institutional frameworks are absent. One of the key distinctions between light IWRM and CBWRM concerns geographic scale. Light IWRM requires a much higher degree of coordination and decentralisation as it focuses on catchment or sub-catchment scale. The starting point for CBWRM is at village scale. This is because coordination across WASH projects is notoriously difficult (see Hirn, 2012) in fragile states and small villages represent the scale at which the vast majority of NGOs operate (WaterAid, 2011). Chapter Five provides evidence that communities can engage in collecting hydrological data, over a sustained period of time. This supports the similar findings of Zemadim et al (2012) and Gowing et al (2016) and expands on these findings by focusing on a fragile state context. Furthermore, communities appear to welcome the introduction of simple monitoring techniques. The volunteer observers have attended monitoring review workshops, they welcome the small incentives provided and they are genuinely interested in the research. The extent of engagement in participatory monitoring was high in both Burkina Faso and Sierra Leone. The quality of data collected appeared good in the vast majority of monitoring locations and the number of months with consistent data collection was also encouraging (see Tables 5-3 and 5-4). Chapter Seven also reaffirmed that the WASH sector does not routinely engage in WRM activities, so the ability of NGOs to work at catchment scale will be severely limited. Over the past two decades scholars have devoted considerable attention to the ability of groups in society to manage CPRs in a sustainable manner. Notable examples include: Ostrom et al, 2002, Trawick (2002) and Schlager (2007). It is here that ideas on groups in society managing natural resources have been shaped. Current research has also focused on the role of citizen science and participatory hydrological monitoring by farmers who are involved in small-scale groundwater irrigation (Gowing et al, 2016). Thus interest in community-based institutions is not new but this study extends research into FCAS.

Countries vary in their ability to implement IWRM. The question of how to realistically implement sound WRM approaches in fragile states is integral to it. Chapter Six identified that government institutions in fragile states lack experience and expertise in WRM. To assess water resource availability, institutions must get to grips with collecting, processing and analysing hydrometric data at a minimum. On many of these issues the necessary skills are in their infancy, as revealed in Chapters Five and Six. Thus, there are practical limits as to how rapidly fragile states can undertake necessary reforms to implement IWRM – if this is the ultimate goal. Correspondingly, fragile states will have less satisfactory WRM arrangements than other more advanced countries. This is because they constitute more difficult working environments where progress is harder to achieve. For example, Chapter Seven identified that only 31% of 28,850 water points surveyed in Sierra Leone function year round. This implies 69% of water points do not function as intended, which cannot be classed as a satisfactory outcome. As presented in Table 2-1, rates of progress in extending water supply coverage in fragile states are frustratingly slow and in some circumstances service coverage rates are actually declining. This study argues that WRM programmes in fragile states face severe limits when panaceas are introduced to make governments look better, not as realistic solutions to help governments perform better. For this reason practitioners should work with government institutions as they find them, rather than applying a blueprint approach (Ostrom, 2007). The author argues the key issue is to start small and start something, so realistic solutions for monitoring and managing water resources develop. Empirical research suggests necessary transitions can be achieved by focusing on solving problems in an incremental manner, as proposed by other scholars (see Andrews, 2013). Community members will be best placed to solve water management problems, with causes and solutions often hinging on contextual knowledge, time and information (Schlager, 2007). In line with other scholars (see Moss, 1998), this study reaffirms community participation in fragile states will continue to be an important feature in WRA and WRM for the foreseeable future. However, practitioners should be wary of romanticising the capabilities of communities and the internal attributes of communities should be carefully assessed before deciding whether CBWRM is viable (Cleaver, 1999).

8.2 Linking CBWRM to wider approaches

This section explains how a CBWRM approach could hypothetically fit within a larger WRM system. This narrative is primarily focused on the transition from local to national river basin scale. The theory presented has three phases, which are seldom linear, and is described in the narrative alongside Figure 8-2. In the first phase it is envisaged the state is largely *absent.* This implies there is a "strategic gap" due to the absence of planning frameworks that can steer national water resources policy (Chandran et al, 2008). There is also the possibility that government has taken a centralised attitude to governance in a post-conflict context (Wild and Denney, 2011). Communities and farmers are therefore compelled to monitor and manage water resources remotely, with some support from NGOs and government technicians who themselves may be working in a constrained system. During this phase the author argues communities may follow a CBWRM process aligned to the distinctive markers described in Section 1.5. This means WRM may be confined to small villages and communities that are primarily interested in safeguarding their own point water sources. While this scenario is not ideal, the author maintains village level CBWRM can still take place, although it is hoped that data collection by communities and growing awareness of the resource helps WRA and WRM to become a salient political issue. During this period it is anticipated that government will be defining its strategic priorities and adopting a policy approach to solve real water management problems.

Figure 8-2: Division of river basins into smaller management units (Source: Lankford and Hepworth, 2010)

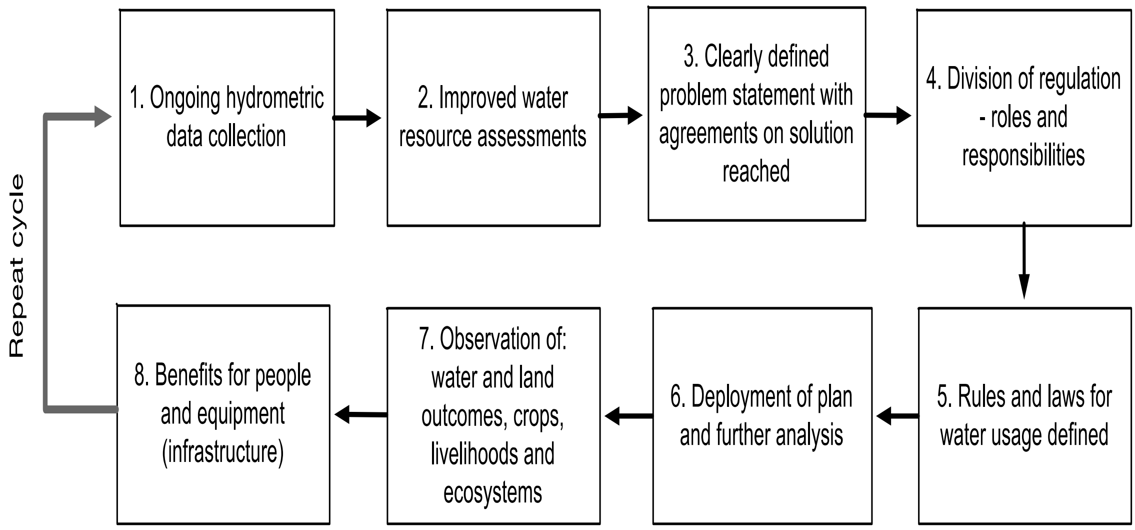


As a result of this ongoing work and practice, CBWRM enters a second *transitional* phase, whereby multiple small villages come together and share information and learning experiences. During this phase it is envisaged governments are pursuing a polycentric model approach, rather than a centralised regulatory approach (see Lankford and Hepworth, 2010). Over time and with experience, water resources are managed at sub-unit level and there is growing interaction between different sub-units. Where formal state institutions may be weak, or deemed illegitimate, there are often informal institutions, such as customary local governance institutions, that may be able to fulfil some of the functions expected of the state (Wild and Denney, 2011). This phase on its own cannot result in water resources being managed at river basin scale; however, there should be increased interaction between communities and government. This is achieved through a process of growing mutual respect and more meaningful decentralisation. To have impact over a wider area, CBWRM should be part of a broader system of WRM that encompasses sharing of hydrometric data, engagement with upstream and downstream water users and analysis of how one group's water usage requirements impacts on another group. In this scenario government introduce localised water policies and CBWRM is increasingly backed by legislation (byelaws), with support from more capable government institutions. Autonomy is given to each farmer or small village to work on its own water policies within the sub-units. A number of institutional reforms are required during this stage at the centre of government. However, reforms cannot simply be of an administrative nature and support must strengthen intermediate level capability as proposed by Moriarty et al (2004). It is recognised that representative government support will be required to coordinate management arrangements within the sub-units. This will help ensure upstream users are not using more than their fair share of water. The benefits of this approach are two-fold: first, it allows policies to be tailored to the local context; and, second, in reality communities themselves will need to police water usage on a daily basis, in the absence of highly effective government institutions. Current river basin planning guidance, such as the EU Water Framework Directive (2000), emphasises that thorough engagement with stakeholders is unlikely to be feasible at the scale of river basins alone. Instead engagement at local and catchment levels is required and should support the planning and development of River Basin Management Plans (RBMPs). Rolling out blanket countrywide reforms, without adaptation to local conditions or directly copying models from other countries is seldom effective (Molle et al, 2007).

The third *decentralised* phase is where water resources are managed across sub-basin units as part of a broader river basin planning process. The river basin problem has been analysed over several decades and the evidence is accumulating that river basins should be broken down into smaller management units. Allan (2003), and Lankford and Hepworth (2010) call for polycentrism to be introduced within river basin planning so that smaller management units are introduced. An advantage of this approach is that it encourages decentralisation and greater autonomy to be given to local communities. In such a scenario, communities and farmers have a recognised and defined role within a wider

WRM system. Naturally if river basin planning commenced, the CBWRM process would also need to evolve so it fits within a wider river basin model. Figure 8-3 illustrates how the CBWRM process could evolve beyond the earlier process identified in Figure 1-3.

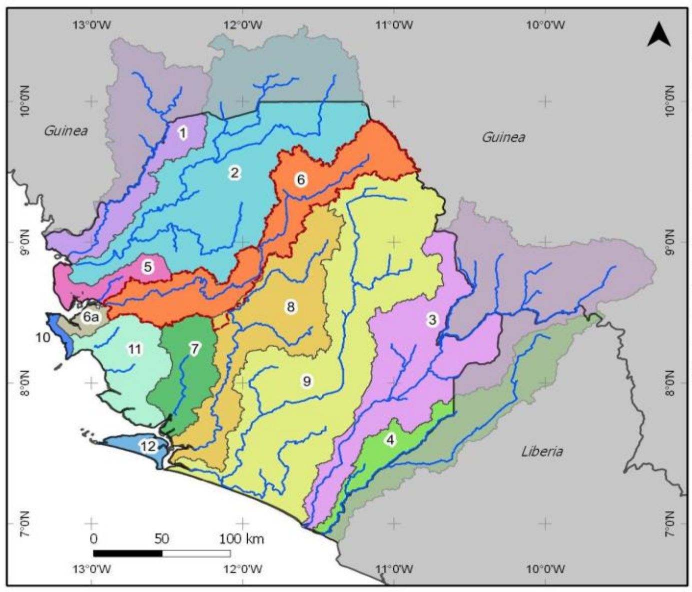
Figure 8-3: Example of the evolving nature of CBWRM process



The process is described in the following stages: The first stage requires hydrometric data to be collected routinely by both communities and government institutions. The distinction being that governments may have established their own formal monitoring networks and participatory monitoring now compliments and “gap fills” these national systems. This process leads to more thorough WRAs and over time and with experience the availability of the resource is known with increased certainty. This infers that government and stakeholders can define a clear problem statement and all stakeholders develop agreed principles for sharing and managing the resource. The next key issue is, where a number of different water user groups exist, the roles and responsibilities and arrangements for implementation must be clearly defined. The agreed principles for sharing water are translated into laws and byelaws for water usage (Perry, 2008). As this system is implemented and develops, further analysis is undertaken. This could include but is not limited to: observation of water and land usage, observation of crops, livelihoods and ecosystem services, and evaluating the tangible benefits for people and infrastructure. Naturally this would be part of an ongoing cyclical process, with RBMPs being revised periodically. The trick will be to ensure governments are addressing the problems that really matter to people and climate change should not frame all water resource problems. The author recognises that several new challenges will arise, for large-scale commons, at regional, national and transboundary level, as activities scale up. This is why national governments must have strong capacity.

That the gap between the absent state and the decentralised state is predominantly due to the characteristics of government, rather than the characteristics of communities, has major implications. Substantial institutional reforms will be required if the decentralised phase is to be achieved and the responsibility to scale up essentially falls on local government rather than communities. It is helpful to consider experiences from West Africa. Sierra Leone has 12 major river basins (presented in Figure 8-4) but no formal management structures currently exist. Since the civil war ended in 2002, there have been no substantial attempts to establish river basin boards, although the structure is described in the Sierra Leone Water Resources Act (2016). The Act, which at the time of writing has been under development since September 2011, proposes the formation of multiple smaller catchment management committees. The Act defines a catchment (sub-unit) as: *"The area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse through surface flow to a common point or common points."* This implies that further research is required as this may inadvertently result in hundreds of sub-units or catchments being established within a larger river basin, which would be impractical to coordinate. Water supply in Sierra Leone is typically delivered through administrative arrangements, thus these established management units may offer an interim solution while river basins boards are established and sub-management units better defined. The CBWRM process lends itself to this uncertainty because it is aligned to existing service delivery approaches. Even if a fragile government wanted to pursue an IWRM approach from the outset, it would likely need to do this in an incremental manner. The performance of weak government institutions would not change overnight and some consideration would need to be made as to how to engage with rural communities during any transition period. Thus the researcher argues CBWRM could sit within a weak or evolving IWRM model if necessary.

Figure 8-4: Sierra Leone river basins



Basin	Name	Area	Inside	Largest
B 1	Great Scarcies Basin	8303	2979	7921
B 2	Little Scarcies Basin	18955	13383	18788
B 3	Moa Basin	19835	9583	19821
B 4	Mano Basin	7776	1959	7734
B 5	Lokko Basin	1565	1565	965
B 6	Rokel Basin	8043	8043	8043
B 6a	Freetown East	579	579	162
B 7	Gbangbaia Basin	3121	3121	2699
B 8	Jong Basin	8481	8481	7972
B 9	Sewa Basin	19022	19022	18701
B 10	Western WRA	223	223	34
B 11	Ribbi/Thauka WRA	3670	3670	1089
B 12	Sherbro WRA	612	612	112

Notes:
* Source HydroSHED catchment boundaries http://hydrosheds.cr.usgs.gov/index.php
* All areas are in square kilometres
* WRA - Water Resources Area
* "Area" is total of all catchments in basin area
* "Inside" is basin area inside Sierra Leone
* "Largest" is largest single catchment area in basin
* Basin 6a is part of the Rokel River management area shown in GOSL documents. It is subdivided here for clarity

Taking into account experiences from Sierra Leone the time required to move from: absent to transitional to decentralised state is likely to be considerable. The requirement for a transitional approach is of course more acute in fragile states, particularly if governance and accountability to communities is lacking. For example, Fanthorpe and Gabelle (2013) explain that the government's responsibility to consult with communities, does not necessarily grant communities in Sierra Leone a right of input into mining lease agreements, or the monitoring of environmental and social management programmes. Thus ministers in a transitional government may sign contracts that concede very generous terms to extractive companies for signature bonuses with less consideration for environmental management (Collier and Venables, 2008). In this study the argument put forward is that it is better if government is representative in supporting better WRA and WRM. However, a government that is "extractive" and unaccountable to its citizens will have a host of problems to address that that are more fundamental than the management of water resources. Whether governments harness the opportunities provided by international donors depends specifically on their accountability and governance. If this is not forthcoming, the role of government in managing water resources will appear peripheral, especially if government is heavily involved in the exploitation of natural assets (such as gold, diamonds and iron ore). If governments cannot make credible commitments to improving stewardship of water resources, one partial solution is to work directly with communities at village level. If communities are worried about the mismanagement of water resources, a possible solution is to safeguard their own point sources and to collect hydrometric data to create commitment that can bind future water management over a wider area. For example, if a major water abstractor is perceived as having an impact over a wider geographical area, collecting data on the impacts may be an attractive proposition for communities, especially if they understand the data presented. Local communities then have an incentive to share data and collaborate. Incumbent governments have an obligation to assess the data and support communities to find an acceptable solution agreeable to all parties. The ongoing water crisis in Flint, Michigan provides a clear example of collective action by a coalition of local residents and a failed response from the state's environmental department until actual scientific data was presented (Guardian, 2016). A conclusion argued in this study is that community-based approaches should be pursued so both bottom-up and top-down approaches can occur simultaneously. But as Ostrom (2009) argued, *"people can't just sit and wait for the global solution."*

8.3 Limitations of the research

This study adopted AR as the research method; this cyclical approach that combines qualitative and quantitative data collection methods increases the transferability and generalisability of insights. Although extensive efforts have been made to ensure the validity, reliability and transferability of this research, some limitations are identifiable. This section explores limitations related to the research methodology in terms of data collection and analysis, and the extent of the CBWRM process investigated.

8.3.1 Limitations related to the overall methodology and approach

Due to the field research being disrupted (see Section 4.5) and the adoption of case study approaches, the transferability of insights from Darfur, Niger, Burkina Faso and Sierra Leone is restricted. Limitations of case studies include the ability to generalise to the wider public and difficulty in replicating findings (McLeod, 2008). However, the goal of a case study approach is to achieve analytic generalisation rather than statistical generalisation (Yin, 2009). The aim of this research is not to provide an accurate picture of the general population; it is highly possible that CBWRM would not be appropriate in urban and densely populated environments, where the sense of community and collective action is absent (Day *et al; forthcoming*). The purpose of the case studies in this research is to identify the potential effectiveness of a small number of rural communities to engage in participatory monitoring. The case studies are particularly useful for understanding "how" and "why" when building and testing theories (Rose et al; 2015). Research was conducted in both dry and arid environments (such as Darfur, Niger and Burkina Faso) as well as states considered blessed with abundant rainfall, such as Sierra Leone. This has allowed the CBWRM theory to be assessed in different contexts, which increases the generalisability and transferability of the results because it has not been restricted to failed states with very low annual rainfall. The hydrological data recorded by communities is considered reliable and data from both Burkina Faso and Sierra Leone (respectively) was overlaid so it could be compared. This revealed a high correlation between rainfall and groundwater level data for both case studies. The willingness of communities to record hydrological data was also shown to be high and data collection by communities has continued with negligible external support from government institutions or persuasion from the researcher (see Chapter Five). Some limitations in the reliability and validity of the research findings may have been increased in the focus group discussions on rating institutional ability to provide effective external support, as the scoring system is subjective (see Section 4.3.2). Thus the findings could vary if repeated by other researchers. However, the impact of this is likely to be minimal because no government institutions interviewed in Burkina Faso or

Sierra Leone were currently validating, analysing or publishing hydrological data routinely. It would be unwise to generalise from these case studies to the whole of SSA, but the study provides some useful insights into the benefits of a localised approach for WRA.

Arguably, the greatest limitation of the research is that it has not been possible to compare research samples of communities who have and have not engaged in WRAs. A comparison of these cases would have provided a clearer indication of whether participatory monitoring leads to improved water security for communities or whether water points continue to experience problems with seasonality. However, differentiating between “adopters” and “non-adopters” would also be complex; there may well be several factors beyond the communities’ control, especially if point water sources had been poorly sited and installed. The definition of an adopter would also be difficult to define. This study identified that communities in arid environments (notably Darfur and Niger) already had informal techniques for assessing water availability (see Chapter Five) and the notion of there being no water management arrangements whatsoever may be misleading.

Working simultaneously as a practitioner and researcher in FCAS over a long period of time is not an easy fit. As a practitioner, the daily work demands are driven by human energy and the need to deliver rapid, short-term change. As a researcher, the author is trying to analyse problems with a theoretical starting point and theoretical framework. Creating the space to do this is challenging, and the working environment is far removed from the comforts of an academic desk. This study has highlighted the difficulties encountered when undertaking research in some of the world’s most difficult working environments. In doing so the author has worked in countries that exceed the insurance limits of academic staff in UK Universities. This makes replication of the research findings difficult; however, an increase and improvement in research in FCAS is much needed if the Post-2015 Development Agenda is to be achieved. Due to disruptions to this study in Darfur and Niger, new research sites had to be established. It is often difficult to identify any donor supported CBWRM activities ongoing in SSA and on each occasion new funding had to be secured and new monitoring sites had to be established in Burkina Faso and Sierra Leone. It is a time consuming process to re-establish participatory monitoring activities from scratch and the collection of data needs to run for at least a 12-month period to capture data covering one full dry and rainy season. There is also a high incidence of lack of water resources knowledge and experience amongst the technical wings of government and NGOs, and substantial foundational training and support is required. Consequently, it is not possible within this study to determine how water resources can be managed more effectively, and it is not possible to identify the causality between WRAs undertaken by communities, and improved WRM. Even though volunteer observers, farmers and community members were positive about their involvement in CBWRM activities, a much longer-term study is required to order to fully explore the potential benefits of CBWRM, both for communities and government. For example, it was not possible to determine whether the collective action and management decisions taken community members in Burkina Faso resulted in water points functioning year round or whether groundwater levels continued to recede and reach a natural equilibrium. However, although only the WRA elements of CBWRM were investigated, this has allowed community members and practitioners working in the WASH sector to understand the extent of groundwater recovery and recession in both Burkina Faso and Sierra Leone. The visualisation of the relationship between rainfall and groundwater is likely to have helped both community members and practitioners understand hydrology in action and increase interest.

8.4 Summary

This chapter has highlighted the links between insights presented earlier in the literature review and shown how CBWRM sits within a broader approach. The second section provided some suggestions of why the WASH sector should engage in CBWRM and how this could enable community groups to come together to monitor and manage water resources over larger areas or sub-catchments. The influence CBWRM could have on an IWRM process, even if “weak” IWRM is still the preferred model, is also discussed. This also identifies how the CBWRM process could evolve to incorporate a broader range of actors. The final section identified some limitations of the research study and insights gained. The next and final chapter of this thesis provides a summary of the main insights gained and relates them back to the research objectives. It also outlines the contribution of this study to theory and practice.

9 Conclusions

The final chapter of this thesis identifies the main insights from this research and relates them back to the aims and objectives. It also reflects on the implications of the fieldwork for the bodies of work discussed in the opening chapters and, in particular, the literature review. In doing so it re-establishes a connection with existing theory and practice.

9.1 Recapitulation of aims and summary of insights

Despite widespread promotion of the IWRM paradigm since the 1990s (GWP-TAC, 2000), evidence of its successful application in developing countries and FCAS is limited (see Biswas, 2004; Carter, 2009, Lankford and Hepworth, 2010 and Giordano and Shah, 2013). In response, scholars and practitioners have put forward alternative approaches, such as AM (see Pahl-Wostl et al, 2007) and “light” IWRM (Moriarty et al, 2004) to encourage the implementation of IWRM. Other literature (see Lankford and Hepworth, 2010) argue that governments should pursue a polycentric model where sub-units are established within river basins and hydrologists and scientists are deployed as mediating agents between sub-units. This study supports this decentralised, polycentric model, but emphasises we should also recognise the low base from which many FCAS are starting. Many difficult problems (such as corruption, failed institutional reforms, unwillingness to decentralise resources and limited experience and expertise in WRM) must all be addressed if the polycentric model is to be successful. Governments in FCAS may be slow to address WRM problems and it will inevitably take time for central and local government to become fit-for-purpose. This study argues the potential for a successful transition towards polycentrism is much greater if community level institutions and the WASH sector are actively trying to address real water management problems during this transitional period. The rationale is two fold: first, rural communities can’t simply sit and wait for long periods of time; and second, it is counter-intuitive the WASH sector continues to extend water supply coverage with negligible consideration for water resources. The challenge is to pursue both top-down and bottom-up approaches simultaneously, while inter-linking the two domains of WRM and water supply.

The overarching research aim was: to investigate the extent to which rural communities can actively participate in monitoring water resources by working alongside government authorities in fragile states.

The research objectives were:

- To assess the potential effectiveness of rural communities in monitoring water resources.
- To determine the barriers to improving community participation in WRM.
- To identify obstacles linking WRM and water supply in the WASH sector.

Each research objective has been largely fulfilled, and the rationale for the three research objectives is clearly explained in Chapter One. This research has focussed primarily on the WRA steps of the CBWRM process (see Figure 1-3). Thus, the ability of communities to manage water resources has not been fully determined.

The AR approach adopted in this study was highly appropriate for conducting research in fragile states, which are characterised as being some of the most difficult working environments in the world. This is because fieldwork was disrupted on a number of occasions and AR demands a continuous process of reflection and learning to assess progress being made. The methodology used followed Denscombe's (1998) process for AR, which adopts practitioner experience as the starting point for the investigation. It also follows Eisenhardt (1989) guidance on building research from case studies. Three case studies were located in arid environments where typically average annual rainfall is low. The fourth case study site was located in Sierra Leone, a country that typically receives >2,500mm rainfall annually. Data collection techniques included focus group discussions, semi-structured interviews, participatory mapping, transect walks and hydrometric monitoring with both community members and government institutions. Full details of the methodology used are described in Chapter Four.

9.2 Main insights generated through this research

The case study areas were all located in difficult working environments, where limited or negligible WRA and WRM are taking place. This is reflected in Chapter Two that describes the context of fragile states and the “cause and effect” diagram (see Figure 8-1) provided in Chapter Eight. Use of a CBWRM process provided insight into some of the ways governments and practitioners can re-establish hydrometric monitoring in FCAS. Although this study was limited in scale, the author believes it would have been extremely difficult to evaluate wider WRM approaches, such as integrated RBMPs, when countries are starting from such a low base. The following section draws together the insights gained from Chapters Five to Eight in relation to the research objectives.

9.2.1 Objective 1: To assess the potential effectiveness of rural communities in monitoring water resources

In line with national trends, access to adequate and reliable water supplies is a major problem for rural communities in the case study areas. As expected, the two domains of water supply and WRM was often artificially separated in the case study areas and limited hydrometric monitoring was taking place. Addressing the problems of point water sources running dry was a priority for communities. There was also a high level of understanding among communities that major water abstractors (such as mining companies and agribusiness) have the potential to affect local water resources. All communities in the case study areas could be described as remaining on the margin of government support, with low levels of external support to keep water supply services functioning. All communities were engaged in subsistence livelihoods and required water for both domestic and productive use. Customary water management practices were evident in Darfur and Niger although water management was not sophisticated and was largely reliant on informal monitoring and observations.

Communities used a variety of water management methods. In some cases community members would observe groundwater fluctuations and try to determine whether it had been a “good” or “bad” rainy season.

Volunteer observers selected by host communities, were directly involved in collecting rainfall and groundwater data in Burkina Faso and Sierra Leone. Rainfall data was collected on a daily basis with groundwater levels being measured weekly or monthly. From the outset there was scepticism by some government representatives as to whether community members would be capable of recording hydrometric data accurately. However, engagement with government authorities from the outset and careful selection of monitoring equipment helped to ensure any concerns were addressed. Volunteer observers received substantial training and support prior to commencing monitoring.

Overall the data collected by volunteer observers in Sierra Leone (shown in Chapter Five) looks promising. Some anomalies occurred due to misreading, as levels of literacy varied across the community monitoring sites. However, when compared to data collected by paid government observers and the automated weather station at Addax’s agribusiness site, community data from Sierra Leone looks very encouraging when extrapolated using the CRD method. Data collected in Burkina Faso, albeit over a limited geographical area, also looks promising with a good correlation between rainfall and groundwater levels. In line with studies elsewhere by (see Zemadim et al, 2013, Gowing et al, 2016) participatory hydrometric monitoring was found to work well. Despite periods of limited engagement from government authorities (for example, during the West African EVD outbreak) communities continued to record hydrometric data to imply they had genuine interest in WRAs. At the time of writing, monitoring of rainfall and groundwater levels in Burkina and Sierra Leone has continued to this day and this has apparently led to a much greater focus on water management issues by communities. The research has also challenged the belief of other researchers (see Hardin, 1968) that communities have limited capacity to engage in monitoring and managing water resources.

The argument often presented has been that communities and citizens will have limited ability to interpret the data collected. Tabulated data sets may be difficult to understand and government institutions may be less inclined to actually share information with communities, because scientific data is the preserve of central government. This means communities are essentially reduced to "bookkeeping." However, the plotting of hydrometric data alongside community members led to greater understanding of the relationship between rainfall and groundwater levels. This challenges the belief of other researchers (see Grey, 2012) that data should be the preserve of government or institutional institutions. It also highlights that communities can play a role (albeit slightly unsophisticated) in interpreting data. This work builds on findings from other studies (see Govardhan das and Somasekhara Rao, 2000; Ravindranath and Sharma, 2008; Zemadim et al, 2012; and Gowing et al, 2016) that have also included participatory monitoring. This research also found the visualisation of data was sufficient to improve understanding and generate wider interest to manage water resources. This led to community members actively discussing water management problems they experience and attempting to devise arrangements (including rules, laws and graduated sanctions) for managing groundwater. Although this study does not permit any strong conclusions to be drawn on water management, this research has provided some insight as to the interest that CBWRM can generate.

Effective external support was identified as an important factor for successful WRA and broader CBWRM. However, there was limited evidence that government institutions have capacity to validate, analyse and publish monitoring data themselves without substantial capacity building support. In Sierra Leone this was due, in part, to the fact that hydrometeorological monitoring stations were destroyed during the nation's decade-long civil war (1991–2002) and the technical wings of government had limited experience of WRA and WRM. The research also found that external support from government institutions was not considered sufficient to provide necessary support for community-based initiatives. Overall, evidence indicated community-based initiatives and ongoing capacity building of government institutions should happen simultaneously. When compared to other studies (see Chow et al, 1988 and Kongo et al, 2010), this study argues that solely relying on top-down monitoring approaches will likely make a minor contribution to solving real water management problems at community level. This study reaffirms that modularity should be introduced into the monitoring process so data processing is not exclusively reliant on the actions of central government institutions.

9.2.2 Objective 2: To determine the barriers to improving community participation in WRM.

Regardless of the level of engagement shown by community-based institutions, it is likely that meaningful external support from government will be required. However, there were clear problems both in terms of government experience and expertise, as well as their willingness to decentralise resources. The problem of centralisation was related to a number of factors including: lack of clarity over line ministry responsibilities and competition over limited funding opportunities. Intermediate levels of government in Sierra Leone, termed local councils, did not have access to material or financial resources to engage in WRA or WRM. This implies central government may resist pursuing a polycentric model and the establishment of sub-units within river basins may take substantial time to establish at national scale.

As is generally the case in developing countries, central government in Sierra Leone and Burkina Faso in the past were encouraged to adopt the IWRM concept. However, the ability of central ministries in Sierra Leone to implement these approaches was generally very low. As found elsewhere (see Giordano and Shah, 2013), the production of IWRM policies, strategies and road maps is likely to become an end in itself. Thus, governments focus on trying to implement perceived best practice rather than addressing real problems (Andrews, 2013). This research found evidence that polycentrism is gaining some acceptance, however little advancement had been made in progressing these models (see Chapter Eight). Not only is WRM afforded a low priority in national planning it is dominated by the desire to extend nationwide water supply coverage. Consequently, sub-national governments have almost invariably no experience or expertise in WRA or WRM. These insights agree with the findings of Lankford and Hepworth (2010) who do not foresee that basin management will be the subject of funded technical programmes for the foreseeable future.

However, evidence suggests that decentralisation should be widely encouraged; during periods of violence and conflict that affects all sectors of society, government institutions have not maintained essential skills to manage water resources, such as an ability to calculate the local water balance. The consequence for environmental management is severe, because the very skills needed to pursue polycentric models, such as "light" IWRM are lacking. Some scholars (see Giordano and Shah, 2013; Coleman, 2013) argue that China has delivered WRM by having no stakeholder participation in decision-making. This implies governments could be following the European centralised regulatory model for WRM. People will continue to disagree on the merits of a centralised or decentralised model. However, the author argues: If transitions are mismanaged what are citizens expected to do in the interim? Community interests cannot be dismissed, because in any democratic society the government must reflect the interests of the majority of its citizens. Thus, in pursuing top-down WRM policy, governments must balance the interests of the rural poor by providing interim solutions. Thus, a centralised approach in SSA and fragile state contexts may not be so viable or play out as well as they do in China.

Given the ubiquitous constraints faced by government institutions (see Chapter Six) the use of a community-based approach, which works below basin and catchment scale, would potentially allow for further investigation of how communities can monitor and manage water resources in the absence of robust government institutions. This study argues that for individual WASH organisations, working at village or multiple village scale, CBWRM is probably a more realistic approach than trying to work in isolation at catchment or basin scale from the outset (see Chapter Eight). Rather than trying to promote all-inclusive IWRM approaches in an unpromising environment, this research has demonstrated the importance of ensuring water points function year round, supporting communities to build resilience and supporting government to build experience and expertise in WRA and WRM.

9.2.3 Objective 3: To identify obstacles linking WRM and water supply in the WASH sector.

As found elsewhere, findings from this study suggest the WASH sector has engaged comparatively little in WRM. Previous studies (see Smits et al, 2009) correctly identify that this is because IWRM has remained at the higher levels of national policies, which extends far beyond service delivery of community water supplies. However, many of the findings in this study suggest the WASH sector, at times, inadvertently undermines its own good intentions. The root cause of the problem is the ability to link theory and practice of WRM. The interconnection of factors is described in Chapter Seven.

This study has shown that even displaced people demand water for both domestic and productive use – even in protracted humanitarian emergencies. This finding places doubt on the misconception that people want small quantities of potable water and supports earlier findings (see van Koppen and Smits, 2012) that people actually demand water for both domestic and productive use, which will likely impact on water resources. Recent important studies by Gowing et al (2016) and Villholth et al (2013) highlight the opportunities for increasing small-scale groundwater irrigation in SSA; however, this will demand better WRA and WRM by local communities and farmers. Evidently, the problem of water point seasonality is already a major problem, even in countries like Sierra Leone that receives high average annual rainfall (see Section 7.2.2). This reiterates the necessity for participatory hydrometric monitoring. This finding reaffirms the availability of water resources should not be perceived as a foregone conclusion and thus monitoring is not required. It has also demonstrated the importance of evolving current community management models so both infrastructure and resource issues are considered. The use of a CBWRM approach strengthens the water component in rural water supply programmes.

The survey responses in Chapter Seven provide further evidence that practitioners perceive community water supplies, as being under threat from multiple pressures, yet this does not result in the uptake of WRAs. Indeed, growing awareness of climate change is encouraging WASH organisations to help people adapt to climate risks, yet continuous change to water resources is not being routinely monitored. In respect of climate change, analysts have identified the limitations of GCMs for local-level planning. In respect of IWRM it is widely recognised the paradigm is difficult to implement, because it is beyond the capacity of any single organisation. This research demonstrates interim measures should be found to help communities understand risk to their water resources. Thus the WASH sector is not really at the stage where it can routinely provide reliable answers to WRM problems. Indeed recent WASH sector technical briefs (see GWP and UNICEF, 2014) may not necessarily be informed by empirical field research and this research challenges the belief that NGOs should begin by engaging at catchment scale. This research found the immediate requirement is to link the domains of water supply and WRM at village scale. The use of a CBWRM approach may help to ensure environmental concerns are factored into rural water supply approaches.

The interconnection of factors identified in this study suggests there is potential to increase the uptake of CBWRM if a wider approach is taken to sustaining point water sources, as it would increase understanding of local hydrology and the problems of water point seasonality. In particular, it would allow NGOs to work alongside governments in monitoring constant and continuous change. The limitations of GCMs to downscale and provide a sound lookout for the future has been emphasised in this study and physically monitoring water resources is identified as being more critical in adapting to climate change and other risks.

9.3 Contributions of this thesis

Stewardship of water resources in FCAS is in bad shape. An important priority must be to concurrently lay the foundations for better WRA and WRM within government institutions and to strengthen the resilience of rural communities.

This section demonstrates the contribution of this study to current theory and practice.

9.3.1 Contributions to theory

Typically there are two contemporary theories for WRM. One is centralised river basin management with an apex authority that seeks hydrometric data and has decision-making authority over water allocation. This model is commonplace in European countries. The other polycentric model is institutionally, organisationally and geographically more decentralised (Lankford and Hepworth, 2010). This study argues the polycentric model is a more realistic option in FCAS, because central government may be weak and local level institutions should be involved in WRA and WRM. However, the dominance of the IWRM paradigm means that river basins may inadvertently adopt centralised control structures and community-based initiatives may be dismissed for being small in scale. In FCAS technocrats may argue the stakes are too high not to introduce a centralised regulatory model, but that more training and finance is needed. However, it is less certain how these initiatives will lead to real water management problems at various levels being resolved. Many scholars (see Andrews, 2013) argue that institutional reforms in developing countries often have unsuccessful outcomes. The decentralised approach demands a different capacity building pedagogy because capacities, skills, finances and materials all need to be strengthened at various levels (Lankford and Hepworth, 2010). Two legitimate concerns are: how this can be actually achieved if central government is unwilling to decentralise and political blocks are imposed, and the time required establish effective polycentric models. These problems have been illustrated in this study. The researcher argues that top-down and bottom up models should be pursued simultaneously. Critically the researcher also argues that polycentric models need to go beyond catchment scale. By linking WRM to the day-to-day activities of the WASH sector the two domains of water supply and WRM can be inter-linked in fragile states. In other words village level CBWRM can function as the principles of polycentric local basin management are promoted and hopefully adopted. This would serve to address the current dichotomy whereby the WASH sector strives to extend water supply coverage to rural communities. Meanwhile, major international organisations encourage governments to pursue all-inclusive IWRM approaches through a centralised regulatory approach. Analysis shows ambitious IWRM plans have not delivered the desired outcomes. The most common complaint is: the IWRM paradigm is extremely difficult to implement (see Mehta and Movik, 2014). A real risk factor that emerges is that virtually no WRA and WRM is taking place, because the two approaches do not correspond.

Most programming in fragile states is fundamentally about change processes (DFID, 2013). To that end, the development of new pragmatic approaches is vital (see Giordano and Shah, 2013; Muller, 2015). This requires that, at a minimum, real water management problems be addressed, even if they are not as wide-ranging as IWRM. There are few proven WRM approaches in fragile states and activities should be constantly monitored to see if they are having the desired impact. One belief is that WRM is not really a local problem because there are so many international river basins (Grey, 2012). Grey maintains policy boundaries must progress from the local to planetary scale. However, without some basic grounding in assessing and managing water resources it is questionable what skills national institutions can offer.

This study builds on findings from other research concerning groups in society managing CPRs (such as Ostrom, 1990, 1998, 1999 and Trawick, 2002 and 2003). These studies highlighted that community-based institutions can monitor and manage water resources with reasonable degrees of success. This study extends this work to fragile states and, importantly, links activities to current WASH sector practice in response to calls for more pragmatic approaches (see Giordano and Shah, 2013 and Muller, 2015). A relatively recent insight is that community water supplies may be threatened by groundwater depletion. So the availability of the resource should not be perceived as a foregone conclusion (Robins et al, 2013a and 2013b).

9.3.2 Contributions to practice

If rural water supplies are to be scaled up, the resource base must be sustainable – that is, the service should not fail at any time due to drought, excessive drawdown or sources drying up (Schouten and Moriarty, 2004). This implies that constant and continuous monitoring of water resources is required. But who should undertake these WRAs? This study has shown that government institutions have limited capacity to assess the water balance and rural water supply programmes in the WASH sector have a narrow focus. Typically they focus on domestic water supply and extending coverage in accordance with national and international targets (WaterAid, 2011; World Bank, 2012).

This study has illustrated that rural communities demand water for both domestic and productive use – even in humanitarian contexts. A key variation between domestic and productive water demand will be the resultant impact on point water sources, especially if small-scale groundwater irrigation is practiced. This study also illustrated the seasonality of water points is a major problem, even in countries like Sierra Leone that are perceived as having abundant water resources. It also highlighted that the visualisation of the relationship between rainfall and groundwater levels helps communities to understand local hydrology, which in turn supports the uptake of WRM. Overall, there was limited evidence that WASH practitioners have routinely engaged in WRAs, despite a perceived risk to groundwater resources. Insights from the survey questionnaires did not support current WASH sector practice. Practitioners generally recognised that hydrometric monitoring was important but WRA and WRM was somehow beyond the scope of WASH programming. Thus, rapid improvements in local hydrometric data collection and analysis are much needed. This research also highlights a dichotomy that currently exists: GCMs are impressive but they do not facilitate local-level adaptation planning. That the WASH sector does not monitor important hydrometric parameters raises questions as to exactly what information is being used to climate-proof WASH infrastructure and to help communities adapt to climate threats?

This research builds on the traditional community management model presented by Schouten and Moriarty (2004), which see communities play an integral role in operating and maintaining rural water supplies. It also proposes local-level solutions, but differs to other recent studies (see GWP and UNICEF, 2014) in that WRAs can initially take place at village level and not at catchment scale. Catchment management plans will likely require substantial collaboration and capacity building of government institutions. As explained in Chapter Eight, this approach is seen as being more realistic approach for organisations involved in rural water supply service delivery. Therefore, the CBWRM approach has two distinctions: first, it evolves the community management model, which is important if the state remains absent in WRM and second it helps lay the foundations for strengthening government institutional capacity, before progressing onto wider catchment management plans. WaterAid[25] has adopted this methodological approach and in 2015 received a USD $1 million grant to expand CBWRM activities across West Africa.

9.4 Future work

An indication of the direction that future work might take related to CBWRM is provided by the discussion on research limitations in Section 8.3.1. The starting point is to reflect whether this research is generalisable. This study is relatively small in scale and the research into CBWRM has been restricted to the aspect of WRA. Thus, detailed evidence of sound WRM is not sufficiently robust to suggest that CBWRM should be widely replicated. However, the researcher argues the insights from this study suggest the CBWRM approach warrants further investigation. A degree of generalisability can be demonstrated because this study was undertaken in different contextual settings. For example, multiple monitoring sites were established across the Rokel-Seli River Basin in Sierra Leone and further monitoring sites created in more arid environments in Burkina Faso (see Chapter Five). The rural communities selected were typical of remote rural populations in both countries and had no prior experience of formal WRA.

[25] WaterAid is the largest NGO in the United Kingdom dedicated to working on water supply and sanitation in developing countries.

Furthermore, the literature review explained the common problems multiple FCAS experience, with failed institutional reforms and a ubiquitous lack of virtually any WRA or WRM. Thus, the need for more pragmatic WRM approaches is not confined to a small number of countries in SSA. However, a concern identified by the researcher is that experience and expertise in WRA and WRM within government institutions and WASH sector organisations is likely to be limited, because stewardship of water resources is often omitted in current field programming. Put simply, CBWRM requires further investigation before it should be scaled up more widely. In particular more analysis is needed on the use and benefits of participatory monitoring to communities over the long-term. This would require the WRA and WRM components of CBWRM to be fully investigated to increase transferability and generalisability of the research findings. This would also require research to be undertaken over a longer time period to see how water management problems change over time and the level of influence communities can really have in preventing water points from running dry. The time dimension required to link CBWRM with wider WRM approaches, such as engagement with other villages and sub-units in catchments, is likely to be longer still given WRM in fragile states appears to be in its infancy.

This study has attempted to describe the relationship between community-based institutions and government agencies in FCAS for undertaking WRAs. It has shown that the informal observations by remote communities can be strengthened by some core considerations (see Chapter Five) and community-based WRAs can help governments to re-establish hydrometeorological monitoring networks. In contrast to top-down models for re-establishing national monitoring networks, it has been argued that a localised approach helps to build the resilience of rural communities, by forging links between communities and the technical wings of government. It also enables government institutions to build hydrological experience and expertise in an incremental manner. A further indication of the direction of future research relates to the growing interest in citizen science in hydrology and water resources. These informal mechanisms are seen as a cost-effective way to obtain scientific data and create new hydrological knowledge in remote rural areas (see Gura, 2013 and Buytaert et al, 2014). In contrast to the conventional rural water supply approach it has also been argued that consideration for the water resources that sustain community water supplies enhances the community management model. It has been shown that consideration for the water resources that sustain community water supplies is currently afforded inadequate attention.

There remain, however, several problems that future research should try to address. Firstly, more work is required to determine how the behaviours of community-based institutions can lead to improved WRM so that water availability extends throughout the dry season. Secondly, further research is also required to understand how community groups can join together so the collective efforts of villages extend over sub-catchments and river basins. This is likely to be a lengthy process that would require long-term collaboration between communities, local government authorities and practitioners in a range of different settings. Thirdly, and perhaps most importantly, the management aspects of the CBWRM model and the evolving nature of CBWRM have to be based largely on assumptions for which data is not currently available. WASH practitioners have struggled to scale up community water supply projects to cover larger geographical areas. Scaling up WRM approaches in FCAS likely offers a far greater challenge because the time periods required will be substantially longer and coordination more complex.

9.5 Closing remarks

Engaging in this work has given the author the opportunity to study in depth the relevant literature on WRA and WRM, which has been very interesting and informative. The direct links with WaterAid in Burkina Faso and the MWR in Sierra Leone as well as attendance at various international conferences has enabled the author to link “thinker and practitioner” approaches, which has been most beneficial.

The involvement with a research programme mid-career is consistent with continuing professional development and a willingness to learn. Undertaking applied research in conflict-affected fragile states would also seem consistent with the Cranfield University motto: after darkness, light. In many respects this programme has taught the author a great deal about conducting research, which is after all the primary purpose of undertaking a PhD.

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APPENDICES

Appendix A : Key Informant Interviews

A.1 Summary of key informants from case study areas

Key informant category	Number interviewed	Description
Darfur (North Sudan)		
Water sector and development professionals	9	Including senior staff from KSCS and rural water staff from private sector
Local government representatives	4	Including representatives from GWWD and Water and Environmental Sanitation Project
Academics from national and international Universities	2	Senior academics from the natural resources department
Community water user committees	8	A range of community members displaced from across North Darfur
Senior community leaders	5	Including Sheikhs, Omdas and the King of Al Fasher
Niger		
Water sector and development professionals	5	Including senior staff from Karkara, UNICEF and Oxfam
Local government including representatives from Agricultural departments	3	Including representatives from Ministry of Agriculture
Academics	3	Senior academics from national research institutions

Women's gardening committee	4	Community members belonging to women's gardening committee
Senior community leaders	4	Including community leaders and commune Mayor
Burkina Faso		
Water sector and development professionals	5	Including senior technical staff from WaterAid UK and DAKUPA
Local and central government including Commune Mayor	6	Including representatives from DEIE, DRAH and Commune Mayor
Community Water User Committees	9	5 female and 4 male members of local water user associations
Senior community leaders	3	Including community leaders
Sierra Leone		
Water sector and development professionals	9	Including international and national NGOs
Local and central government staff	7	Including representatives from MWR, Environmental Protection Agency and Local Councils
Academic from Fourah Bay College	1	Senior academic from research institutions
Community volunteer observers	6	A range of community members and school teachers

Senior community leaders	2	Including paramount chiefs

A.2 List of full interview respondents

Code	Organisation	Position	Area of expertise
Darfur Case Study			
Practitioners and Academics			
KI-1D	UNEP	Technical Advisor	Natural Resources Management
KI-2D	UNEP	Hydrogeologist	Hydrogeology
KI-3D	UNICEF	Regional Coordinator	Water and Sanitation
KI-4D	Oxfam	Hydrogeologist	Hydrogeology
KI-5D	Oxfam	Technical Lead	Water and Sanitation
KI-6D	ODI	Senior Research Associate	Policy and Practice, Livelihoods
KI-7D	Kebkabiya Smallholders Charitable Society	Programme Director	Rural Development
KI-8D	Sudanese Environmental Conservation Society	Programme Director	Rural Development
KI-9D	Al Fasher University	Head of Department	Natural Resources Management
KI-10D	Tufts University	Senior Lecturer	Pastoralism and Nutrition
Government Institutions			
KI-11D	Groundwater and Wadis Department	Regional Manager	Hydrogeology and Hydrology
KI-12D	Groundwater and Wadis Department	Technician	Hydrogeology and Hydrology
KI-13D	Water and Environmental	Director	Water and Sanitation

	Sanitation Programme		
KI-14D	Water and Environmental Sanitation Programme	Technician	Water and Sanitation
Community-Based Institutions			
KI-15D	Abu Shouk Water User Committee	Member	Water Management
KI-16D	Abu Shouk Water User Committee	Member	Water Management
KI-17D	Abu Shouk Water User Committee	Member	Water Management
KI-18D	Al Salaam Water User Committee	Member	Water Management
KI-19D	Al Salaam Water User Committee	Member	Water Management
KI-20D	Al Salaam Water User Committee	Member	Water Management
KI-21D	Kebkabiya Water User Committee	Member	Water Management
KI-22D	Kebkabiya Water User Committee	Member	Water Management
Community Leaders			
KI-23D	Al Fasher	King	Local Governance
KI-24D	Abu Shouk	Sheikh	Local Governance
KI-25D	Al Salaam	Sheikh	Local Governance
KI-26D	Kebkabiya	Sheikh	Local Governance
KI-27D	Kebkabiya	Omda	Local Governance

Niger Case Study			
Practitioners and Academics			
KI-1N	Karkara	Programme Manager	Agriculture
KI-2N	Karkara	Technician	Agriculture
KI-3N	Karkara	Programme Director	
KI-4N	Oxfam	Country Director	International Development
KI-5N	UNICEF	Programme Manager	Water and Sanitation
KI-6N	University of Oxford	Institute Director	Climate Science
KI-7N	ACMAD	Director	Climate Science
KI-8N	AGHRYMET	Scientist and researcher	Hydrology
Government Institutions			
KI-9N	Ministry of Water Resources	Minister	Governance
KI-10N	Ministry of Water Resources	Director	Water Resources Management
KI-11N	Ministry of Agriculture	Agronomist	Agriculture
Community-Based Institutions			
KI-12N	Banibangou Gardening Cooperative	Chair Woman	Water Management
KI-13N	Banibangou Gardening Cooperative	Member	Water Management
KI-14N	Banibangou Gardening Cooperative	Member	Water Management
KI-15N	Banibangou Gardening	Member	Water Management

	Cooperative		
Community Leaders			
KI-16N	Banibangou	Manager	Water Supply
KI-17N	Banibangou	Youth Leader	Local Governance
KI-18N	Tillaberi Regional Office	Director	Rural Development
KI-19N	Banibangou Mayors Office	Mayor	Local Governance
Burkina Faso Case Study			
Practitioners and Academics			
KI-1BF	WaterAid	Technical Advisor	Hydrology
KI-2BF	WaterAid	Head of Regional Learning Centre	Water Resources
KI-3BF	WaterAid	Programme Manager	Water and Sanitation
KI-4BF	Global Water Initiative	Programme Manager	Water Resources Management
KI-5BF	DAKUPAH	Programme Manager	Water and Sanitation
Government Institutions			
KI-6BF	DHAH	Director	Hydrology
KI-7BF	DRAH	Deputy Director	Hydrology
KI-8BF	DEIE	Director	Hydrology
KI-9BF	DEIE	Director	Hydrology
KI-10BF	PAGIRE	Permanent Secretary	Hydrology
KI-11BF	Tenkodogo Commune	Mayor	Governance
Community-Based Institutions			

KI-12BF	Sablogo Water User Committee	Member	Water Management
KI-13BF	Sablogo Water User Committee	Member	Water Management
KI-14BF	Sablogo Water User Committee	Member	Water Management
KI-15BF	Basbedo Water User Committee	Member	Water Management
KI-16BF	Basbedo Water User Committee	Member	Water Management
KI-17BF	Basbedo Water User Committee	Member	Water Management
KI-18BF	Kampoaga Water User Committee	Member	Water Management
KI-19BF	Kampoaga Water User Committee	Member	Water Management
KI-20BF	Kampoaga Water User Committee	Member	Water Management
Community Leaders			
KI-21BF	Sablogo	Village Chief	Local Government
KI-22BF	Basbedo	Village Chief	Local Government
KI-23BF	Kampoaga	Village Chief	Local Government
Sierra Leone Case Study			
Practitioners and Academics			

KI-1SL	Adam Smith International	Institutional Reform Advisor	Institutional Reform and Local Government
KI-2SL	Adam Smith International	Public Finance Manager	Financial Manager and Local Government
KI-3SL	Adam Smith International	Team Leader	Economics
KI-4SL	Oxfam	Technical Advisor	Water and Sanitation
KI-5SL	UNICEF	WASH Specialist	Water and Sanitation
KI-6SL	DFID	Deputy Country Director	Economics
KI-7SL	ADB	Country Representative	Water Supply
KI-8SL	Guma Valley Water Company	Senior Engineer	Water Supply
KI-9SL	Sierra Leone Water Company	Senior Engineer	Water Supply
KI-10SL	Fourah Bay College	Senior Lecturer	Hydrogeology
Government Institutions			
KI-11SL	Water Directorate, MWR	Director	Water Supply
KI-12SL	Water Directorate, MWR	Head of Water Resources Unit	Water Resources
KI-13SL	Water Directorate, MWR	Water Quality Analyst	Water Resources
KI-	Decentralisation Secretariat	Director	Local Governance

14SL			
KI-15SL	Tonkolili Local Council	Chief Administrator	Local Governance
KI-16SL	Bombali Local Council	District Engineer	Water and Sanitation
KI-17SL	Koinadugu Local Council	District Engineer	Water and Sanitation
Community-Based Institutions			
KI-18SL	Kamathor	Community Observer	Water Management
KI-19SL	Masongbo	Community Observer	Water Management
KI-20SL	Mayawlaw	Community Observer	Water Management
KI-21SL	Waia	Community Observer	Water Management
KI-22SL	Magburaka	Community Observer	Water Management
KI-23SL	Rosinth	Community Observer	Water Management
Community Leaders			
KI-24SL	Bumbuna Chiefdom	Paramount Chief	Local Governance
KI-25SL	Mabonto Chiefdom	Paramount Chief	Local Governance
Ghana			

KI-1G	Accra	Director	Water Resources Commission

Appendix B : Interview Topic Guide

B.1 Key informant interviews with communities

Introduction	
Provide an introduction to the aims and purpose of the research.	• Introduce myself. • Explain the purpose of the research interview. • Keen to learn more about their experiences of water resources management and government policy and practice. • Provide an explanation of key terms – such as water resources management. • Interviews take a maximum of 40 mins. • If there are no initial questions or concerns we can proceed.
Participant and village background.	
Can you tell me a bit about your village and your work?	• How long have you lived in the village? • Are you a member of any community committees? • What work do people in the village undertake? • Can you describe the village briefly, for example the number of water points available?
Experience with water resources management.	
Can you tell me a little bit about your experiences of water resources management?	• How is the water situation here? • Is there a difference in the amount of water available in the dry season? • What do you do with the water you collect? • When there is less water available do you do anything to reduce the amount of water you use? • Can you describe how water is managed across the community? • Does the community have a

	system (structure) for managing water? • Has the water situation changed over time? • If yes, why do you think this is occurring? • What do you think is happening with the amount of water underground?
Experience with policy and practice.	
Can you tell me about your experiences of Government policy and practice?	• Has the village received any support from the government? • What is your experience of working with the government on water issues? • Do you receive regular support visits? • Can you cite any examples where the community and the government have worked together to address problems?
Others issues.	
Before concluding the interview is there anything else you would like to mention that was not already discussed.	• Any other issues that haven't already been discussed? • Other people to talk to? • Any final remarks?
Conclusion.	
Thanks for taking the time to meet.	• Do you require a summary of the interview findings? • Feel free to contact me if you wish to provide additional information.

Appendix C : Sierra Leone Site Monitoring Register

District	**Site Number**	**Monitoring Site**	**Monitoring Parameters**		
			Rainfall	Groundwater	Stream flow
Bombali	SN01	Addax Environmental Office	■	■	
Bombali	SN02	Addax – Lungi Nursery	■	■	
Bombali	SN03	Makeni – Bombali District Council Office	■	■	
Bombali	SN04	Mayagba – Chester Heath Primary School	■		
Bombali	SN05	Mayawlaw Primary School	■	■	
Bombali	SN06	Mayawlaw Secondary School	■		
Bombali	SN07	Rosinth Secondary School	■		
Tonkolili	SN08	Bumbuna - Boyo Primary School	■	■	
Tonkolili	SN09	BWMA Office	■		
Tonkolili	SN10	Kadala Spring			■
Tonkolili	SN11	Kakutan Spring	■		■
Tonkolili	SN12	Kamathor 1 (Borehole)		■	

Tonkolili	SN13	Kamathor 2 (Spring)	■		■
Tonkolili	SN13b	Kamathor 2 (Borehole)		■	
Tonkolili	SN14	Kasokira Stream	■		■
Tonkolili	SN15	Mabonto Primary and Secondary Schools	■	■	
Tonkolili	SN16	Magburaka Boys School	■		
Tonkolili	SN17	Magburaka National Secondary School	■		
Tonkolili	SN18	Magburaka – Tonkolili District Council Office	■	■	
Tonkolili	SN19	Maraka Primary School	■		
Bombali	SN20	Masongbo	■	■	
Tonkolili	SN21	Mathora Primary School	■	■	
Tonkolili	SN22	Kathombo Primary School	■	■	
Koinadugu	SN23	Waia	■		
Bombali	AD01	Addax Automated Weather Station			
Bombali	AD02	Addax River Gauging Site (Upstream)			
Bombali	AD03	Addax River Gauging Site (Downstream)			
Tonkolili	AD04	Addax Block 7 - Raingauge	■		

Bombali	AD05	Addax Block 11 - Raingauge	■		
Tonkolili	BD01	Bumbuna Raingauge	■		
Tonkolili	BD02	Bumbuna Weir	■		
Tonkolili	BD03	Bumbuna Reservoir			
Bombali	MD01	Makeni Weather Station (SL Met Department)	■		

Appendix D : Hydrological Monitoring Forms

D.1 Rainfall recording form

Sierra Leone Water Security and Water Resources Management Projects — **Rainfall Records**

Location:	District:	Month & Year
Observer's Names:	Title	Telephone:

All records to be taken at 9 am each morning (see instruction sheet). Readings should be recorded on the actual date they are taken. (These will be adjusted to the preceding date when processed). Use the space below to include each measurement when the measurement cylinder has overflowed into the outer container (for example: 20.0 + 16.5 + 18.0 + 19.0 = 73.5 mm).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1

Daily Total Rainfall

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1

Please maintain two copies of this sheet for each month.

1 copy is to be kept by the School or Organisation.

1 copy is be collected by the Ministry of Water Resources or BWMA after the end of each month.

Total Rainfall for Month (1st to 31st) ______ mm

Appendix E : Conferences and Events

E.1 Events organised at Institution of Civil Engineers

WaterAid Oxfam ice Institution of Civil Engineers

Integrated Water Resources Management
Moving from Theory to Practice

The Appropriate Development Panel (ADP) at the Institution of Civil Engineers, in collaboration with Oxfam GB and WaterAid, is hosting a season of presentations and panel discussions devoted to Integrated Water Resources Management (IWRM).

These interactive events will highlight complex and uncertain risks that regional and local water resources face. The series will showcase the role of social groups in natural resource management and provide insights into operational water resources and land management. The series will also discuss the need to integrate operational field practice to land and water policies that reflect reality.

Event 1 - 1830 Tuesday 15th December 2009
Complex Risk: *The Future of Regional & Local Water Resource and Land Management.*

The sustainable management of water and land resources is fundamental in the delivery of health services and food security. This discussion will set the scene highlighting the need to operationalise water resource and land management.

Professor Richard Carter (WaterAid) and **Roger Calow (Overseas Development Institute)** will lead discussions on these complex risks.

Event 2 – 18.30 Tuesday 13th April 2010
Recognizing & Respecting Community-Led Adaptation

Community Water Resource Management should form an integral component of broader IWRM initiatives, yet relief practitioners frequently overlook traditional approaches for managing water and land resources.

Dr. Paul Trawick (Cranfield University) and **Dr. Nick Brooks (Tyndall Research Centre)** will provide an insight into traditional community led management of natural resources.

Event 3 - (to be confirmed) June 2010
Practical Integrated Water Resource Management

To become effective IWRM needs to be broken down into integral components, which encourage decentralisation and accountability towards end water users.

St John Day (Oxfam GB) and a **representative from WaterAid Nepal** will present examples of ongoing field based initiatives to operationalise IWRM into field programmes.

Event 4 - (to be confirmed) September 2010
Moving from Practice to Policy: *The Role of Communities in Effecting Change*

To manage water resources effectively requires water and land policies that reflect operational reality rather than remaining aspirational. Mutual respect must exist between end water users and policy makers.

Dr. Bruce Lankford (University East Anglia) and **Dr Julie Trottier (University of Montpelier)** will discuss the requirement to align operational field practice to more realistic water and land policies.

These events will be held at the ICE, One Great George Street, SW1P 3AA. Presentations will also be **Broadcast Live Online** with the chance to ask the panel questions remotely from anywhere in the world – so please circulate details of these events to your own global mailing lists. Events will be recorded and available for download.

To book your seat at the ICE for each event contact Daphne Guthrie via email: daphne.guthrie@ice.org.uk

Visit our website (http://www.ice.org.uk/conferences_events/newsevents_events.asp) for updated event details.

E.2 Follow up survey for expert academics and practitioners

Institution of Civil Engineers

One Great George Street

Westminster

London

SW1P 3AA

Dear Colleague

The Appropriate Development Panel (ADP) at the Institution of Civil Engineers has recently collaborated with Oxfam and WaterAid to deliver a series of interactive events devoted entirely to water resources management. These events have generated wide interest in a theme that is of growing importance. The ADP, Oxfam and WaterAid are now planning to produce a joint publication that captures learning from the four IWRM events and from practical field experiences. This will provide a useful guide for water sector professionals and practitioners and we request your expert assistance to help inform this publication.

Collectively the ADP, Oxfam and WaterAid, are promoting a concept termed Community- Based Water Resources Management (CBWRM). CBWRM seeks to operationalise water resources management at local/community level. Our hypotheses are based on the assumption that CBWRM can co-exist and complement the decentralization of state IWRM plans – where they exist. However, where state intervention has tragically failed CBWRM can provide local institutions and communities with a *fighting chance* of managing local resources relatively well. Oxfam and WaterAid are embarking on a series of pilot projects in 2011 to help develop best practice and identify key principles for CBWRM.

In order to inform our publication we are keen to obtain the opinions of expert academics and practitioners. As someone with specialist knowledge and experience of international development and water resource management we would be extremely grateful if you could assist us in our research by responding to a short questionnaire that is attached below.

WATER RESOURCES MANAGEMENT QUESTIONNAIRE FOR ACADEMIC AND PRACTITIONER EXPERTS

The questionnaire is divided into two parts. Part 1 allows for short Yes/No answers, while Part 2 seeks slightly more in-depth responses. The findings of this research will be published in June 2011 and discussed at the publication launch to be held at the Institute of Civil Engineers in June 2011. We will also acknowledge your support and response in contributing to this publication.

Please answer as many questions as possible:

PART 1:

e) Do you think Integrated Water Resources Management - as promoted by the Global Water Partnership - is a viable and realistic mechanism for operationalising water resources and land management in low-income countries and fragile states?

   Yes or No

b) IWRM has become the orthodoxy or recognised norm when referring to the management of water resources and land. Do you think water sector professionals and policy makers' use the IWRM mechanism in practice?

   Yes or No

c) Do you think there is a role for rural communities and local institutions in managing and regulating water use?

   Yes or No

PART 2: Please respond with sentences or bulleted points.

d) Can you cite good examples of IWRM in practice, in low-income countries and fragile states?

   Please give examples.

e) Can you cite any relevant field tools that you have used to operationalise water resources management?

   Please provide brief details.

f) What are the key principles for operationalising water resources management at local or community level in low-income countries and fragile states?

   Please state.

g) Do you think Non Governmental Organizations, specializing in water supply, sanitation and hygiene (WASH) has engaged meaningfully in water resources management?

   Please give examples or details of your own experience.

The deadline for submission of the completed questionnaire is Friday 01st April 2011. Please email your response to sday@oxfam.org.uk or s.j.day@cranfield.ac.uk.

Thank you in advance for any assistance you are able to provide and please do not hesitate to contact me if you require further details.

Yours Sincerely

St John Day

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[1] The Global Water Partnership promotes IWRM as "a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." The GWP supports the four guiding Dublin principles that state:

- Principle No. 1 - Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Principle No. 2 - Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
- Principle No. 3 – Women play a central part in the provision, safeguarding and management of water.
- Principle No. 4 – Water has an economic value in all its competing uses and should be recognised as an economic good.

Appendix F : Survey Questionnaire

F.1 Household water usage survey: Darfur

OXFAM GB –Darfur, North Sudan
منظمة أكسفام لبريطانية –دارفور –شمال السودان
Water Management in Darfur
April 2007

Household Water Usage Survey
جدول مسح الاستخدام المنزلى للماء

Date:التاريخ			
Campالمعسكر :			
Interviewer Name أسم السائل			
1. Location of the household موقع منزل الاسرة			
2. Sample type طبيعة العينة المستهدفة	Household منزل	Tap stand محطة مياه	Brick making موقع إنتاج الطوب الطينى
3. No of h/holds in the compound عدد الاسرة فى تلك القطاع او المربع			

4. No of people in the household عدد أفراد الاســـــرة	Adult male ذكور كبار	5-15 male ذكور فى سن 5- 15 سنة	<5 male ذكور أقل من 5 سنة
	Adult female أناث كبار	5-15 female أناث فى سن 5-15 سنة	<5 female إناث أقل من 5 سنة
5. No of pregnant women or chronically ill people in the h/hold عدد النساء الحوامل و عدد الافرادذات الامراض المعجزة			
6. What water point do you normally use? ماهى محطة المياه المعتادإليكم			
7. How long does it take you to walk there? كم من الزمن للوصول إلى محطة المياه المعتادة			
8. Do you collect water from any other place? هل هنالك محطات أخرى للحصول على المياه	Yes نعم	No لا	
8B. If yes, where? إذا كلان الإجابة نعم , اين ؟			

9.How many water containers/jerry cans does your household share? كم عدد الجركانات او أوانى المياه المشتركة فى الاسرة	2	3	4	5
	6	7	8	9+
10. How many jerry cans of water do you collect per day usually? كم عدد جركانات الماء التى تتحصل عليها فى اليوم				
11. How often is water collected? كم عدد مرلت جلب المياه إلى المنزل	More than once/day أكثر من مرة فى اليوم	Once/day مرة واحدة فى اليوم	Every 2 days بعد كل يومين	
	Every 3 days	Every 4 days	Other	
12.When you go collect water, how many trips do you make in the day? كم عدد مرات التردد على محطة المياه للحصول على الحصة اليومية من الماه	2	3	4	Other
13. If you collect every 2nd, 3rd or 4th day – Why is this? لماذا تجلب الماء إلى المنزل كل يومين , كل ثلاثة أيام و أو كل اربعة أيام	Queues too long صفوف الجركانات طويلة جداً	Lost place in queue عدم وجود مكان للصف		
	Water point too far away محطة المياه بعيدة جداً	Other أسباب أخرى		

<table>
<tr><td rowspan="2">14. When you place your jerry cans in the queue – how long do you wait until you can fill the jerry cans?
متى تضع الجركانات فى الصف و كم مدة الإنتظار حتى مرحلة ملء الجركانات التابعة لك</td><td>Under 1 hour
أقل من ساعة</td><td colspan="2">1-4 hours
4-1 أربعة ساعات</td><td colspan="2">4-12 hours
12-4 ساعة</td></tr>
<tr><td>More than 1 day
بعد أكثر من يوم</td><td colspan="4">Other أخرى</td></tr>
<tr><td rowspan="2">15. At what time do you normally collect water?
ماهى الأوقات التى تورد فيها إلى الماء</td><td>Morning فى الصباح</td><td colspan="2">Afternoon
فى المساء</td><td colspan="2">Early evening
فى وقت مبكر من المساء</td></tr>
<tr><td>Late evening
فى وقت متاخر من المساء</td><td colspan="2">Night فى الليل</td><td colspan="2">Early morning</td></tr>
<tr><td>16. Explain why you collect at the time you do?
ماهى الاسباب التى تستدعيك ان تورد للماء فى الوقت بالذات</td><td colspan="5"></td></tr>
<tr><td>17. Do you feel safe when collecting water at this time? هل تشعر بامان عند لحظات الذهاب الى محطة المياه فى هذا الوقت بالذات</td><td colspan="2">Yes نعم</td><td colspan="3">No لا</td></tr>
<tr><td>17B. If no – why not</td><td colspan="5"></td></tr>
</table>

إذا كان الإجابة بلا – لماذا لا		
18. Have you noticed any changes in the water supply in the camp in the last 3 months? هل لديك اى ملاحظات تغيير فى عملية إمداد المياه خلال الثلاث أشهر الماضية	Yes نعم	No لا
18B. If Yes – what ?إذا كان إجابة – بنعم – ماهى , أذكر تلك الملاحظات		
19. Do you have any concerns about the water supply and access to it? هل لديك اى تحفظات بشان امداد المياه و مستوى الحصول اليها	Yes نعم	No لا
19B. If YES – what? إذا كان الاجابة – بنعم – أذكر تلك التحفظات –		

20. What does your household use the water collected for? ماهى استخدامات المياه بالاسرة	Drinking للشرب	Cookingللطباخة	Washing clothes غسيل الملابس
	Bathing للاستحمام	Brick making لصناعة الطوب	Selling للبيع

	Water animals لسقى الحيوانات	Garden للحدائق	Other اخرى

21. If appropriate, ask how much water is used DAILY for the following activities:

هل يمكن تحديد كميات المياه المستخدمة لاى من الانشطة التالية :

Activity النشاط	Number Jerry Cans عدد الجركانات								Where Water Collected? من أين تجمع أو تتحصل على الماء المستخدم
21A.Brick making for own house construction صناعة الطوب لأغراض بناء منازلهم	1	2	3	4	5	6	7	8	
21B.Brick making for sale صناعة الطوب بغرض البيع									
21C.Sale of water جلب الماء لاغراض البيع									
21C.Vegetable plot for own consumption لري الخضروات للاستخدام المنزلى									
21D.Vegetable plot for sale لرى الخضروات لاغراض البيع									
21E.Drinking									
21.F.Bathing									

<table>
<tr><td>21.G. Washing clothes</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>21.H. Watering animals</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>21.I. Other أى نشاط آخر</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

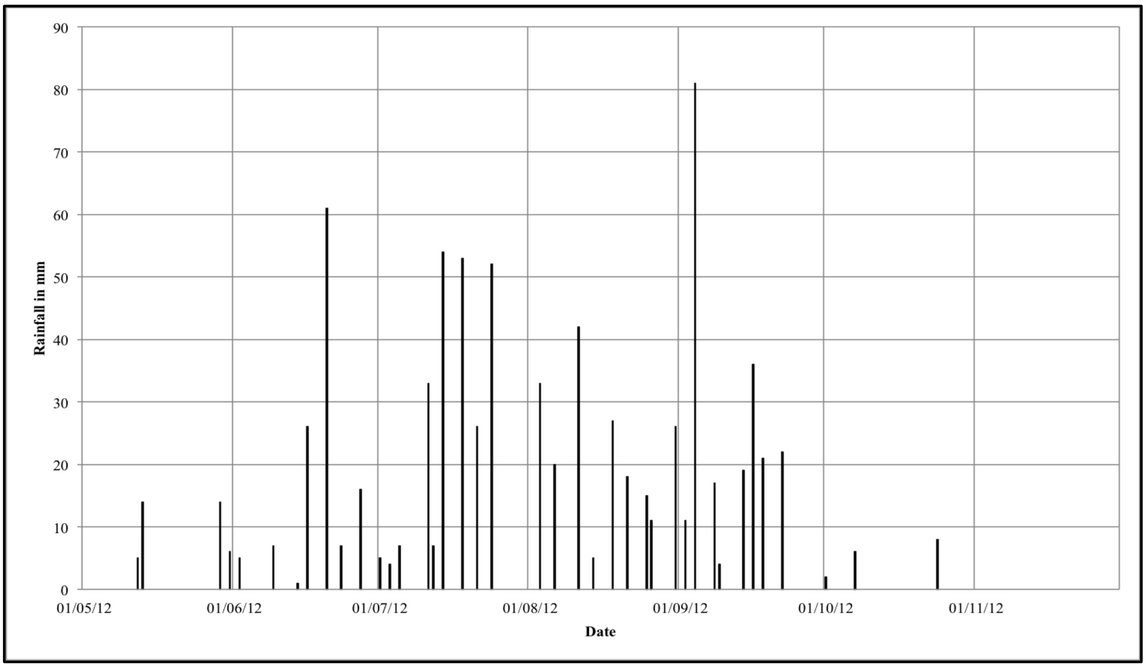
<table>
<tr><td rowspan="3">22. How does your household get money?
كيف تتحصل أسرتك على المال النقدى</td><td>Firewood selling
بيع الحطب</td><td>Daily Labour
عمل باليومية</td><td>Small Trader
نشطة تجارة هامشية</td></tr>
<tr><td>Sale of Water
بيع الماء</td><td>Sale of Bricks
بيع الطوب</td><td>Sale of grass/sorghum
بيع علف/ القش / العيش</td></tr>
<tr><td>Portering و شحن تفريغ</td><td>Other أخرى</td><td>Other أخري</td></tr>
</table>

<table>
<tr><td>23.Do you pay to collect water?</td><td>Yes نعم</td><td>Noلا</td></tr>
<tr><td>24B. If yes, how much do you pay against one jerry can? إذا كان الاجابة – بنعم – كم من المبالغ تدفع مقابل الماء</td><td colspan="2"></td></tr>
<tr><td>25. Do you know what this money is used for?
هل تدرى كيفية صرف أيرادات المياه من المحطة</td><td>Yes نعم</td><td>Noلا</td></tr>
</table>

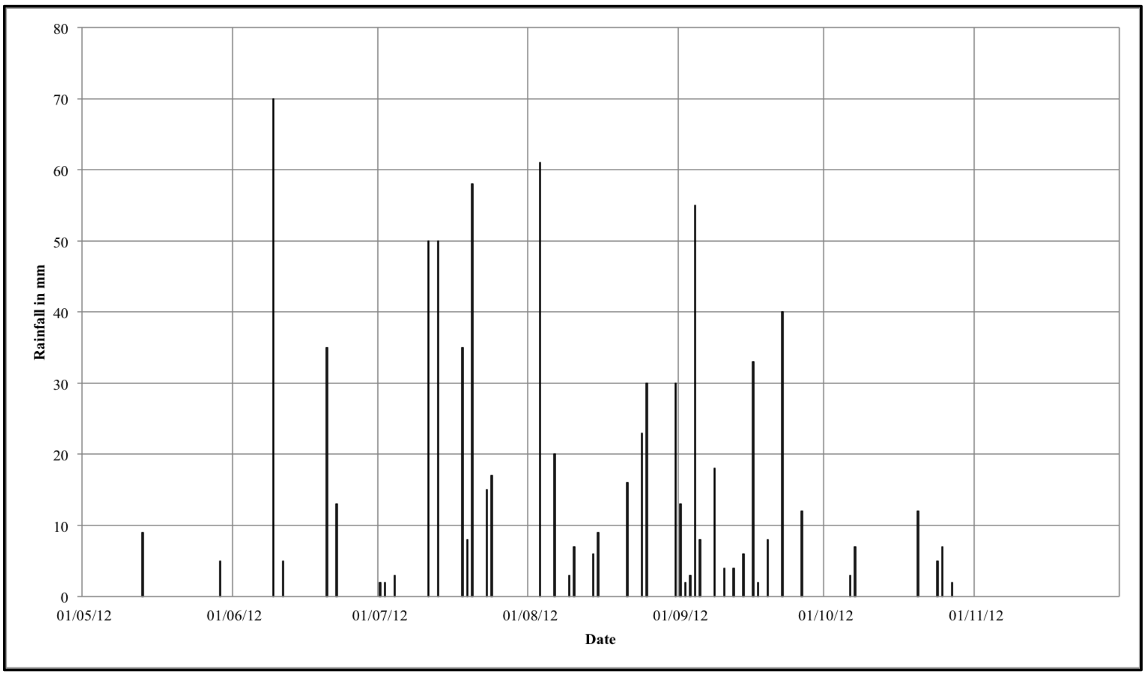
25B. If yes, what is it used for? أذا كان الإجابة – بنعم – أذكر بنود صرف إيرادات محطات المياه	

Appendix G : Hydrometric Data Collected in Burkina Faso

G.1 Sablogo rainfall data: 2012



G.2 Kampoaga rainfall data: 2012



Appendix H : Hydrometric Data Collected in Sierra Leone

H.1 Rainfall data from 2013

ID	Site Name	Start Date	J	J	A	S	O	N	D	Total
SN01	Addax Environmental Office	21 Feb 13	119.3	397.5	683.8	411.9	452.5	118.0	7.0	2190
SN03	Makeni – Bombali District Council Office	31 May 13	288.0	378.2	807.5	459.5	411.4	109.0	7.5	2461.1
SN04	Mayagba – Chester Heath Primary School	4 June 13	391.0	357.3	878.7	524.5	444.0	59.0	13.2	2667.7
SN05	Mayawlaw Primary School	4 June 13	409.0	377.0	970.5	668.5	415.5	72.0	10.0	2922.5
SN06	Mayawlaw Secondary School	4 June 13	367.5	313.5	671.5	665.0	434.1	79.7	0.0	2531.3
SN07	Rosinth Secondary School	3 June 13	241.2	308.0	756.0	504.5	474.0	0.0	0.0	2283.7
SN08	Bumbuna - Boyo Primary School	6 June 13	210.3	216.5	778.5	341.0	377.5	40.5	2.5	1966.8

SN09	BWMA Office	5 June 13	169.0	242.0	763.0	402.5	324.5	79.5	4.5	1985
SN10	Kadala Spring									
SN11	Kakutan Spring	20 June 13	79.5	177.0	304.0	175.0	221.0	0.0	0.0	956.5
SN12	Kamathor 1 (Borehole)									
SN13	Kamathor 2 (Spring)	11 June 13	133.0	326.5	822.5	405.5	363.5	90.5	3.5	2145
SN13b	Kamathor 2 (Borehole)									
SN14	Kasokira Stream	06 June 13	160.0	293.0	890.8	446.0	396.5	93.0	4.0	2283.3
SN15	Mabonto Primary and Secondary Schools	30 June 13	22.5	426.5	955.5	448.5	501.0	146.5	0.0	2500.5
SN16	Magburaka Boys School	04 June 13	401.5	403.5	426.2	637.0	454.0	57.0	0.0	2379.5
SN17	Magburaka National Secondary School	04 June 13	372.0	406.0	931.7	638.0	453.8	55.3	6.0	2862.8
SN18	Magburaka – Tonkolili District Council Office	04 June 13	379.5	397.8	873.8	615.8	377.1	45.3	10.7	2700

SN19	Maraka Primary School	05 June 13	466.4	325.3	858.1	555.6	406.0	71.4	0.0	2682.8
SN20	Masongbo	11 June 13	158.5	233.0	771.0	433.5	467.0	87.0	3.0	2153
SN21	Mathora Primary School	05 June 13	427.0	369.5	1001.5	527.5	407.5	68.5	9.0	2810.5
SN22	Kathombo Primary School	13 June 13	233.0	301.0	943.0	422.5	398.0	87.0	2.0	2386.5
SN23	Waia	21 June 13	78.0	297.0	554.5	434.1	336.5	76.3	2.5	1778.9
AD01	Addax Automated Weather Station	07 Feb 13	364.0	203.9	12.8	61.9	20.2	7.5	0.0	670.3
BD01	Bumbuna Raingauge	2007	155.6	155.4	890.4	408.2	324.2	77.8	5.2	0.0
MD01	Makeni Weather Station (SL Met Department)	1921	348.1	254.3	896.9	645.3	358.8	78.2	13.3	4.6

H.2 Rainfall data from 2014

ID	Site Name	J	F	M	A	M	J	J	A	S	O	N	D	Total
SN01	Addax Environmental Office	0.0	0.0	0.0	0.0	180.0	429.5	384.5	398.5	nd	nd	nd	nd	1392.5
SN03	Makeni – Bombali District Council Office	5.5	0.0	0.0	35.5	276.5	677.5	559.0	882.5	450.0	414.5	236.0	0.0	3537.0
SN04	Mayagba – Chester Heath Primary School	0.0	0.0	0.0	92.5	218.1	432.5	604.4	588.3	595.5	328.5	245.5	0.0	3105.3
SN05	Mayawlaw Primary School	0.0	0.0	0.0	112.5	208.5	382.5	617.5	614.5	613.0	381.0	248.0	27.5	3205.0
SN06	Mayawlaw Secondary School	0.0	0.0	0.0	87.5	176.0	409.6	518.0	617.0	501.5	376.5	233.0	24.5	2943.6
SN07	Rosinth Secondary School	0.0	0.0	0.0	31.0	193.5	302.0	451.0	590.0	398.0	431.0	201.5	20.5	2618.5
SN08	Bumbuna - Boyo Primary School	1.5	0.0	0.0	27.0	232.0	293.0	471.0	646.0	496.0	277.0	188.0	41.5	2673.0
SN09	BWMA Office	1.5	0.0	0.0	45.0	159.5	272.5	670.0	456.5	581.5	390.0	192.5	56.5	2825.5

SN10	Kadala Spring													
SN11	Kakutan Spring	18.0	0.0	0.0	nd	298.5	263.0	489.0	385.5	623.5	342.0	97.5	15.1	2532.1
SN12	Kamathor 1 (Borehole)													
SN13	Kamathor 2 (Spring)	0.0	0.0	0.0	48.0	190.5	295.5	466.5	344.5	653.0	324.0	147.0	61.5	2530.5
SN13b	Kamathor 2 (Borehole)													
SN14	Kasokira Stream	1.5	0.0	0.0	38.0	277.0	347.5	480.0	386.5	625.5	383.5	180.0	14.5	2734.0
SN15	Mabonto Primary and Secondary Schools	1.5	0.0	0.0	89.0	330.5	338.0	396.5	729.5	573.5	401.0	243.5	68.5	3171.5
SN16	Magburaka Boys School	0.0	0.0	0.0	89.5	215.0	394.0	471.5	626.0	439.5	323.5	58.1	nd	2617.1
SN17	Magburaka National Secondary School	0.0	0.0	0.0	69.5	191.3	nd	532.5	632.8	nd	351.0	227.5	24.5	2029.1
SN18	Magburaka – Tonkolili District Council Office	8.4	0.0	0.0	92.5	203.0	342.0	467.0	641.0	490.0	349.5	101.5	nd	2694.9

SN19	Maraka Primary School	8.0	0.0	0.0	113.5	282.6	314.9	535.4	724.4	449.0	323.5	294.7	30.0	3076.0
SN20	Masongbo	1.0	0.0	0.0	44.0	199.0	318.5	579.5	694.0	489.0	324.0	288.5	10.0	2947.5
SN21	Mathora Primary School	1.0	0.0	0.0	99.0	287.0	316.0	552.0	693.5	404.5	354.0	294.0	30.0	3031
SN22	Kathombo Primary School	4.5	0.0	0.0	11.0	73.0	320.5	446.0	648.0	620.0	333.0	221.0	12.5	2689.5
SN23	Waia	0.0	0.0	0.0	0.0	68.0	314.0	436.0	292.0	416.0	234.0	165.0	7.0	1932.0
AD01	Addax Automated Weather Station	0.0	0.2	0.0	6.9	7.0	nd	nd	nd	nd	nd	nd	nd	14.1
BD01	Bumbuna Raingauge	0.0	0.0	0.0	35.8	206.2	272.6	428.8	520.6	604.4	309.0	175.4	12.8	2665.6
MD01	Makeni Weather Station (SL Met Department)	4.6	0.0	0.0	62.5	128.7	338.7	506.4	454.5	538.7	122.6	79.2	70.9	2306.8