Report

Adaptation to Climate Change in Water, Sanitation and Hygiene

Assessing risks, appraising options in Africa

Naomi Oates, Ian Ross, Roger Calow, Richard Carter and Julian Doczi

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The Adaptation case study referenced in this report, which is part of the Adaptation to Climate Change in WASH project is available here

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Abbreviations

ADB	Asian Development Bank
BAU	Business as usual
BCR	Benefit-cost ratio
BPEICV	Best practice under existing and increasing climate variability
CAPEX	Capital expenditure
CAPMANEX	Capital maintenance expenditure
CBA	Cost-benefit analysis
CC	Climate change
CEA	Cost effectiveness analysis
CIF	Climate Investment Fund
CLTS	Community-led total sanitation
CRGE	Climate-Resilient Green Economy
CUA	Cost utility analysis
CV	Climate variability
DALY	Disability-adjusted life year
DEFRA	Department for Environment, Food and Rural Affairs
DFID	Department for International Development
DRA	Demand-responsive approach
DRR	Disaster risk reduction
ET	Evapo-transpiration
EU	European Union
FAO	Food and Agriculture Organisation

FCC	Freetown City Council
FUWC	Freetown Urban WASH Consortium
FWMC	Freetown Waste Management Company
GCM	Global circulation model
GDP	Gross domestic product
GHG	Greenhouse gas
GVWC	Guma Valley Water Company (Sierra Leone)
HEA	Household economy analysis
HDI	Human Development Index
INGO	International non-governmental organisation
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rates of return
ITCZ	Inter-Tropical Convergence Zone
IMR	Infant mortality rate
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Programme (WHO/UNICEF)
LCCA	Life-cycle cost approach
LGA	Local Government Authority (Tanzania)
LPCD	Litres per capita per day
MDG	Millennium Development Goal
M&E	Monitoring and Evaluation
MoHS	Ministry of Health and Sanitation (Sierra Leone)
MoW	Ministry of Water (Tanzania)
MoWDI	Ministry of Water Development and Irrigation (Malawi)
MoWR	Ministry of Water Resources (Sierra Leone)
MUS	Multiple-use water services
NAPA	National Adaptation Programme of Action
NGO	Non-governmental organisation
NPV	Net present value

ODA	Official development assistance
ODI	Overseas Development Institute
OPEX	Operational expenditure
RDM	Robust decision making
ROA	Real options analysis
SAGCOT	Southern agricultural growth corridor of Tanzania
SALWACO	Sierra Leone Water Company
SoPs	Standards of protection
SSA	sub-Saharan Africa
SWAp	Sector-wide approach
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Funds
USAID	United States Agency for International Development
WASH	Water, sanitation and hygiene
WASHCOs	Water, sanitation and hygiene committee
WELS	Water economy for livelihoods
WHO	World Health Organization
WP	Water point
WRM	Water resources management
WSDP	Water Sector Development Programme (WSDP)
WSP	Water and Sanitation Programme
WUA	Water user association

Glossary

Adaptation - Adjustment in natural or human systems to a new or changing environment; adaptation can be anticipatory or reactive, private or public, autonomous or planned

Adaptive capacity - The ability of a system (e.g. community or household) to anticipate, deal with and respond to change

Climate change - A statistically significant change in either the mean state of the climate or in its variability, persisting for an extended period (decades or longer)

Climate model - A quantitative approach to representing the interactions of the atmosphere, oceans, land surface and ice (see also Global Circulation Models)

Climate proofing - Ensuring that current and future development policies, investments or infrastructure are resilient to climate variability and change, reducing climate-related risks to acceptable levels

Climate risk - Likelihood of a natural or human system suffering harm or loss due to climate variability or change

Climate variability - The departure of climate from long-term average values, or changing characteristics of extremes, e.g. extended rainfall deficits that cause droughts or greater than average rainfall over a season

Community management - An approach to service provision in which communities take responsibility for operating and maintaining their own water supply systems

Coverage - Level of access to a minimum standard of service, usually defined by government

Domestic water - Water used by households for drinking, washing and cooking

Ecosystem services - Benefits people obtain from ecosystems. Includes *provisioning* services (e.g. production of food and water); *regulating* services (e.g. flood control); *supporting* services (e.g. nutrient cycling) and *cultural* services (e.g. recreational, spiritual)

Food security - When all people, at all times, have access to sufficient, safe, and nutritious food to maintain a healthy and active life

Functionality (of water systems and services) - A measure of whether systems and services are 'fir for purpose' and functioning as intended; typically used to distinguish between systems that work and provide services, and systems that do not because they have fallen into disrepair

Global Circulation Models (GCMs) - Global climate models used to project future climates using various scenarios to see how the climate would evolve under certain parameters

Green economy - An economy with significantly reduced environmental risks and ecological scarcities, resulting in improved human well-being and social equity

Household water economy - The sum of the ways in which a household accesses and uses water to support its livelihood(s)

Improved water supply/source - A source that is likely to be protected from outside contamination, particularly from faecal matter. The WHO/UNICEF Joint Monitoring Programme (JMP) includes within this category piped water, public taps, boreholes, protected dug wells, protected springs and rainwater

Integrated Water Resources Management (IWRM) - 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

Mal-adaptation - Changes to a system or human actions that inadvertently increase vulnerability to climate-related hazards; these may be beneficial in the short-term but erode adaptive capacity in the longer-term

Millennium Development Goals - A set of eight international development goals that UN member states and international organisations agreed to achieve by 2015

Multiple Use Services (MUS) - Water supply systems that incorporate both domestic and productive uses of water in their design and delivery. Multiple services can be provided from a single source or from different sources

Potable water - Water that is safe for humans to drink

Productive water - Water used for economic activities, including livestock watering, small-scale irrigation, brick-making, brewing etc.

Resilience - The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a shock or stress in a timely and efficient manner

Robust decision-making - Those decisions made with consideration of uncertainty, such as climate uncertainty. A robust decision will deliver desired benefits under a range of possible scenarios but will not necessarily be the optimal decision for any one single (e.g. climate) scenario

Self-supply (facilitated) - Approach to service provision in which the initiative and investment to build or improve water or sanitation sources comes from individual households, usually with some support from external agents

Unimproved water supply/source - A source that is considered to be at risk from contamination. The WHO/UNICEF Joint Monitoring Programme (JMP) includes within this category unprotected dug wells or springs, vendor-provided water, surface water, tanker-truck supply and bottled water

Vulnerability - The exposure and sensitivity of a system (or population) to external shocks and stresses, such as climate impacts, mitigated by the ability of that system to adapt

Water and Sanitation Committee (WASHCo) - A committee nominated by a community to operate local water systems and carry out minor repairs

Water scarcity - Lack of an acceptable quantity and quality of water for health, livelihoods, ecosystems and/or production. Sometimes described as *physical scarcity*, where water availability is limiting, or *economic scarcity*, where access to water is constrained

Water security - The availability of an adequate quantity and quality of water for health, livelihoods, ecosystems and production, and the capacity to access it, coupled with an acceptable level of water-related risks to people and environments, and the capacity to manage those risks

Water service - The quantity, quality, reliability and cost of water accessible to users over time

Executive summary

This report presents the findings of research into the risks to delivery of WASH results posed by climate change in Africa, drawing on rapid case study reviews of WASH programming in Malawi, Sierra Leone and Tanzania. A separate Case Study Report provides further detail on country background and findings.

Water is predicted to be the main channel through which the impacts of climate change will be felt by people, ecosystems and economies. However, predicting impacts on the availability and quality of freshwater resources, and more so water-dependent services and sanitation, remains difficult. While there is a high level of confidence in the processes linking emissions to warming, much less is known about how warming will manifest itself at the local level through changes in rainfall, runoff, groundwater recharge and climate extremes. This reflects challenges with the downscaling of climate models, but also the significance of intervening factors such as changes in land cover which may have a greater influence on local systems and services than climate change. In general, the level of confidence in climate change projections decreases as their potential utility for making decisions on how to adapt increases (OECD, 2013).

At the same time, the rapid increase in awareness and concern about climate change, and the need to identify concrete adaptation responses, risks driving demand for certainty beyond what the science community can realistically achieve (Conway, 2011). What is clear, however, is that existing levels of climate variability, together with other pressures on resources and services, already cause major problems. These will undoubtedly get worse as climate change intensifies and other pressures increase, with the result that hard-won public health and poverty alleviation gains could be lost (Howard et al, 2010; Calow et al, 2011).

Against this background, Section 1 of this report begins by looking at the WASH landscape, the gains made, but also some of the bottlenecks that hold back progress. In view of their importance and the sums of money involved, it is remarkable how little is known about the performance of services, why they so often fail, and the resources they depend on. For example, donor-supported programmes across Sub-Saharan Africa (SSA) prioritise both service extension and rehabilitation, but do so with little if any evidence on performance or the causes of failure.

Given the uncertainties with rainfall projections, but also the known risks associated with existing variability, there are strong arguments for a vulnerability rather than an impact-led approach to risk assessment and planning. This implies a **stronger focus on ensuring the reliability and protection of drinking water sources and simple changes to latrine design to reduce the risks of flooding under current climate variability as a first step towards adaptation through relatively low cost changes in design or practice**. Where long term investment decisions are involved, e.g. with dams, treatment works and piped networks, a greater range of variability should be considered to avoid costly mistakes. In terms of economic appraisal, longer time frames and the need to balance current costs with more distant benefits raise questions around the appropriate discount rates to apply.

How can this be achieved, and what needs to change? While there is a proliferation of toolkits and guidance on climate change adaptation, there is remarkably little on WASH, or on the practical substance of adaptation more widely (Fankhauser & Burton, 2011). Moreover, what there is has focussed almost exclusively on system vulnerability and technical change. The technical emphasis mirrors a wider trend in adaptation policy: specifically the preference for concrete and more readily identifiable (and measurable) things, and the reduction of adaptation policy to lists of analytical, planning and delivery processes that need technical know-how to make them work (Lockwood, 2013). As Section 1 makes clear, however, it is far from clear that a lack of technical capacity (or the toolkits that support it) are the most pressing constraints. Rather, we see problems with the ability to deliver basic public services, resilient or not. Hence the argument, summarised in Section 1, to reframe the problem: from climate change and WASH to WASH governance in an era of climate change.

Having looked at the context for adaptation decision-making in WASH, **Section 2** of the report looks at the risks to delivery of WASH results in three countries: Malawi, Sierra Leone and Tanzania. In each country, the aim was to canvass opinion on a **risk screening approach that could be applied by programme designers and implementers to identify and mitigate risks**. In light of the discussion above the approach considered climate change in context – as one of a number of threats affecting WASH outcomes - and focussed also on WASH institutions and governance. The approach is relatively simple and straightforward to apply and is based on a two-step process. **Step 1 is a national level assessment of risks to WASH that can be set out as a 'traffic light' scorecard, using documented indicators of vulnerability and expert judgement. Step 2 attempts to determine the extent to which a WASH programme addresses key risks and vulnerabilities**, again using a simple scoring system, documented evidence and expert judgement. This helps identify adaptation options or measures. Guidance on the approach and how to apply it is presented in Appendix B. While the scorecard approach is not intended for country comparisons, and the focus of the country visits was on the screening approach rather than results and option identification, a number of common issues emerge from the country consultations.

Firstly, while there is a **general awareness of climate risk in all three countries, there are opportunities to translate this into practical measures that could increase the resilience of WASH programmes**. In terms of longer term *climate change*, uncertainties in climate projections present perhaps an entirely rational barrier to prioritisation, at least for simple systems with a design life of 10-20 years (Conway, 2011). However, this is more difficult to justify given the widely perceived impact *current climate variability* already has on WASH results. While the causes of service failure or under-performance can be difficult to unravel, floods undoubtedly cause sanitation systems to overflow, result in damage to infrastructure and create widespread health problems. Existing seasonality of rainfall affects the performance of springs and shallow wells tapping smaller groundwater systems with low storage, leading to water rationing and use of unsafe sources. And environmental degradation exacerbated by intense rainfall events clearly impacts on infrastructure and poses a longer term threat to the resource base. In all three countries, simple steps could be taken to mitigate some of these risks, identified in the country workshops and Step 2 of the screening process. Addressing issues such as catchment protection, water resources management and the lack of basic knowledge on resource conditions and trends will take longer, but is essential as climate change accelerates and competition for water grows (Howard et al, 2010; Calow et al, 2011).

Secondly, the risk screening process suggests that **existing political and institutional bottlenecks act as a serious brake on service delivery and sustainability**. An effective central state remains important for adaptation because of its direct role in allocating resources and setting incentives. Effective local government is necessary to deliver services, or oversee their provision by others. Yet capacity constraints continue to block pathways to better WASH outcomes. These include the ability to supervise construction and enforce standards, and the ability (and incentive) to build and use a knowledge base on local climate, water resource conditions and pressures, and environmental conditions more generally. These bottlenecks are being addressed in partnership with government in each of the country programmes. Overcoming them is central to the delivery of more resilient water and sanitation services – arguably more so than technical change alone.

Section 3 of the report looks at the use of cost-benefit analysis (CBA) as a means of appraising the adaptation options prioritised through the risk screening process. The value of CBA lies in its ability to narrow the scope for 'pure judgement', providing a more secure and transparent basis for investment decision making. However, robust CBA requires reasonable data on what would happen to WASH interventions and outcomes 'with' and 'without' adaptation. Since there are few hard data linking climate to WASH outcomes, and the current study was based on very limited time in-country, the examples provided in this report are indicative. The main aim is to **show how CBA could be used as an appraisal tool, alongside risk screening, to identify a broad set of adaptation options and then go about prioritising them**.

The approach outlined in Section 3 focuses on potentially low regret interventions that could be expected to offer significant economic benefits under a range of different climate futures (IPPC, 2012). These include changes to water point construction, and simple changes to the design of sanitation systems. These are termed *Best Practice (options) under Existing and Increasing Climate Variability (BPEICV)*, and are compared with *Business as Usual (BAU)* baselines in which low regrets measures are not implemented. This provides us with the 'with' vs. 'without' comparison needed to identify differences in costs and benefits. Also considered are a number of softer adaptation options, including better catchment management, flood risk mapping and hydro-meteorological data collection, where benefit estimation and attribution become more difficult.

The **low regrets measures tend to increase net benefits relative to the BAU case**, with benefits estimated using Disability Adjusted Life Years (DALYs) averted and projected time savings. Global studies have shown that these comprise the largest proportion of benefits of WASH interventions. The simplest CBA applications described in Section 3 take the form of a 'discrete option analyses' in which the impact of a single type of intervention within a WASH programme is examined. In the Tanzania case, the best practice intervention involves improved, drought-resistant construction of boreholes for rural water supply. This incurs additional upfront costs in the form of deeper drilling and the supervision of contractors, but results in an uninterrupted stream of benefits over a 10 year period, compared with a baseline in which drought results in the failure of the source, loss of benefits and extra rehabilitation costs. In this illustration, the benefit-cost ratio (BCR) rises from roughly 1.4 to 1.7 with the intervention – a modest increase. Discrete option analysis is also used to show how the performance of alternative rural sanitation designs can be evaluated. In Malawi, raising and lining rural latrines in a (hypothetical) flood-prone area incurs additional costs but is assumed to prevent most flood-induced collapses. The result is an increase in the BCR from 2.1 to 2.9. In each case, assumptions (e.g. around flood frequency and severity) can be changed to see how sensitive the results are to key variables.

More challenging programme-level CBAs are illustrated for Malawi and Sierra Leone that include several (linked) interventions. In the Sierra Leone case, for example, CBA is applied to flood risk mapping and improved (flood resistant) latrine design in the informal settlements of Freetown, assuming major floods occur every five years. In the Malawi example, the most detailed of the three country illustrations, data on the functionality of rural water supplies over time and likely causes of failure are used to identify benefits that *could* be attributed to investments in (climate-sensitive) water resources assessment, monitoring and catchment protection that might increase the functionality of water points. In both cases, BCRs increase *with* the interventions compared with the no intervention baseline, in the Malawi case from around 2.8 to 3.1 over a 20 year period, and in Sierra Leone from 2.3 to 2.7. Again, key variables such as flood and drought frequency, the costs of infrastructure damage and the benefits arising from uninterrupted access to services can be changed as better data become available. Although these worked examples are tentative, the findings suggest that adaptation pays: across all three countries and in each CBA illustration, **investment in additional adaptation** (the difference between best practice and business as usual) **incurs extra upfront costs, but leads to greater future benefits over modest (10-20 year) time horizons**.

Finally, **Section 4** of the report summarises the main conclusions of the project and identifies some next steps in terms of the application of research findings and further research needs. A main conclusion is that **clear opportunities exist to increase the resilience of WASH, and that adaptation should start with the measures that tackle existing climate risks that countries such as Malawi, Tanzania and Sierra Leone already face**. A key argument is that many of these measures, such as improved siting, design and construction of water points, or changes in latrine design, are relatively simple, if capacity exists to implement. The preliminary CBA conducted on this project suggests that such measures are likely to bring positive returns, even over short time periods. Perhaps more importantly, the report illustrates *how* CBA can be used to compare the costs and benefits of different adaptation measures, and how sensitivity analysis can be applied to see how results change under different scenarios and assumptions. **From a policy angle, the distinction drawn between 'Business as Usual' programme design and 'Best Practice under Existing and Future Climate Variability' may also be helpful in defining - and putting a monetary value on – additionality**. That is, the demand from developing countries for adaptation to be supported over and above Official Development Assistance (ODA), and the need for developed countries to ensure that any additional finance is used to reduce vulnerability to climate change specifically.

In terms of next steps, it is important to highlight the limitations of the research presented and the gaps that need to be filled. Firstly, the risk screening approach outlined in Section 2 attempts to be both simple enough to be applied quickly, and detailed enough to provide useful insight into programme design. This is a difficult balance, and the end result may be too generic for some. An obvious **way forward would be to provide a programme breakdown between rural water supply, rural sanitation, urban water supply and urban sanitation along the lines of WSP's Country Status Overview** (WSP, 2011). This could replace or supplement Step 2 – the programme level assessment.

Secondly, the **economic analysis could be strengthened and extended in a number of ways**, since this report provides only a preliminary set of examples. Sticking to relatively simple options such as water point construction and latrine design, the aim would be to flesh out some damage/failure functions based on previous climate events, assembling available data and case histories on what happened to WASH infrastructure and services during and after flood or drought episodes (for example). Using a stronger mix of primary and secondary data than we were able to gather here, **future investment scenarios and sensitivity tests could then be prepared, using different frequencies of extremes, or increasing the damage function to represent more intense extremes in the future**. This could also inform decisions around whether to invest heavily in upfront *climate proofing*, or accept damage and cost 'spikes' associated with the periodic repair or rehabilitation of less robust, lower cost infrastructure.

1 Climate change adaptation and WASH

1.1 WASH context

Extending and securing access to water and sanitation services plays a key role in poverty reduction. Households benefit through a range of health, educational, nutritional and broader livelihood impacts; local, regional and national economies benefit from greater economic activity, spending and investment; and over the longer term, households and economies benefit through greater resilience to climate change. In monetary terms, the numbers are compelling: combined water supply and sanitation interventions have a combined return of at least US$4.3 for every dollar invested (Hutton, 2012), if services can be sustained in the face of multiple risks, including that posed by climate change.

At a global level, significant progress has been made in extending access to improved water services. The international target for halving the number of people without access to safe water – Millennium Development Goal (MDG) 7 – has already been met, three years before the 2015 deadline (WHO/UNICEF, 2012). However, the figures for Africa are less impressive: although 322 million Africans have gained access to safe water over the period 1990-2010, 65 million *more* people in Africa lacked access to an improved source in 2010 than did in 1990. The numbers also conceal major national and local disparities, particularly the divide between urban and rural populations. Progress on sanitation lags further. Over 2.5 billion people globally still lack access – over one third of the world's population – and more people live without access to sanitation today than in 1990, including 197 million more Africans (*ibid*). Globally, the costs of inadequate water supply and sanitation amount to US$260 billion annually (Hutton, 2012).

As the quarter-century for completion of the MDGs approaches in 2015, there is now growing debate over appropriate goals for the next quarter-century. While a final set of Sustainable Development Goals (SDGs) has yet to be agreed, it is clear that an aspiration of universal coverage will not be realised unless investments are resilient to both current levels of climate variability and future change. Failure to ensure that services are resilient will have major public health consequences if water quality deteriorates, water availability becomes less certain and sanitation systems cause environmental contamination (Hunter, Zmirou-Navier, & Hartemann, 2009; Howard & Bartram, 2010; Calow et al, 2011). Indeed not taking climate change into account, alongside other pressures on services, could result in a reversal of progress against future targets and the loss of hard-won public health and poverty alleviation gains (*ibid*).

While much has been written about resilience and adaptation in general terms, relatively little has been written about its practical substance (Fankhauser & Burton, 2011). In short, what 'adaptation' and 'resilience building' actually mean in the context of delivering sustainable water and sanitation services in the face of multiple pressures. In part, this is because of the ‘deep uncertainty’ regarding the translation of large-scale climate scenarios into local adaptation solutions on the ground (Ranger, 2013), and the difficulties associated with untangling the climate signal from the many other factors affecting the sustainability of services – see Box below (Conway, 2011; OECD, 2013). This has not stopped a simplistic crisis narrative emerging around climate change and WASH, in which climate change is held principally responsible for perceived increases in water scarcity and system failure (Calow et al, 2011; Conway, 2011). The evidence, such as it is, does not support such claims. Rather, an understanding of the known risks posed by existing climate variability reinforces the need for responses that are robust to both existing variability and future uncertainty, alongside other pressures on resources, systems and services.

Why do rural water supplies fail? Insights from Ethiopia

Achieving long-term, enduring increases in coverage that reach the poorest people continues to present a huge challenge for governments in Africa, not least because of the largely hidden crisis of functionality: many systems fail to provide safe water on a continuous basis because they deteriorate or break down completely (Hayson, 2006; Reitveld, Haarhoff, & Jagals, 2009; Calow et al, 2011; WHO/UNICEF, 2012; Calow, Ludi, & Tucker, 2013).

Ethiopia is one of the few countries in SSA to have collected comprehensive data on the functionality of water systems. The National WASH Inventory (NWI), completed in 2011 at a cost of roughly US$12M, collected both user (access) and provider (scheme) data through a sector-specific household and water point census. The data confirm what many sector professionals already knew: that coverage data based on inventories of built infrastructure and assumed levels of service significantly over-estimate the services people actually receive (Federal Democratic Repunlic of Ethiopia, 2013). Hence the recent downward revision of WASH coverage figures for the country. Secondly, however, the data provide a much better understanding of the types of water and sanitation systems that exist across the country and their functional status. Frustratingly, they do not reveal why services have failed.

In reality, the causes can be difficult to untangle, with environmental, financial, institutional, technical and social factors at play (Calow, Ludi, & Tucker, 2013). What is clear, at least from local water audits, is that existing levels of climate variability affect the services people receive, to the extent that even in ‘covered’ communities with functioning infrastructure and robust institutions, households can struggle to meet even minimum (emergency) drinking water needs.

Water audits conducted along a highland-lowland transect in the Oromia Region of eastern Ethiopia (Coulter, Kebede, & Zeleke, 2010; Tucker et al., forthcoming) showed that very few households in any livelihood zone exceeded the domestic (drinking, cooking, personal hygiene, laundry) water requirements recommended by the Sphere project (Sphere, 2011) for humanitarian emergency situations (7.5 – 15 lpcd), let alone reached the levels recommended for non-emergency situations. The majority of households used 8-12 lpcd - levels which present a high level of health concern (Howard & Bartram, 2003). Moreover, poorer households were consistently using less water than their better-off counterparts, particularly for hygiene, and especially in the dry season. Increasing collection times affected the poorest households most severely, as they had the least labour to release, the fewest assets to collect and store water, and the least cash to pay for it. They were also more likely to forego vital income generating activities in favour of water collection, and more likely to see the condition of their livestock deteriorate as a result of constrained water access. Work currently being conducted with the COWASH programme in Ethiopia highlights similar problems, with community managed springs and hand dug wells failing to provide secure water in the dry season (Calow et al, 2014).

1.2 Climate change and WASH: risks and uncertainties

Water is predicted to be the main channel through which climate change impacts will be felt by people, ecosystems and economies (Bates et al, 2008). Both observation records and climate projections provide strong evidence that freshwater resources are vulnerable, with the potential to be strongly impacted. However, predicting impacts on the availability and quality of freshwater resources, and more so on water-dependent services, remains extremely difficult. Changes could be gradual or dramatic, but with the potential to jeopardise water security over the long term, making it more costly over time for governments to adjust to changing circumstances (Elliot et al, 2011; OECD, 2013).

While there is a high level of confidence in the scientific community about the geophysical processes that link emissions to warming, much less is known about how warming will manifest itself at the *local level* through changes in rainfall, runoff, groundwater recharge and climate extremes (Conway, 2011; Taylor et al, 2013). Some of this information can be obtained by downscaling GCMs, but resolution remains coarse and levels of uncertainty are high, particularly for rainfall. As a result, the usefulness of climate models for adaptation decisions has been questioned (Stainforth et al, 2007).

Most studies linking climate modelling to impacts have focussed on long term changes - generally beyond the 2050s - with relatively little work on near-term changes, impacts and the practical needs of decision makers (Conway, Adapting climate research for development in Africa, 2011). The Vision 2030[1] work on the resilience of water supply and sanitation in the face of climate change (Howard & Bartram, 2010; Howard et al., 2010), ODI's review of climate change and WASH (Calow et al., 2011) and IRC's recent Thematic Overview Paper on adaptation in WASH (Batchelor, Smits, & James, 2011) remain exceptions. However, these studies note the major uncertainties associated with translating (uncertain) rainfall projections into impacts on the ground, with levels of confidence in projections decreasing as their potential utility for making decisions increases. In part this reflects the significance of confounding factors such as changes in land use and land cover as well as the downscaling issues noted above. The local water balance (how rain falling at a particular place becomes divided between surface runoff and infiltration, and then between evapotranspiration and groundwater recharge) is very sensitive, not only to changes in climate, but to changes in soil properties and vegetation cover (see box below). Hence untangling the climate signal from the many other direct and indirect factors influencing resource conditions, and the services they support, remains challenging, especially given the lack of meteorological and hydrological data in Africa.[2]

A recent DFID topic guide (Ranger, 2013) tackles the issue of adaptation decision making under uncertainty, noting that accounting for the changing and uncertain climate need not paralyse decision-making. Building on the earlier work of Hallegatte (Hallegatte et al, 2012), Ranger (*ibid*) highlights 'deep' uncertainty - a situation in which commentators agree neither on which are the best models, nor on how the probabilities attached to key variables are distributed. This is the case in the Sahel and parts of central and eastern Africa where individual climate models provide no clear signal of future rainfall trends in the regions, beyond the continent-wide 'intensification' of the climate-hydrological system and resulting increases in intense rainfall events and rainfall variability (Bates et al, 2008; Allan & Soden, 2008). In contrast, a clearer climate signal is apparent for southern Africa and

1 A DFID and WHO study that looked at the projected impact of climate change on water and sanitation services by 2020 and 2030. See http://www.who.int/water_sanitation_health/publications/9789241598422/en/

2 As an example, research conducted on nine major river basins in SSA found that robust identification and attribution of hydrological change was severely limited by data limitations and difficulties in quantifying the effects of land use change and other anthropogenic influences (Conway et al, 2009).

parts of western and northern Africa, where rainfall and runoff (though not necessarily groundwater recharge – see box below) are expected to decline significantly this century.[3]

Drawing on the above, what can say about the range of possible rainfall scenarios and associated risks? Despite the uncertainty and knowledge gaps, there is a growing body of evidence documenting the *range* of possible changes in water systems that *could* be expected in a changing climate. Drawing principally on Howard et al. (2010), Calow et al. (2011), Elliot et al. (2011) and OECD (2013), the effects of climate change can be grouped into four categories:

Increasing intensity of rainfall, such that even in those areas where average rainfall is expected to fall (e.g. southern Africa), a greater proportion of rainfall is likely to fall in heavy rainfall events.

- Increased risk of flooding, leading to both infrastructure damage and contamination of surface and groundwater supplies. In rural areas for example, floods can damage or inundate springs, wells, rainwater harvesting systems and boreholes, though boreholes are typically less vulnerable. This can hamper both access to water and cause contamination and health risks. Piped systems are also vulnerable because of their size and complexity, and their exposure to multiple threats from source, through treatment to delivery. The pit latrines widely used in rural areas are also vulnerable to flooding and can cause serious environmental contamination, although adapted designs are available and latrines can be upgraded.
- Depending on timing and intensity, and whether critical recharge thresholds are breached, an increase or decrease in groundwater recharge and groundwater levels (see box below). Longer term increases in groundwater levels could reduce the potential for pathogen and chemical attenuation or removal, and cause flooding of sub-surface infrastructure such as pit latrines or septic tanks. Longer term declines in groundwater levels could affect the viability of springs and wells drawing on shallow groundwater systems with limited storage.
- Increased flushing of fertilisers, animal wastes and particulates into water supplies, potentially affecting both quality and flow.

Greater rainfall variability, including changes in the timing, duration and distribution of rainfall across the continent.

- Longer and/or more frequent droughts, with implications for all water supply systems relying on limited storage to buffer seasonal and inter-annual variability. These include urban systems relying on limited and variable surface water flows and storage, and also groundwater-based supplies – particularly springs and shallow wells - drawing on aquifers with limited storage. Water-borne sanitation may also be compromised.
- For many areas, a proportional increase in winter flows may result in further reductions in water availability during low-flow periods, reducing the capacity of rivers to dilute, attenuate and remove pollution and sediment loads.

[3] Scientific understanding of the African climate system as a whole is low. For certain regions, e.g. southern Africa, the level of understanding is reasonable. For other parts, such as the Sahel and Congo basin, very little is known (Conway, 2011). Outside South Africa, there has been no coordinated programme of research on climate change supported by government or other bodies (*ibid*).

Longer term decline in rainfall and run off, such as that projected for southern Africa

- While impacts on groundwater resources remain uncertain even with decreasing rainfall (see box below), declining annual rainfall will lead to reductions in river flows, especially in conjunction with population growth and the need to grow more food. This, in turn, could increase the demand for groundwater, potentially threatening sustainability.
- As above, long term declines in water availability could also threaten the viability of water-borne sanitation systems, and the capacity of surface water to dilute, attenuate and remove pollution.

To this list, we could also add **sea level rise** and the threat this poses to coastal zones in terms of saline intrusion, and damage to/contamination of water systems and treatment works from inundation during coastal storms.

The description above is far from comprehensive. By far the most detailed assessment of climate-related risks to water and sanitation systems and potential adaptation responses remains that compiled by the Robens Centre for Public and Environmental Health in their Technology Fact Sheets (Charles, Pond, & Pedley, 2010).

Understanding the impacts of climate change on groundwater

Despite rapid urbanisation in SSA, the majority of people still live in rural areas and poverty remains an overwhelmingly rural phenomenon. The development of groundwater for rural water supply offers significant advantages (compared to surface water sources) in terms of climate resilience because of the storage groundwater aquifers offer; specifically, large storage volume per unit of inflow makes groundwater less sensitive to annual and inter-annual rainfall variation and longer-term climate change (MacDonald et al, 2009; Calow et al, 2010). The relative ubiquity of groundwater, its generally higher quality and (typically) lower development costs for meeting dispersed demand provide additional benefits.

Nonetheless, uncertainty remains about the impacts of climate change on groundwater resources as a result of both the major uncertainty in GCM projections of rainfall, but also that associated with the downscaling of GCM projections, the hydrological models used, and intervening factors such as land cover and land use change (Taylor et al, 2013). Climate variability and change can also affect groundwater indirectly through changes in groundwater use – for example increasing demand for irrigation water to help buffer the effects of more erratic rainfall (Taylor et al, 2013).

Recharge to groundwater is highly dependent on prevailing climate as well as land cover and underlying geology. Climate and land cover largely determine rainfall and evapotranspiration, whereas the underlying soil and geology dictate whether a water surplus (precipitation minus evapotranspiration) can be transmitted and stored in the subsurface. Recharge is strongly influenced by climate extremes – droughts and floods – with recharge in semi-arid environments often restricted to heavy rainfall events (Taylor et al, 2013; MacDonald et al, 2012) The result is a non-linear relationship between rainfall and recharge (*ibid*). Land use change can exert an even greater effect and a much stronger influence than climate change. In the West African Sahel, for example, groundwater recharge and storage increased in the latter part of the 20th Century despite a multi-decadal drought because of a shift from savannah to crop land that increased surface runoff and focussed recharge (Taylor et al, 2013).

What are the implications for groundwater resources and groundwater dependent services in SSA? Much will depend on the distribution, timing and intensity of rainfall, underlying soil and geology, and future land use change. However, as climate models are broadly consistent in indicting increases in the proportion of total rainfall that falls in heavy events (Allan & Soden, 2008), impacts on recharge could potentially be positive. However, increased runoff and flooding could result in greater microbial contamination of water supplies and cause damage to infrastructure, highlighting the importance of source-catchment protection.

The conclusions of MacDonald et al. (2012) and Taylor et al. (2013) also demonstrate that modest yields of groundwater are quite widely available at accessible depths and sufficient to sustain small communities, but larger yields (>5 l/sec) suitable for urban development or major agricultural schemes are unlikely outside sedimentary basins. The availability and accessibility of groundwater over much of Africa is therefore favourable to rural domestic supply and minor productive use, rather than intensive development of the kind seen in south Asia (Calow & MacDonald, 2009; Edmunds, 2012).

1.3 Risk screening approaches

Climate risk management describes the process of identifying climate-related risks and implementing measures to reduce such risks to acceptable levels (Olhoff & Schaer, 2010). Risk assessment has been defined as '…*a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend*' (UN, 2004). Therefore, both the physical climate hazard, and the vulnerability of the system, is considered under 'risk'.

Climate risk screening typically avoids statistical probabilistic calculations associated with traditional (more technical) conceptions of risk assessment. Rather, it involves systematically examining activities (or projects, programmes, policies, technologies) with the aim of:

- Identifying hazards which could potentially cause harm.
- Identifying inherent vulnerabilities in the system.
- Assessing whether these risks – the product of hazard and vulnerability - are being taken into account.
- Considering the extent to which risks can be reduced or mitigated.

Since the probability of the hazard occurring cannot be reduced, this implies exploring opportunities for reducing the vulnerability associated with physical hazards. The utility of a risk management approach lies in its emphasis on preventative rather than reactive measures. Whilst the complete elimination of risk is seldom possible [4], what is important is identifying the most significant risks and prioritising their mitigation. This is the broad approach adopted here.

There are opportunities to learn from the application of existing climate risk screening tools such as ORCHID[5] and CRiSTAL[6], although to date many of these experiences are limited to pilots or tests, and case studies for WASH are limited (Traerup & Olhoff, 2011). A forthcoming review of risk screening approaches describes the approaches and tools

[4] The term 'climate-proofing' has been used to describe this desire to eliminate the vulnerability of physical infrastructure to climate variability and change. Good engineering practice (though not all aspects of WASH system design) has always taken account of climate variability, by designing to estimated return periods (statistical frequency) of extreme events. Even under relatively well-known variability, engineers have never designed structures to withstand every single extreme event. Under greater future variability it is economically unrealistic to design engineering structures to withstand all extremes.

[5] Opportunities and Risks from Climate Change and Disasters (IDS)

[6] Community-based Risk Screening Tool (DFID)

currently available and their application - or potential application - to WASH (Doczi, forthcoming).

One risk management framework for ensuring water quality gaining wide recognition is the Water Safety Plan (WSP). There has been some interest expressed in widening the scope of WSPs from their water quality and health focus to encompass climate risks (Bartram, et al., 2009), and concerns with water availability and reliability. The obvious appeal is building on an existing framework. In their assessments of climate change and WASH, both Howard and Bartram (2010) and Calow et al. (2011) highlight the potential to adapt existing WSP approaches for climate screening. Experience to date is limited (Doczi, forthcoming), though ODI's work on risk screening for rural water supply in Ethiopia is currently being integrated in WSPs under the Government of Ethiopia's One WASH National Programme (see box below) .

Water Safety Plans

The World Health Organisation (Bartram et al, 2009) promotes WSPs as the most effective way of ensuring the safety and acceptability of a drinking water supply. The approach was designed to safeguard water quality for human health, and offers a comprehensive risk assessment and management methodology which considers all steps in the water supply chain from source to consumer. Crucially, this is a preventative approach which aims to avert contamination before it happens by identifying and mitigating risks in advance, rather than rely on end-of-pipe testing and *ad-hoc* measures. WSPs require identifying all potential hazards which could occur along the water supply chain and assessing the risk associated with the hazards, with the aim of distinguishing more significant risks from less significant risks (see box above).

Most experiences of implementing WSPs have taken place for utilities within a developed country context, but there have been some reports of applying the methodology for small community-managed schemes in developing countries (e.g. (Mahmud et al, 2007). Generic, technology-based WSPs are based on an understanding of the hazards which may pose a risk to each technology type. They provide a framework of typical hazards and risks, appropriate control measures, critical limits (which specify when action is needed), monitoring requirements (who does what and when), and required corrective action if critical limits are reached. These can be adapted as needed to the local circumstances.

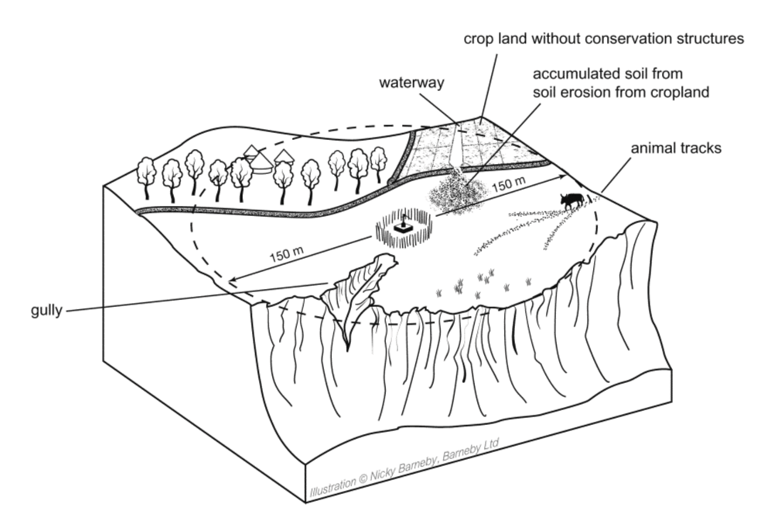
In view of the combined uncertainties along the cause-effect chain described above, but also the known risks associated with existing climate variability, a growing number of commentators argue for planning that is robust to uncertainty – i.e. appropriate to a range of rainfall conditions and potential hazards. Often bracketed under 'no regrets' planning, strategies would generate net social and/or economic benefits under a range of different climate, water and socio-economic futures. In this sense, climate change could be viewed as a driver for improvements that have been insufficiently delivered to date (Howard & Bartram, 2010; Elliot et al., 2011). Similarly, Conway (2011) suggests that the development agenda can approach adaptation effectively though vulnerability reduction, with a particular focus on existing and amplified levels of climate variability. In terms of the current discussion, a growing emphasis on vulnerability reduction under current climate variability implies a shift away from 'impact-led' approaches to risk assessment in which the focus is on predicting, and characterising, climate-specific risks.[7]

[7] A view also supported by the IPCC (IPPC, 2012) in the context of managing the risks of extreme events and disasters, who conclude that "*The most effective adaptation and disaster risk reduction actions are those that offer development benefits in the relatively near term, as well as reductions in vulnerability over the longer term* (high agreement, medium evidence)"

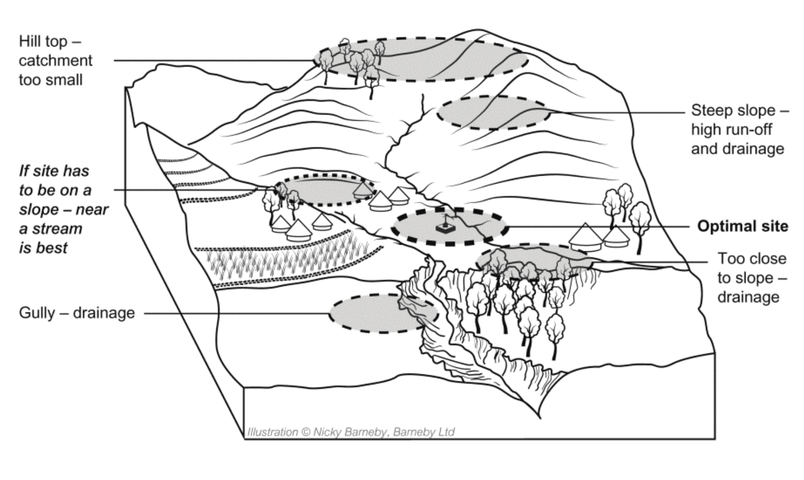
Climate risk screening for rural water supply in Ethiopia

Work carried out by ODI, the British Geological Survey (BGS) and Addis Ababa University has looked at ways of increasing the resilience of rural water supply to climate variability and change. Focussing on low end technologies (springs and hand dug wells) promoted under the Government of Ethiopia's new One WASH National Programme – OWNP (Federal Democratic Repunlic of Ethiopia, 2013), research has highlighted the importance of catchment-source protection, catchment screening and geological field assessment. Simple guidelines have been produced for local government staff that could help protect infrastructure, resources and services from climate related shocks and stresses.

Firstly, guidance on catchment-source protection helps local staff identify threats to water points and underlying resources. Direct threats to the water point include those arising from flooding and landslides (e.g. damage to infrastructure, contamination). Threats to the resource include those arising from land degradation and the development of deep gullies that can draw down local water tables. A simple 'traffic light' assessment of risk is completed, and guidance is provided on how to avoid or mitigate risks. The figure below illustrates the kinds of risk often encountered in degraded catchments.



Secondly, a simple catchment screening tool has been developed to help planners select catchments and site water points that are likely to meet projected water demand, based on precautionary assumptions about rainfall-groundwater recharge, and topographically driven aquifer drainage. The guidance can be applied at a regional level to identify areas where hand dug wells and shallow drilled wells are likely to be appropriate, and to model the impact of potential changes in climate. The tool can also be used to assess the vulnerability of existing water points – identifying those that are likely to be more vulnerable to change (increasing demand, changing climate) because of their catchment size. In the field, the tool can also be used to help site water points.



Finally, a geological field assessment tool has been prepared to allow non-geologists to optimise site selection and predict potential issues in construction. This is based on field recognition sheets.

The field guidance produced is currently being integrated in a new Water Safety Plan approach under the OWNP, combining water quality and health considerations with a new focus on climate risk, including impacts on water availability and reliability.

Source: Calow et al, 2014

1.4 Re-thinking the problem: from climate change and WASH to WASH governance in an era of climate change

A number of recent studies in the general adaptation literature have begun to question prevailing approaches to adaptation finance and policy (Fankhauser & Burton, 2011; Lockwood, 2013). Specifically, the preference for 'concrete' and more readily visible adaptation projects and options, and a relative under-emphasis on the political and governance context in which adaptation funds are being spent. In part, this is driven by a fixation with 'additionality' and the need to identify and measure specific adaptation measures (Fankhauser & Burton, 2011). As the authors argue, this can be unhelpful if softer adaptation paths, focussing on changes in planning, practice and behavioural change, are neglected.

While the preference for concrete adaptation options is understandable, this report makes a deliberate effort to focus on both governance and systems. The implication is that adaptation to climate change in WASH – or any other sector – cannot be considered as one policy issue but many; it must also account for the development context and for gaps in *existing* capacity to deliver basic public goods (Lockwood, 2013). The box below discusses WASH governance issues in relation to climate change further.

WASH governance – a missing link?

The effects of climate change must be recognised and acted upon by a set of stakeholders that include service users, public sector and private sector providers, local and central Government, NGOs and development partners. These stakeholders act within a set of policies, procedures, financing and management arrangements – the enabling (or disabling) environment – that determine the effectiveness of service delivery. Crucially in view of the uncertainties attached to climate change, these actors need data, data derived from the monitoring of water and other resources, and the performance of services. They also need the basic capacity to deliver and support services. If governance and capacity are strong and effective, and able to deliver and backstop, adaptive responses which have expression in more robust physical infrastructure will likely materialise. If not, not.

The implication of this is that a high priority set of adaptive actions need to take place focusing on the capacity of WASH institutions and on strengthening the enabling environment. These include:

- Amendments to national WASH sector policies to take account of climate change.
- Developing climate change -relevant technical guidelines and standards.
- Strengthening or establishment of water resources and WASH service monitoring arrangements.
- Inclusion of investigations of climate change and its impacts within national WASH learning and research efforts.
- Evolution to more flexible planning and budgeting processes to enable responses to slow-onset changes, and also effective rapid onset emergency response.

These actions to strengthen the WASH sector make it possible for the actors involved to:

- Better understand existing climate variability and its impacts on water resources and WASH services, and;
- Understand the corresponding impacts in regard to projected climate change.

Adaptive design and implementation of WASH programmes can then follow – from a position of institutional strength, up-to-date local knowledge, and the ability to respond flexibly and rapidly. Relevant aspects of design and implementation include:

- Taking account of increasing needs for catchment / source protection.
- Choosing water supply sources which are less vulnerable to variations in water resources whether caused by climate change, increasing competition for water, or any other factor.
- Designing water and wastewater treatment systems to allow for future changes in water quality.
- Selecting raw water, potable water and wastewater lifting technologies to allow for future changes in energy costs, with a preference for the use of renewable energy sources.
- Matching water storage requirements to projected and monitored changes in timing and amount of water flows.
- Designing and constructing latrines and other on-site sanitation technologies to be less flood-prone, or to be more cheaply/easily replaced if flooding is unavoidable.
- Paying due attention to stormwater drainage and solid waste management in peri-urban settings.

Source: Richard Carter (background document for this study, unpublished).

1.5 Project objectives

With financial flows to WASH increasing and growing concern about the threat posed by climate change to WASH outcomes, the UK Department for International Development (DFID) commissioned the project *Adaptation to Climate Change in Water, Sanitation and Hygiene.* [8] The broad aim of the research is to analyse the risks to delivery of WASH results posed by climate change and to conduct economic analyses of the costs and benefits of adaptation options. Drawing on case study work in Malawi, Tanzania and Sierra Leone (see the separate Case Study Report for further details), specific outputs discussed in this report are as follows:

- A risk screening approach that can be used by DFID and its development partners in programme planning and design to identify risks and adaptation options. The approach and its application to WASH programmes in Malawi, Tanzania and Sierra Leone is discussed in Section 2.
- A cost-benefit analysis of adaptation options drawn from the risk analysis above, setting out the costs and benefits of options and measures compared with 'business as usual' baselines. This is discussed in Section 3.
- A Guidance Note for sector stakeholders involved in WASH programme design, setting out in simple terms how to integrate resilience in the design, delivery and monitoring of programmes. This is presented in Appendix B.

In addition, this report provides an annotated bibliography of work focusing explicitly on climate change adaptation and WASH in Africa since 2009, including references to the Vision 2030 study published in 2010 (Howard et al, 2010). Parallel work on the economics of climate change in Africa's water sector is published separately (Doczi & Ross, 2014).

[8] Conducted over the period 1 April – 30 November 2013 and led by the Water Policy Programme at ODI, together with Oxford Policy Management (OPM) and Richard Carter & Associates.

2 Risk analysis - approach and key findings

2.1 Introduction

2.1.1 Our approach

Over the last decade or so the literature on climate risk assessment and management has proliferated. Dozci (forthcoming) provides a useful overview of climate risk management approaches for WASH, noting the recent shift in focus from the physical aspects of climate change (an impact-led approach) to a more bottom-up focus on vulnerability and uncertainty. In line with current thinking, this report presents an approach that focuses on robust decision-making, identifying low (or no) regrets options for addressing climate risks and other pressures on systems and services.

The risk screening approach described has two main objectives. Firstly, to offer a reasonably simple and straightforward way of assessing risks to delivery of WASH results posed by climate change and other pressures. Secondly, to illustrate how some basic economic principles can be applied to help identify cost-effective adaptation options. The guidance provided (Appendix B) is intended to inform the planning of country-based WASH projects and programmes by DFID staff and their development partners.

For a development partner or NGO, the screening process could form part of a proposal to DFID to demonstrate that due diligence has been followed in assessing risks and options. The approach requires knowledge of the WASH sector and broader country context to complete, but little expertise on climate science. Ideally the assessment would be conducted in a participatory setting, such as an experts' consultation meeting, allowing a consensus to be reached by key sector stakeholders.

The risk assessment addresses the following questions:

- To what extent is the effectiveness of WASH interventions likely to be compromised by climate change as compared to other trends and hazards?
- Does the proposed WASH programme adequately address (either directly or taking account of the work of others) the impacts of variability and change in present and future climate on water resources and WASH services, and the wider impacts of climate change on the target communities?
- Does the proposed WASH programme adequately address (either directly or taking account of the work of others) the enabling environment and institutional capacity to address climate change risks in WASH programming?

- Are the proposed physical infrastructure improvements sufficiently protected against present and future climate risks?

To date the tendency has been to address climate risks in terms of WASH technologies and scheme design – system ‘hardware’ (Elliot et al, 2011). On the basis that ‘software’ can be equally if not more important for the sustainability of WASH services, a broader approach is outlined here. The starting point is therefore not the technology itself, but rather an understanding of the range of challenges faced by the sector and the institutional context in which decisions are made.

Accounting for climate risks in DFID country WASH programmes

DFID has developed generic guidance on the Climate and Environment Assessment process (DFID, 2012) which is mandatory for sign off at two stages of business case development – the strategic case and options analysis. However, since guidance is not WASH-specific, country approaches to dealing with risks to WASH vary, as does the priority given to climate change relative to other imperatives. DFID Tanzania, for example, is particularly active on climate change issues having undertaken a portfolio risk screening exercise (refreshed in 2012) and poverty and vulnerability assessments. In Sierra Leone, the most pressing need is to rebuild basic infrastructure and strengthen institutions for service delivery following civil war.

Each of the DFID business cases reviewed for Malawi, Sierra Leone and Tanzania includes a short section on climate and environment impacts (and opportunities) as part of the options appraisal, with differing levels of detail. In Sierra Leone for example, the business case for rural WASH acknowledges that any interventions cannot be separated from the wider need for better natural resource management, whilst the urban programme recognises that increasing climate variability is likely to exacerbate the risk of flooding and the spread of water-borne diseases, even if specific actions to address risks are not spelled out. Clearly the sector faces many problems, and getting basic services ‘up and running’ reduces vulnerability to a range of threats, including climate change.

Source: stakeholder consultations and DFID business cases

2.1.2 A two-step process

The new risk screening approach is based on a two-step process followed by an economic appraisal of adaptation options. The first step is a national-level assessment of key vulnerabilities affecting WASH services that can be set out in a ‘traffic light’ scorecard based on documented indicators of vulnerability (or resilience) and more subjective expert judgements. The purpose here is to determine the relative importance of climate change as compared to other risks faced by the WASH sector.

In order to relate this assessment to the risks to DFID (or partner) projects and programmes in a specific country, a second step is needed. Step 2 attempts to determine the extent to which a WASH programme addresses risks posed by climate change to the sector, asking a number of key questions (in the form of a checklist) and providing a scoring system that highlights key areas for closer attention as the programme is designed or modified over time. Step 2 encourages one to consider three main aspects: stakeholders’ understanding of climate variability and change, impacts on water resources and implications for the WASH sector; institutional capacity and the enabling environment, for example including WASH policies and guidelines, hydro-meteorological monitoring, research and learning; and finally design and implementation, encompassing catchment protection and impacts of growing demand/water abstraction, in addition to the hardware of water supply and sanitation systems.

The economic assessment (Section 3) can then be based on the adaptation options arising from Step 2. Given the uncertainties associated with climate change projections, particularly for rainfall, the economic analysis focuses on 'low or no regrets' activities that will increase the resilience of services under a range of different climate and water futures.

2.1.3 Testing the methodology

In order to test the draft methodology, three country visits of four to five days each were undertaken over the period July to August 2013, hosted by DFID offices in Malawi, Tanzania and Sierra Leone. Visit objectives were to:

- Obtain feedback on the proposed risk screening approach to inform the methodology and development of guidance materials.
- Identify some of the key challenges facing the WASH sector, including discussion of risks to delivery of DFID WASH results, building a picture of:
    - Existing sustainability challenges with WASH – problems, causes, evidence, impacts - and people's views on the impact of existing climate variability on the functionality and quality of services.
    - Risks posed by future climate change and other pressures on the functionality and quality of services.
    - What is being done (or could be done) to address these risks in terms of adaptation planning.
- Agree a scenario or set of scenarios for the economic appraisal of adaptation options and collect available data to support cost-benefit analyses (CBA).

The main activities undertaken in-country were discussions with DFID staff, a half-day workshop with invited sector stakeholders (national-level experts) and meetings with other key informants. Workshop participants suggested a number of possible adaptation actions, not all of which were obviously climate-adaptive. A long-list for each country is provided in the Case Study Report. Note that in our risk assessment methodology we would expect adaptation options to emerge from Step 2 of the risk assessment and therefore to focus on DFID programme design rather than the sector as a whole. Unfortunately it was not possible to involve stakeholders in the full risk assessment process in the time available. Nonetheless some of the options identified were considered relevant for the economic analysis.

Comments on the proposed risk screening approach

DFID country WASH programmes and their implementing partners have their own priorities, approaches, capacities and needs. A key challenge was therefore to develop a methodology of relevance to a range of actors in differing national contexts, covering both water supply and sanitation. Noting DFID's existing guidance and processes (DFID, 2013), the task was to develop a sector-specific approach to climate risk screening that could be used by DFID staff and their development partners at various stages of programme design and implementation.

In-country consultations provided a number of useful insights and suggestions which have helped shape final guidance (Appendix B). Participants in the Malawi workshop were particularly interested in the risk screening approach and the translation of abstract resilience concepts into WASH sector realities. In Sierra Leone, a clear message was the need to focus on the existing 'adaptation deficit' – the inability to deal with existing climate variability and other pressures. Hence the importance attached to Step 1 of the of the assessment process that places climate change alongside other risks.

In terms of the economic analysis, most stakeholders could not envisage carrying this out themselves but they could see the value of having the results and understanding the data and assumptions underpinning the analysis. DFID Tanzania is particularly keen to better understand the economics of adaptation options, including examples and guidance on valuing benefits and conducting CBA. It was pointed out that interventions are sometimes necessary even if uneconomic in conventional terms, or if risks are high making benefit (and cost) streams uncertain. Internal cross-subsidies within programmes can help address such cases.

Source: stakeholder consultations

2.1.4 Section overview

In this section we provide a short overview of climate trends and projections for case study countries together with background information on WASH context and DFID programme(s)[9]. A summary of the issues raised by national experts in relation to the risk assessment is then presented. The section ends with a brief comparative analysis.

A number of qualifications should be highlighted. First, the country case studies should not be viewed as comprehensive risk screening exercises or pilot studies. Rather, they provided the means to develop and seek a range of views on the methodology proposed. For this reason we do not present 'results', but rather provide insights from country visits on key national-level issues for WASH and potential implications for DFID programmes. The full case studies are presented in the Case Study Report. Second, the traffic light scores emerging from the risk assessment (Case Study Report) illustrate what a completed assessment might look like, with the proviso that these are tentative and subject to detailed review by relevant national experts. Further detailed discussions with national experts would be required to verify findings and develop solid adaptation plans.

2.2 Climate trends and projections

Malawi, Sierra Leone and Tanzania are tropical countries with highly seasonal rainfall, although precipitation patterns and temperatures vary according to their respective topographies and geographic locations. For example, Sierra Leone's climate is highly influenced by the West African Monsoon (McSweeney et al, 2010b) whilst in Malawi temperatures are relatively low due to its high elevation (McSweeney et al, 2010a). In Tanzania high inter-annual variability of rainfall means that the rains can be difficult to predict and there is a risk of flood or drought in some regions (McSweeney et al, 2010c). In fact flooding is an issue for all three countries, associated with high intensity of rainfall during short periods of time, usually in the rainy season.

Analyses of historic climate data have shown that temperatures have increased since 1960 in all three countries (McSweeney et al 2010a,b c). Trends for rainfall are generally less clear, particularly for Malawi and Sierra Leone, as it is difficult to disentangle long-term trends from natural variability. However, it appears that rainfall has decreased significantly in Tanzania (see Table 1).

Projections to 2060 show continued temperature rises in all three countries but do not indicate significant changes in future average annual rainfall with the exception of Tanzania (*ibid*.). What is more certain is that there will be an increase in the number of extreme rainfall events, implying a heightened risk of flooding. There may also be seasonal changes. For example in Malawi there are likely to be larger seasonal differences over time with projections tending towards increased rainfall in the wet season and decreased rainfall in the dry season (McSweeney et al, 2010a), exacerbating the risk of both floods and droughts. Sierra Leone is also vulnerable to sea level rise which is likely to exacerbate erosion and the risk of flooding in lowland coastal areas (UNDP, 2012).

[9] Note that both the DFID programmes in Malawi and Tanzania are rural in focus, whereas Sierra Leone also has an urban component.

Table 1: Climate trends and projections for Malawi, Sierra Leone and Tanzania

		Malawi	Sierra Leone	Tanzania
Climate trends (1960-2006)	**Mean annual temperature rise**	0.9 °C	0.8 °C	1.0 °C (especially in JF)
	Annual rainfall trends	No significant trends; year-to-year variability very strong	Mean has decreased since 1960s but hard to distinguish from variability	Significant decrease; monthly rate decreased 3.3% per decade
	% rain in heavy events	No significant trend	Insufficient data	No significant trend
Climate projections (by 2060s)	**Mean annual temperature rise**	1.1 - 3.0 °C	1.0 - 2.6 °C	1.0 - 2.7 °C
	Mean rainfall	No significant trends, models say -13% to +32%	Models disagree, but tend towards increases	Models consistently predict increases of median +7 to +14% by 2090s
	Seasonal rainfall trends	Decreases in dry season rainfall (JJA and SON), and increases in wet season rainfall (DJF and MAM)	Clearer increases in late wet season (Aug-Oct)	Seasonal trends more complex, generally suggests increases in wet season of each region[10]
	Trends in % of rain falling in heavy events	Models consistently project increases (especially in wet season)	Tends towards increases, especially in late wet season	Models consistently project increases (especially in wet season)
	Increases 1- and 5-day rainfall maxima	Models consistently project increases by 2090s	Tends towards increases, esp. in late wet season	Models consistently project increases by 2090s

Source: Summarised from McSweeney et al. (2010a,b,c)

2.3 Malawi case study

2.3.1 Country WASH context

Malawi remains a very poor country with a large and rapidly growing population and relatively high population density (UN Data, 2013). The population is predominantly rural, although urbanisation is accelerating (*ibid*.). The majority of people are subsistence farmers who are highly vulnerable to a range of hazards including unreliable seasonal rainfall, floods, droughts and illnesses (for example due to poor sanitation), undermining agricultural productivity and household food security (MoMNRE, 2006).

Malawi has made impressive progress on **water supply** since 1990 and at 84% coverage in 2011 is currently on track to meet the MDG target by 2015 (WHO/UNICEF, 2013). Nonetheless, there are serious present and future threats to the sustainability of water services. In rural areas water supply is characterized by inequitable coverage and non-functionality of water points, the latter currently estimated at 30% (MoIWD, 2012; see also Baumann & Danert, 2008). Meanwhile, the reality in urban areas is that water supplies are often intermittent and unreliable due to low efficiencies in operations and high levels of non-revenue water. Increased levels of local participation are recognised as a crucial factor to improve infrastructure functionality and access to improved services.

Efforts to extend **improved sanitation** face similar challenges to those found elsewhere in SSA, with coverage lagging behind water supply at 53% (UNICEF/WHO, 2013). Urban on-site sanitation and peri-urban faecal sludge management have been identified as key issues in country consultations. Affordability of robust improved latrines coupled with technical

[10] GCAP (2011) also suggest that rainfall projections indicate a seasonal shift, with weaker early season rains and stronger late season rains, but the authors are careful to note the significant uncertainty involved and disagreement between climate models.

difficulties (e.g. ground conditions) in some areas also makes it difficult to ensure sustainability and to convince households to invest.

On a more positive note there have also been clear improvements in WASH sector coordination over recent years. At the national level fora such as annual Joint Sector Review, quarterly Sector Working Group meetings and Technical Working Groups have all served to strengthen performance. Meanwhile the government has made strides on the enactment of the National Water Resources Act (2013) which will support more effective management of the country's water resources, including: improved monitoring, licensing, strategic planning and development at river basin level, as well as improved flood forecasting and flood risk management.

DFID Malawi's WASH programme

DFID is providing up to £20m over a three year period (2012-15) to support the delivery of rural water, sanitation and hygiene services in Malawi. The project is managed by UNICEF and implemented by NGOs World Vision International, GOAL, Development Aid from People to People (DAPP) and Concern Universal, with WaterAid providing policy and governance support. Expected results include 850,000 people (including 442,500 women) gaining access to improved water and sanitation facilities and one million people (510,000 women) adopting key hygiene practices.

The programme goes beyond the provision of new infrastructure to include backstopping support systems for Water User Committees, establishment of spare part supply chains, rehabilitation of existing water points (broken boreholes and community managed piped water schemes) and the strengthening of WASH institutions.

The programme focuses on ten of the 'least served' districts in Malawi identified through waterpoint mapping.[11] Due to the existing imbalance in funding allocations between rural and urban WASH, DFID has chosen to focus on rural areas, targeting the poorest communities and schools. The approach focuses on community or household management for water points and sanitation facilities, respectively (with the exception of schools or clinics), coupled with hygiene promotion and an emphasis throughout on equity, and particularly gender-based equity.

Source: summarised from DFID Malawi (n.d.)

2.3.2 Preliminary findings of the risk assessment

Although there is a high awareness of climate change in Malawi and climate-related activities linked to food security[12], climate change does not appear to be the highest priority concern in the WASH sector. **Step 1** of the risk assessment supported the argument that numerous other factors may be more important to Malawi's development trajectory than climate change alone, the main exception being the (rain-fed) agriculture sector. The major stresses and threats to WASH services appear to arise from: rapid population growth; increasing demands for water; rising production of faecal and solid waste; and the degradation of the natural environment, with knock-on effects on hydrology and water quality (see MoMNRE, 2006; Carter & Parker, 2009). In the latter case, there is evidence that runoff is becoming more flashy and that sediment loads are increasing. These trends may be exacerbated by increasing rainfall intensities, but the underlying causes are primarily population-related.

Step 2 of the assessment highlighted a number of possible gaps in addressing climate-related risks in the WASH sector, both nationally and at programme level. These are

[11] The least served Districts identified are: Karonga and Rumphi in the Northern Region; Kasungu, Dowa, Mchinji and Lilongwe in the Central Region; and Nsanje, Chikhwawa, Phalombe and Balaka in the Southern Region. In particular, areas of Karonga affected by the 2009 earthquake are targeted.

[12] A number of the organisations that took part in the workshop are working on climate change adaptation, particularly in relation to food security.

tentative findings; further verification by national experts would be required to draw firm conclusions.

Understanding of climate impacts

There is a consistent and widespread perception that drought and dry-spell durations have increased over recent decades, as have the magnitude and frequency of floods (although not confirmed by the scientific data). Both would have implications for sustainability of WASH services, although current understanding of climate risks in Malawi remains limited. Stakeholders in the WASH sector appear to have a high awareness of (and interest in) the general risks but few organisations are currently making use of hydro-meteorological data to inform project design and implementation. At the same time, there are considerable gaps in the scientific data that make it difficult to determine how future climate change may impact on programme results. For example, the contribution of climate variability or change to problems such as water source failure is largely unknown. It is similarly unclear whether perceived increases in flood risk reflect climate changes, land management practices or increasing migration to flood-plains.

Developing capacity and enhancing the enabling environment

There are a number of **policies** in place of relevance to WASH. The National Water Policy (MoIWD, 2005) recognises climate variability and change as threats, but the extent to which it addresses these issues – apart from setting policy objectives for disaster management – is limited. The National Sanitation Policy (MoIWD, 2008) does not mention climate or climate change at all. There is a relatively new National Climate Change Policy (2012) but this does not address specific sectors, so WASH is not highlighted. However, Malawi's NAPA (MoMNRE, 2006) does draw attention to the threats posed by dry spells, droughts, intense rainfall, riverine floods and flash floods and their impacts on food and water security, water quality, energy and livelihoods. The links between drought/flood prevalence and water borne diseases are also noted. Sector programmes which acknowledge the importance of climate variability and change could potentially advocate for explicit inclusion of climate statements in the relevant policy documents if not doing so already.

Technical guidelines relating to borehole depth, catchment protection for gravity flow systems and flood protection for sanitation may exist but may not be widely known or used (this needs to be verified). In general, construction supervision is non-existent or very limited. This is a nation-wide problem; more could be done by all sector actors to develop, disseminate and help monitor and enforce technical standards.

Hydro-meteorological monitoring institutions are in place and networks of rain gauges, river flow stage boards and groundwater monitoring points exist. However, significant challenges remain in terms of human and financial capacity. The Water Resources Department of the Ministry of Water Development and Irrigation (MoIWD) is under-funded and monitoring data are not published or easy to access. Large non-governmental programmes (such as the DFID programme) should arguably include an element of support for national monitoring, even if only through advocacy for more appropriate budget allocations.

The inadequacy of environmental monitoring makes responsiveness to slow-onset drought-related impacts difficult. **Emergency response** to rapid-onset flood events does take place, but the links between adaptive responses and disaster preparedness and response are not well developed. In general, more work could be done to identify potential adaptation actions (especially in relation to floods) which would then reduce the need for emergency response.

The Ministry of Environment and Climate Change has a responsibility for national **research and learning** on climate change, but the WASH sector should also undertake relevant studies and investigations. As noted above, there does not appear to be much information available relating climate change to WASH in Malawi (although we have not undertaken a full review of the literature). Large programmes could potentially make a useful contribution here for a limited percentage of the total budget.

The DFID programme (as per the business case) is strong on **capacity development** of households, communities and water user committees (WUCs). The programme also contains an element of capacity building for staff at district level and for the private sector. For example, selected mechanics and shop owners in the area are given training to provide support to communities on operation and maintenance. Although there is no explicit component of climate awareness in planned capacity development activities, the training for staff, WUCs and communities does cover issues of environmental degradation and conservation measures that need to be put in place.

Design and implementation

There appears to be little evidence that **design approaches** for WASH take adequate account of climate risks. In particular consideration should be given to low-regrets design modifications which could increase resilience to increased drought and flood frequency – without attempting to fully 'climate-proof' assets.

Finally, **catchment and source protection** are recognised as key issues in gravity flow system design and rehabilitation. It is also recognised in relation to point sources, although implementing organisations may be less clear on what specific actions regarding source protection zones are appropriate. More work is needed to determine appropriate catchment and source protection measures in different contexts.

2.4 Sierra Leone case study

2.4.1 Country context

Sierra Leone is a country recovering from a decade-long civil war during which much of its WASH infrastructure was put out of service. Since the signing of the peace agreement in 2002 the country has made steady progress in the transition from a state of emergency to recovery and ongoing reform processes (including new laws, policies and institutions) have created an enabling framework for WASH development (AMCOW, 2010a) Nevertheless huge challenges remain. Current estimates provided by the JMP for Sierra Leone put **improved water supply** access at 57%, with **sanitation** lagging behind at 13% (WHO/UNICEF, 2013). There are large inequities between rural and urban areas and national averages also obscure disparities between regions and households (DFID Sierra Leone, 2012).

The government's National Water Supply and Sanitation Policy (2011), which DFID's partners are supporting, adopts a Community-Led Total Sanitation (CLTS) approach focussed on self-supply, the promotion of affordable technologies and awareness raising activities. Meanwhile responsibility for the development of rural water supplies has been devolved to local government, with an emphasis on community operation and maintenance.

In urban areas the situation is somewhat different as WASH services should (in theory) be delivered through utilities such as the state-owned Sierra Leone Water Company (SALWACO), the Guma Valley Water Company (GVWC) and the Freetown Waste Management Company (FWMC). However, in Freetown the deteriorating performance of GVWC, illegal connections and environmental degradation mean that water services are poor or non-existent, particularly for the poorest households. Similarly, waste management systems have broken down and there is an urgent need to deal with the solid waste accumulating in streets and drains, and to ensure the proper disposal of faecal sludge. Low lying slums are particularly vulnerable to flooding due to poor drainage, with contaminated water contributing to the spread of water borne disease, including cholera (DFID Sierra Leone, 2013).

DFID Sierra Leone's WASH portfolio

DFID is implementing a major £50 million programme over the period 2010 to 2016 with the Ministry of Water Resources (MoWR) and the Ministry of Health and Sanitation (MoHS). The programme has three complimentary elements:

- Technical support to the MoWR and MoHS to implement the National Water and Sanitation Policy of 2010, which includes:
    - Legislation to create a National Water Resources Agency and an independent water and energy regulatory commission.
    - Legislation to strengthen the Guma Valley Water Company and the Sierra Leone Water Company.
    - Restructuring and establishment of reform management structures within the Ministry including strengthened relations between MoWR and the MoHS and waste management.
    - Capacity building in seven districts to support planning and management of water including community based approaches for water resource management and water security.
- WASH service delivery improvements in Freetown focussing on slum/poor areas through support to an NGO Consortium, led by Oxfam, to work at community level in cooperation with GVWC and Freetown City Council.
- CLTS programmes in six districts together with improved WASH facilities in rural schools and clinics implemented through PLAN International and UNICEF.

The DFID programme sits alongside other donor programmes, the principal projects being:

- African Development Bank (AfDB) support for urban water and sewerage services in three main towns in Sierra Leone (Bo, Makeni and Kenema).
- Support from the AfDB for rural WASH in regions not covered by the DFID rural WASH projects (DFID is co-funding this programme which includes a GEF co-funded component addressing climate change).
- Planned support from the Netherlands Government for rural WASH in regions not covered by the DFID or AfDB funded rural WASH projects.
- JICA support for urban water supply improvements in small towns in Sierra Leone.

The most climate-relevant aspect of DFID Sierra Leone's current portfolio is the technical support to the Ministry of Water Resources[13]. A large component of this project is focused on improving the way in which water resources are managed and includes establishing WRM institutions, and addressing associated environmental monitoring activities.

Source: DFID Sierra Leone (2012, 2013) supplemented by in-country consultations

2.4.2 Preliminary findings of the risk assessment

An argument made by several stakeholders in Sierra Leone was that more effort needs to be put into coping with the existing variability alongside non-climatic risks, rather than worrying about marginal changes in future (and highly uncertain) climate. A key finding of the government's water point mapping review (MoEWR, 2012) is that many water points are seasonal, with up to 40% of protected in-use water points providing insufficient water during the dry season. Results from **Step 1** of the risk screening support the view that the

[13] Through Adam Smith International

relative magnitude of climate change as compared to other risks is particularly low for Sierra Leone. For example, there is generally little recurrent finance in the WASH sector, communities are extremely poor and WASH institutions weak at all levels.

Environmental degradation is considered a significant and widespread problem. For example deforestation around Freetown is a major concern, and mining and agro-industry are increasing rapidly with little regulation, the latter potentially leading to increased extraction of water resources and pollution. Meanwhile, population is projected to grow by a factor of 1.79 between 2010 and 2050 (UN Data, 2013); less rapid than Malawi or Tanzania, but increasing pressure on existing services and resources.

For the purposes of the **Step 2** of the assessment the focus is on DFID Sierra Leone's new urban WASH component (DFID Sierra Leone, 2013) as the DFID Malawi and Tanzania WASH programmes are both rural in emphasis. Findings are again tentative.

Understanding climate impacts

It is difficult for implementing organisations to have a strong understanding of **current variability** because the availability of hydro-meteorological data for Sierra Leone is extremely limited. Programme design does consider existing variability in the sense that plans account for the regular flooding that occurs in Freetown's informal settlements. However, given 'formal' data constraints, information is restricted to that provided by local people - for example floodwater lines on people's houses are used as indicators. **Climate change**, as opposed to variability, is less of a discussion point in the urban WASH sector. Given the high level of uncertainty (and relatively small magnitude of change) associated with climate projections, future population growth and density are considered to be more pressing issues.

Developing capacity and enhancing the enabling environment

Sector policy development is largely covered by DFID's support to the MoW and MoHS via the technical assistance component of the WASH programme. The national water and sanitation policy was approved in January 2011, but has little climate focus. The environmental sanitation policy is still under review – representing an opportunity to better incorporate climate-related risks. DFID also supports the Freetown Urban Wash Consortium (FUWC) which has an influencing strategy and, in particular, aims to ensure that Freetown City Council (FCC) WASH Development Plans include an environmental sanitation sector plan and budget. Efforts will continue to focus on building climate variability into decision-making processes and policies, given the uncertainties around future climate change.

DFID Sierra Leone's technical support project involves some work on **guidelines and standards** for the MoWS and MoHS, including urban WASH. The FUWC project is contributing to this national level process in addition to the development of internal guidelines and standards for FUWC members (such as for public toilets and tap stands), which has recently been a key area of work. Future influencing objectives are to encourage Freetown City Council to adopt the guidelines developed for public toilets. Guidelines should ideally incorporate consideration of flood risk and suggest appropriate technology options. Supporting for implementation will also be key.

Stakeholders highlighted concerns about the lack of **hydro-meteorological data** and uncertainties around basic trends - whether rainfall is increasing or decreasing, or what is happening to groundwater or surface water. This makes planning for climate risks extremely difficult. Although not part of the FUWC component, support to national **hydro-meteorological monitoring** is being provided through other elements of the DFID WASH programme (including pilot work in the Rokel river basin), and to some extent by UNDP and the UK Meteorological Office. Provided that capacity building efforts continue, routine data collection and dissemination over the longer term, combined with increased coverage of monitoring stations and improved equipment, can help build the evidence base.

There is no distinct **research or learning** component in the FUWC project, and although learning is integrated across many activities they are not directly related to climate change. The FUWC Phase 2 inception report documents two areas for **capacity development**, neither of which are climate-specific but are nonetheless relevant to building resilience: firstly on environmental sanitation, with a focus on relevant government institutions and community level organisations; and secondly planning and coordination, with a focus on FCC, Freetown Waste Management Company, District Health Management Team and Guma Valley Water Company. Given Sierra Leone's post-conflict situation, capacity building at all levels is clearly a short, medium and long-term priority.

Finally, the FUWC programme contains a small but significant component of **disaster-risk management** work, including support for the establishment of a Freetown-level cholera preparedness plan and community flood preparedness. Disaster-risk management has clear links with climate adaptation.

Design and implementation

According to the stakeholders interviewed, climate variability is taken into consideration in **project design and construction** because of the risks it already presents. Areas of focus for urban WASH mostly concern run-off and drainage and the siting of pipes. Anecdotally, local information is gathered during project planning, for example infrastructure is designed to withstand the highest flood levels local people can remember from the past ten years. However, this is difficult to apply consistently. Future change is not considered, though arguably this is of low priority given the impact of existing variability.

In terms of improved **sanitation** and the use of resilient **technologies**, various modifications to latrines are undertaken in flood-prone areas, such as reinforced sub-structures and raised pits. Nevertheless, poor solid waste management is a key issue particularly with regards to flooding and there is little regulation in the city. Environmental sanitation is a focus of FUWC advocacy activities.

Catchment protection is a certainly an issue in peri-urban Freetown. The performance of gravity schemes installed by FUWC has been hampered by deforestation and population growth (the latter possibly driven by migration due to water availability). The prevailing view is that little can be done to prevent this in the current policy environment. On the positive side, there are some measures for catchment protection in the WRM bill currently going through parliament, which will give some legal basis to possible natural resource management efforts in future.

2.5 Tanzania case study

2.5.1 Country context

Tanzania is a relatively large country with a rapidly growing population. The country is predominantly rural but by 2050 the population is projected to be over 50% urban, and Dar es Salaam is expected to become a mega-city even sooner (over 10 million people by 2040) (GCAP, 2011). Water is critical to Tanzania's economy, underpinning the agriculture sector, hydropower generation, the ecosystems of national parks and protected areas (key to the tourist sector), as well as human health and well-being (MoWLD, 2002).

Tanzania is currently not on track to meet the MDGs for water and sanitation. In fact JMP figures show a decline in access to **improved water supply** from 55% in 1990 to 53% in 2011 (WHO/UNICEF, 2013). Although **sanitation** shows an upwards trend coverage remains very low at 12% (*ibid.*). To some extent these trends may reflect the difficult transition the sector has made in the past decade from projects to programmatic support (AMCOW, 2010b). Although the current Water Sector Development Programme (WSDP) has helped increase coordination between different actors and attract growing sector finance, a number of governance issues remain (DFID Tanzania, n.d.a; see also MoW, 2013).

In urban areas the limited extent and poor functioning of water supply networks mean that many people use private vendors and water quality is often unregulated. Waste water treatment is also very limited: for example there are about eight collection points in Dar es Salaam but only one or two are functioning. Key informants stated that drainage and sewerage systems are outdated and poorly maintained, and in unplanned settlements in particular people rely mainly on make-shift latrines.

In rural areas Local Government Authorities (LGAs) deliver services while communities are mandated to manage and operate water schemes. The implementation capacity of LGAs to deliver services is still low and although community-led WUAs are being established and trained, legal registration has not kept pace with their creation (DFID Tanzania, n.d.a). Moreover, some communities have opted for more expensive technologies than necessary and maintenance has been poor. Sustainability of rural water supply remains a challenge with around 20% of water points breaking down within two years of installation due to lack of funds, inappropriate technology, wells drying up and lack of technical support (TAWASANET, 2011).

DFID Tanzania’s WASH portfolio

DFID is providing £30 million from 2012 to 2015 in support of the government of Tanzania’s Water Sector Development Programme (WSDP) through a pooled (basket) funding mechanism, with the intention to scale up to an additional £150 million from 2013 to 2018 through a results-based financing arrangement. In light of the current bias of funding allocations towards urban areas, DFID Tanzania has decided to earmark its contributions for rural WASH. The programme has three main components:

- **Water supply infrastructure:** Funding through LGAs to rehabilitate existing water schemes and construct new schemes, including support (training) for the establishment of community-based WUAs. The construction itself would be carried out by the private sector.
- **Sanitation and hygiene:** Funding for the National Sanitation Campaign covering all 132 LGAs. In addition to promotional activities (described above) this will include training for masons in constructing and selling household sanitation platforms (sanplats) and construction of hand washing and sanitation facilities in schools.
- **Management support:** This includes training for key staff at ministry and district levels on programme management and implementation, capacity building in the private sector, capacity building at LGA level, training on gender awareness, and the recruitment of a consultancy firm to support the Ministry of Water and Prime Minister’s Office (Regional Administration and Local Government) on rural WASH.

In addition to WSDP support, DFID Tanzania is working with the Ministry of Water to develop a sector climate change action plan which will help to identify specific activities to fund. They are also supporting the development of climate action plans for agriculture, energy and urban sectors. Furthermore, DFID is putting £5 million towards a first phase of ‘climate-proofing’ its investments in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT). The first project phase will support hydro-meteorological data generation and institutional strengthening on water resources management in the Rufiji River Basin, with a view to securing significant additional funds from the UK Climate Investment Fund (CIF) for water security infrastructure development. DFID has previously commissioned a report on the economics of climate change in Tanzania which highlights an urgent need to scale-up financing for adaptation (see box below).

Source: DFID Tanzania (n.d. a,b&c) supplemented by in-country consultations

2.5.2 Preliminary findings of the risk assessment

As in Malawi and Sierra Leone, **Step 1** of the risks screening process suggested that other pressures on resources and services may be more important to Tanzania's development trajectory than climate change *per se*. For example, rapid population growth and urbanisation is increasing demand for water and the production of faecal sludge and solid waste, and pressure on natural resources is leading to environmental degradation. The lack of hydrological monitoring networks and data has also been identified as a key challenge by stakeholders, hindering effective WASH and WRM planning. Moreover, the lack of institutional capacity for implementation and management, particularly at local level (LGAs, private sector and among communities), remains a bottleneck for rural WASH and natural resources management. To date attention in Tanzania's WASH sector has focused on new infrastructure rather than recurrent costs or capacity building needs. Finally, several stakeholders highlighted the need to consider WASH in the context of IWRM.

Accepting that climate change may not be *the most* important issue to consider, research has nevertheless shown that at national level climate risks place a significant burden on Tanzania's economy, constraining economic growth (see box below). Furthermore, climate variability already poses a challenge in certain regions or locations that are exposed to flood risks or drought. With future increases in heavy rainfall events, coupled with land degradation and poor drainage, high runoff and flooding may be exacerbated with implications for WASH infrastructure and the quality and quantity of water available.

The economics of climate change in Tanzania

A study was commissioned by DFID to assess the impacts and economic costs of climate change in Tanzania, the costs and benefits of adaptation and the potential for low carbon growth.

In the past, climate variability has exacted a heavy economic burden due to the country's dependency on climate sensitive activities, particularly rainfed agriculture, and periodic droughts and floods have caused major socio-economic impacts and reduced economic growth. For example, the 2005/6 drought affected millions of people and had a cost of at least 1% of GDP. In short, Tanzania is not well-equipped to deal with existing climate risks. Future costs are much more uncertain but climate variability and change could incur losses of 1.5-2% of GDP/year by 2013.

"The combined and cumulative effects of current climate variability and future climate change are large enough to reduce the chances of Tanzania achieving key economic and development targets and challenging the timetable for achieving middle income status."

The funding required to mitigate these climate-related costs is considerable. Immediate needs (for 2012) to build adaptive capacity and address priorities are estimated at USD100-150 million/year, whereas the medium-term costs are of the order of USD250-1000 million/year by 2030.

Source: summarised from GCAP (2011)

Given that DFID's current approach to delivering on WASH in Tanzania is sector budget support to WSDP, in **Step 2** we decided to assess the WSDP as a whole, considering water and sanitation issues, rural and urban contexts, and WRM. However, there is some bias in focus towards rural water and sanitation as DFID funds are earmarked for this component of the national programme.

Understanding climate impacts

Several stakeholders suggested that climate risks were relatively low and location-specific in Tanzania as compared to other East African countries such as Ethiopia. Nevertheless, it was generally understood that climate variability and change posed a threat to WASH services, particularly in relation to water resources management (and in urban areas, waste and storm water management). As in Malawi, there was some awareness of the general risks but a lack of detailed understanding of how to integrate climate risks into WASH planning and implementation. Although data are available from the national meteorological office (on a cost sharing basis), it was unclear whether the WASH sector makes regular use of this data in designing projects or programmes. The analysis of impacts on specific WASH subsectors is also made difficult by the wide variation in climate projections, and this uncertainty may hinder concrete responses.

Developing capacity and enhancing the enabling environment

Whilst there is no explicit reference to climate change, it has been argued that national **WASH policy** prescriptions are compatible with a national climate change response, for example addressing IWRM and catchment management. However, there is a view that more could be done to strengthen links between WASH and IWRM. The Ministry of Water has commissioned the development of the Integrated Water Resources Management and Development (IWRMD) plans across nine river basins. Plans are expected to provide an up to date assessment of baseline and future supply-demand balances for different sectors and water users in the basins. However, implementation of plans will require long term institutional capacity strengthening and support.

The **WSDP programme** as a whole is comprehensive and has been designed based on best practice for the sector. Climate change is considered to some extent in the WRM component (although in practice little has been done to date), yet there is little explicit consideration of climate risks in other programme components. In general WASH activities are not currently planned with climate change in mind. A climate change action plan for the agriculture sector is currently under development with DFID support and other donors are currently exploring the possibility of supporting a similar initiative for the water sector. Assuming the latter goes ahead, it will be important to ensure ownership of this plan by the ministry, particularly the WSDP steering and technical working groups, as well as integration across WSDP components.

Both DFID and government staff thought that adequate **guidelines** for WASH practitioners and contractors were available, although climate change may not be explicitly considered[14]. In theory feasibility studies should be conducted before implementation as a matter of routine, including consideration of flood and drought risks. The key issue is lack of LGA capacity for monitoring and enforcement of best practice standards. In addition to capacity building and promotion of best practices, development actors can play a role in ensuring that technical guidelines are updated to include explicit consideration of climate-related risks.

With the exception of the Tanzanian Meteorological Agency which collects and disseminates climate data, **hydro-meteorological monitoring** networks and agencies in Tanzania are fairly weak, and data on surface water and groundwater are not routinely collected or disseminated. Recognising this challenge, DFID is already providing some support in the Rufiji river basin to strengthen the hydrological monitoring network and institutions for water management, with the potential to scale up with funding from the UK Climate Investments Fund. DFID is also considering how best to incentivise better monitoring (e.g. of water point functionality) in the next tranche of funding for WSDP using a results-based financing approach. In short, it is likely that considerable long-term investment is needed to rehabilitate monitoring facilities, update equipment and expand the network. The ‘software’ will be equally important, including the recruitment and training of staff.

[14] The National Sanitation Options and Construction Guidelines (MoHSW) do not mention the risk of floods, although there is a chapter on providing emergency sanitation facilities.

At present the WSDP does not include a **research and learning** component, and climate change research is mainly funded by donors through *ad hoc* studies. There is some degree of collective learning as technical working groups meet to discuss issues, but action points are not always followed up on. Learning objectives may need to be formalised in the WSDP, particularly in the next few years once implementation is fully underway. Technical assistance may be needed in articulating research and learning needs on climate change and WASH specifically.

The WSDP includes **capacity building** as one of four main components but the Phase 1 evaluation (MoW, 2013) found that, to date, there has been a lack of clarity as to how this will be implemented. Human resources development needs to be approached systematically and with capacity building interventions integrated into the work plans and budgets of the three 'technical' components of WSDP (*ibid.*). The evaluation also highlighted the need for training in the analysis and use of hydro meteorological information .

In terms of **flexibility and responsiveness**, tentative findings suggested some degree of collective 'learning by doing' in the WSDP, with Phase 2 of the programme informed by the experience of implementing Phase 1. Nevertheless, there is a need to ensure that information on climate and other risks (e.g. population, environmental degradation) feeds into programme design at regular intervals – building in mechanisms for data uptake. Budgets for emergency response are also limited, but perhaps a bigger issue for WASH is the lack of funds to cover recurrent costs.

Design and implementation

The extent to which climate variability and change are factored into the **design of WASH infrastructure** and the selection of technology options was discussed with stakeholders but remains unclear. The general approach to rural water supply in Tanzania is demand-led design, yet the tendency to date under the WSDP has been for communities to select higher-cost options which are not always affordable over the longer term. In theory, the menu of options offered under demand-led approaches should be shaped by an understanding of resource conditions, trends and climate risks, and certainly those related to existing levels of climate variability.

Catchment protection was repeatedly highlighted by stakeholders as a key issue for sustainability of surface and groundwater sources and the mitigation of flood risk. Institutions are in place in Tanzania, but budgets for implementation are inadequate. Donors could consider providing additional funds for WASH-related catchment protection under the IWRM component of WSDP. The next phase of DFID support for 'climate proofing' SAGCOT through WRM infrastructure development could perhaps provide a for investment in catchment protection.

Functional **drainage and waste water** treatment systems (urban) and improved **sanitation** facilities (rural and urban) are severely lacking in Tanzania. Consequently flooding is a major health hazard, destroying poorly built latrines and leading to contamination of surface water from sewerage, contributing to outbreaks of cholera and other water-related diseases. An obvious first step is to tackle the existing deficit in improved sanitation coverage, yet some immediate climate-specific actions can also be taken to increase resilience. For example, targeted support (financial or other) could be provided to communities or households most at risk of flooding to enable them to upgrade their latrines in flood-prone areas or re-build latrines following collapse. Some support is already provided by communities themselves through community action plans which target vulnerable individuals such as the elderly, disabled or people living with HIV/AIDS. In urban settings, the maintenance and upgrade of existing systems, alongside expansion of the network to cover newly settled areas, are priorities.

2.6 Emerging issues

Malawi, Sierra Leone and Tanzania are all making progress on WASH, albeit from very different positions. All three countries are vulnerable to existing climate variability and change, though the direction and magnitude of future changes in rainfall remain uncertain. What is clear is that existing variability already affects the performance of WASH, and there is interest in understanding what more could be done to secure WASH results and safeguard hard-won benefits.

In terms of urban WASH service delivery, the extension of water supply and drainage networks is clearly a priority given high rates of urbanisation, alongside the use of flood-resilient technologies. Meanwhile, delivery of improved water and sanitation in rural areas through devolved government structures relies heavily on community-based operation and maintenance. The lack of adequate resources and capacities at local level, reliable supply chains for spare parts and enforcement of best practice present problems in all three countries. Indeed throughout SSA, the drive for new infrastructure development has often diverted attention away from the sustainability of existing schemes, and capacity building efforts for operation and maintenance have tended to lag behind construction. Although water point mapping has been carried out in all three countries, the underlying causes of poor performance remain under-researched and poorly understood

Explicit consideration of flood and drought risk in both urban and rural WASH planning and design remains a priority. In Sierra Leone, this is being addressed through DFID-supported FUWC work. The development, use and enforcement of best practice guidelines on WASH that address climate risks, for example through better siting of water points or changes in latrine design in flood-prone areas, could increase the resilience of WASH services to climate change and other pressures.

Complicating matters is the fact that major uncertainties exist in all three countries about their climate and water futures. Data on resource conditions and trends, water withdrawals and pollution loads, the functionality of WASH services and the causes of failure are also limited. The lack of information, coupled with the inherent limitations of climate modelling, makes it difficult for decision-makers to plan for the future. Some relevant initiatives are underway to build hydro-meteorological monitoring capacity, such as the DFID Tanzania investments in the Rufiji river basin and DFID Sierra Leone support for pilot work in the Rokel river basin. Nevertheless, large uncertainties are likely to remain. In this context, robust decision-making is important, including the selection of options that are likely to perform well over a range of future scenarios. Simple risk screening exercises can provide a useful starting point for identifying ‘no’ or ‘low’ regrets interventions.

A number of the adaptation options identified by stakeholders in country consultations focussed on links between WASH and natural resources management, including catchment protection. Integrated water resource management plans implemented through river basin organisations will take many years to implement; countries such as Tanzania are making a start. At the watershed scale, however, there may be tangible opportunities to link WASH planning with soil and water conservation programmes supported (typically) through the agriculture-food security sector.

3 Economic analysis of adaptation options

3.1 Introduction

This section addresses the economics of adaptation in WASH programmes. The aim is to demonstrate economic analysis setting out costs of business as usual for WASH delivery, and cost-benefit analysis (CBA) of adaptation options. The approach is strongly linked to Step 2 of the risk screening process above as this should highlight areas in WASH programme design that need to be addressed. It is written in the form of guidance for others wishing to carry out such analysis during programme planning.

Wherever possible, examples of possible adaptation options are drawn from the country risk screening and country consultation exercises outlined in Section 2. Key examples from each country are discussed. Several different approaches to the economic analysis are demonstrated, each with varying levels of detail, to allow readers to tailor the approach to their needs. Throughout this project, the intended user has been DFID country office advisors and staff of implementing agencies such as UNICEF, with focused support from in-house or consultant economists where appropriate The methodology therefore needs to be as accessible to non-economists with a focus on practicality.

In addition, it is implicit that economic analysis is being undertaken at an early stage of programme design in order to inform intervention options, rather than as a retrospective box ticking exercise. CBA can indeed be used as a decision rule, in the sense of deciding whether or not a project, activity or intervention is viable. Here, however, CBA is viewed as one aid to programme design. Different design options are being tested in order to understand what approaches to capital investment and operational expenditure can be implemented to increase resilience.

A number of different methods can be used for economic analyses but in this project we focus on CBA. This is because CBA is an explicit objective of the project, and also the preferred approach for the preparation of DFID business cases. In the interests of supporting programme design and planning, it is sensible to adopt methods which are already used and understood. In the context of climate change however, CBA has some important weaknesses, outlined below. It may be advisable to use additional approaches alongside CBA, such as Robust Decision Making (RDM), also discussed below.

A recent ODI Working Paper reviews the literature on the economics of adaptation in Africa's water sector (Doczi & Ross, 2014). While there is some literature on the costs of adaptation in WASH, there is far less on economic *appraisal* (i.e. the comparison of costs and benefits) of specific adaptation interventions. This chapter therefore presents several innovations in CBA practice.

3.2 Issues in CBA of adaptation in WASH

3.2.1 Introduction to economic analysis

Economic analysis comprises approaches to comparing interventions based on their economic costs and benefits. It aims to determine the allocation of scarce resources by comparing two or more alternatives in achieving an objective under given assumptions. Various methods of economic analysis exist, including CBA, Cost-Effectiveness Analysis (CEA) and Cost Utility Analysis (CUA). Doczi & Ross (2014) provide an overview of the different methods, along with references for specific examples in the water sector. As noted above, our approach focuses explicitly on CBA. Outputs include net present values (NPVs), internal rates of return (IRRs) or benefit-cost ratios (BCRs).

While this chapter aims to provide guidance on the economic analysis of adaptation options, some existing understanding of CBA is assumed. This is in order to keep things short and focused. Good existing overviews of CBA exist, such as the ADB's (2013) *Cost-Benefit Analysis for Development: A Practical Guide*, as well as the guidance in HM Treasury's 'Green Book', or DFID's internal investment appraisal guidance. In addition, economists from the World Bank's Water and Sanitation Programme (WSP) are currently working on a toolkit under the Economics of Sanitation Initiative which will provide a comprehensive overview focused on the WASH sector (Hutton, forthcoming).

In brief, the main steps involved in CBA are to:

1. Define the project's objectives.
2. Specify a set of implementation options.
3. Estimate the economic costs and benefits of each option.
4. Calculate a cash flow for each option over a set time-period.
5. Apply a set discount rate to the cash flow, to account for time preference.
6. Calculate BCRs and NPVs.
7. Use sensitivity analysis to explore areas of uncertainty in the data, and draw balanced conclusions

A key point to emphasise is that CBA implies a comparison of *economic* costs and benefits, not simply financial costs. The economic costs of an intervention comprise costs incurred by all stakeholders involved, including opportunity costs where appropriate.[15] For example, if an NGO installs a borehole with hand-pump, the cost of parts and labour for installation are considered, but also (i) a proportion of the overhead necessary for that NGO to function, (ii) costs incurred by the community in the form of operational expenditure (OPEX) and capital maintenance expenditure (CAPMANEX) in the delivery of the *service* it provides. In practice, it may prove impossible to monetise all costs and benefits, but a clear rationale for inclusion and exclusion should be provided. In addition to the inclusion/exclusion of costs, a second key issue is pricing, i.e. the valuation of key commodities and benefits. People's time, energy and water itself may not have an obvious price, but in CBA the aim is to attribute prices to some of these items to allow *economic* costs and benefits to be compared.

In the WASH sector globally the work of Guy Hutton is most regularly cited. Hutton's work has focused mainly on the MDGs at a global and regional level rather than at programme or project level, but the principles involved are similar. A paper by Hutton & Haller (2004) was the first to quantify BCRs for meeting the WASH MDGs. The methodology has since been refined (Hutton, 2012), with a major difference being the aggregation upwards from national-level cost data (where available) rather than making regional assumptions.

[15] Financial costs are those incurred by an agent in a market transaction, whereas economic costs are the broader costs of a project to society, not just from the point of view of the single agent. For example, subsidies or transfers are not economic costs, as they do not change the costs and benefits to society.

3.2.2 Challenges in CBA of adaptation interventions

There are a number of challenges inherent in the economic appraisal of adaptation options. Section 1 of this report discussed the deep uncertainty surrounding projected future climate and societal scenarios. This makes methodologies based on assigning probabilities unreliable. Secondly, the time horizons for economic appraisal of adaptation options may be longer than those usually used. If so, this has implications both for the validity of assumptions and for discounting. These issues are explained in more detail by Doczi and Ross (2014).[16] Both factors have implications for the assumptions we can make in economic appraisal about different future scenarios, impacts on systems and services attributable to climate change specifically, and hence the impact of adaptation interventions.

The kinds of impacts that are predicted are damage and reduced operational efficiency of WASH and WRM infrastructure, e.g. through flooding, drought or increased pollution. This comes on top of their significant vulnerability to existing climate variability, summarised in Section 1. A key challenge in economic analysis of adaptation is how to balance the costs of adaptation with the expected loss from climate damage. It is the various types of uncertainty (particularly around future climate, but also its impact on WASH) that make this difficult. However, one dimension around which some consensus is emerging is greater climate variability and increases in climate extremes (IPCC, 2012).

Importantly, a recent DFID topic guide emphasises that with deep uncertainty[17] such as that surrounding climate change, conventional economic tools like CBA can become useless, because the mathematical optimisation inherent in their working can be very sensitive to uncertainty (Ranger, 2013). It is argued that a resilient intervention is one that achieves its objectives today, but is also robust (i.e. high benefits under a variety of scenarios) and adaptive (i.e. can be altered to changing future conditions). Robustness can be tested through sensitivity analysis and ‘switching value’ analysis[18], as well as through more in-depth extensions and alternatives to CBA such as Robust Decision Making (RDM) and Real Options Analysis (ROA). It is likely that these alternatives to CBA will increasingly be used in adaptation decision-making, and any extension to this work could certainly explore the options.

3.2.3 Previous work on CBA of adaptation in the water sector

One key decision in methodology selection for this project was the extent to which multiple climate scenarios and time horizons could be taken into account. It was clear that to incorporate these would rapidly increase the complexity of the approach, making it less practical as a tool for use by DFID country advisors and staff of implementing agencies such as UNICEF. Moreover, we were repeatedly told during country visits that the key climate challenge in the WASH sector was existing variability and the ‘adaptation deficit’. Allocating limited funds to downscaling climate models or complex scenario development would have been unwise, given that WASH services in most developing countries are not fully resilient to existing floods and droughts. In addition, none of the four water-related CBA studies cited in UNFCCC (2011) as good examples of adaptation CBA actually consider more than one climate scenario, as set out in Table 2 below.

[16] Academic debates are unresolved, but policy is coalescing around the idea of a declining discount rate, which is one way of balancing current costs and distant benefits. For example, the UK government’s preferred rate starts at 3.5% and declines steadily to 1% for more than 300 years into the future (see HMT ‘Green Book’ referenced elsewhere). For the moment, most development interventions (and appraisals thereof) continue to use short time horizons and fixed discount rates.

[17] Deep uncertainty is a situation in which we agree neither on which are the best models, nor on how the probabilities attached to key variables are distributed (Hallegatte et al., 2012)

[18] A switching value is the point to which benefit estimates need to decline or cost estimates need to increase in order for the CBA recommendation to be different (i.e. the clearing value)

Table 2: Summary of approaches to climate risk in CBA case studies in UNFCCC (2011)

	Approach to dealing with climate	Options considered	Links between options and climate scenarios	Sensitivity analysis
CBA of flood and coastal management options in Redcar, UK	No climate scenarios. Focus on different 'standards of protection' (SOPs) for coastal defences, noting that existing risk of flooding is 10% in any given year	Adaptation options to reduce the risk of flooding 1. Do-Nothing (base line) 2. Do-Minimum 3. Do-Something (for various SOPs in terms of risk of flooding event)	Climate risk analysed through *current* modelled flood risk, i.e. only 1 scenario considered (see tables on p.15 of UNFCCC 2011)	None (but full project document not available)
CBA of water management options in Bolivia	No climate scenarios, just basic project CBA	Options mainly technical e.g. reservoirs of varying capacity, storage tanks with or without pumping	Not attempted. Benefits compared to 'no-project' baseline	None (but full project document not available)
CBA of DRR measures in Nepal	No climate scenarios. Post-project CBA with 2 time horizons (10 & 20 yrs) - see Willenbockel (2011)	Various interventions had already been implemented, e.g. irrigation investment, crop farming skill enhancement	Not attempted. Benefits compared to 'no-project' baseline	3 discount rates and 2 time horizons
CBA of irrigation adaptation options in the Gambia	Theoretical analysis considers 2 climate scenarios (C0 and C1) and three options, but *empirical* CBA considers only the current climate and 2 options (Nkomo & Gomez, 2006: p116)	Two options (irrigation or no irrigation)	Not attempted. Benefits compared to 'no-project' baseline	2 discount rates

Two of the studies in Table 1 (Nepal and Bolivia) treated their projects as normal interventions. The UK study considered only one flood risk scenario, and the Gambia study only considers the current climate. Furthermore, DEFRA's (2009) supplementary Green Book guidance on 'Accounting for the Effects of Climate Change' states that sensitivity analysis can be used to examine the implications of alternative climate change scenarios.[19] Based on this, as well as the objective of supporting programme design, our approach focuses on modelling the interventions themselves and the implications of different assumptions in the short-to-medium term, rather than complex scenario development.

3.3 Overview of the approach used in case study examples

Several different approaches to CBA of adaptation options in WASH are demonstrated below. Brief explanations are given in the following sub-sections to illustrate key points.

3.3.1 Programme design scenarios

Given the focus of this study on DFID programmes, the bulk of our analysis was at the programme level. However, several different approaches are demonstrated in later sections, allowing the reader to pick and choose based on their priorities and the time available.

It is common in CBA to compare an intervention case to a Business as Usual (BAU) baseline. Our focus is alterations in usual programme design to increase resilience, which we are calling adaptation options. Hence the BAU case is basic programme design, i.e.

[19] The Green Book is HM Treasury's guidance for project appraisal and evaluation, including how CBA should be conducted. It has not been substantially updated since 2003, except the supplementary guidance noted above, which is available at http://archive.defra.gov.uk/environment/climate/documents/adaptation-guidance.pdf

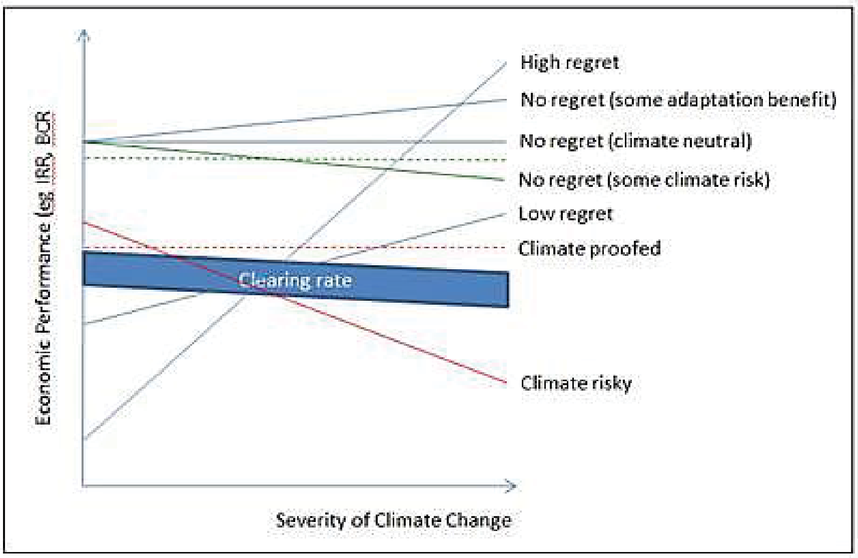
without the changes defined as adaptation options. The intervention case comprises adaptation options *supplementing* the BAU case. This allows a focus on the options themselves and, in addition, allows it to be more applicable to existing WASH programmes.

As discussed in Section 1, it is important to clarify the inter-relation between adaptation and development. The principle of 'climate-resilient' development emphasises that adaptation should not be treated as an additional activity that is separate from development, since investment into one often brings about gains in the other. Furthermore, some interventions that may be termed 'adaptation options' are really what WASH sector actors should be doing anyway in the face of *existing* climate variability, which is significant in all our case study countries.

Our approach has been to identify 'low regrets' adaptation options as part of a 'best practice' programme design. Low regrets options are robust to a range of possible future climates, i.e. they are relatively insensitive to climate uncertainty. By contrast, high regrets options perform better than low regrets ones under more damaging climate changes (but worse under less damaging ones). Figure 1 demonstrates a typology of adaptation options, based on Nicholson (2013). It considers an option's economic performance relative to a 'clearing rate' under different predicted levels of climate change severity.[20] For example, an intervention would be 'high regret' if the BCR now was much lower than the clearing rate, and climate impacts then turned out to be less severe than expected. If the opposite were the case, the intervention would be 'climate risky'. Similarly, it would be 'low regrets' if there was not much difference between the BCRs under high or low severity, and 'no regrets' if the BCR was greater than one under all scenarios.

Our focus on 'low regrets' options should not be interpreted as implying that these are somehow better than 'high regrets' options. Good low regrets options may still not bring positive BCRs in all scenarios. As uncertainty around climate projections decreases over time, high regrets adaptation to flooding based on increased return periods may be more sensible than a low regrets approach.

Figure 1: Typology of adaptation options



For the reasons identified in Sections 1 and 2, we focus on low regrets interventions for which BCRs could be expected to increase relative to BAU as climate changes take place. Therefore, we term our intervention case as '*Best Practice under Existing and Increasing Climate Variability*' (BPEICV).

[20] The clearing rate is the point at which a decision related to a criterion would change, such as a BCR of one

In the present exercise we are therefore comparing two *programme design* scenarios: BAU and BPEICV. In other words, the BAU programme reflects a programme that pays little attention to existing climate variability, whereas the BPEICV programme takes account of both existing and increasing climate variability. A more complex approach could consider dealing with existing and increasing variability separately. However, for this analysis it was thought better to keep them together to avoid unnecessary confusion, and also because of a view that few present WASH programmes do enough to address existing variability. Clearly for future work it may be useful to separate them out in order to demonstrate how high and low regrets options perform under different scenarios. The BPEICV programme design goes beyond WASH best practice in WASH programme design, because it deliberately focuses on interventions (i.e. adaptation options) for which BCRs would increase relative to BAU as climate change intensifies.

During in-country visits for this project, various adaptation options were discussed with key stakeholders. A prioritised list for each country is presented in Table 3. In the interests of brevity, the CBA approach is demonstrated for half of these (for a full list refer to the separate Case Study Report).

Table 3: Adaptation options prioritised in the country risk assessment

Step 2 level	Malawi (rural)	Sierra Leone (urban)	Tanzania (rural)
1. Understanding climate impacts	Study of groundwater levels, surface water flows, and climate variability	Flood risk mapping in programme areas	Public education around flood risk
2. Capacity and enabling environment	Recurrent hydro-meteorological data collection and publication	Guidance on appropriate latrine technologies in high water table areas	Training for LGAs on encouraging groundwater recharge
3. Design and implementation	Catchment protection	Simple rainwater harvesting to supplement other sources during dry season	Catchment protection
	Lined and raised pit latrine	Latrine with small vault instead of pit, above ground for regular emptying	Proper supervision and drilling boreholes to the bottom of the aquifer

3.3.2 Approach to modelling costs

There has been increased attention on the modelling of the costs of WASH programmes in recent years, particularly the idea of the life-cycle cost approach (LCCA) promoted by the WASHCost project. Historically, programme designers have mostly focused on the initial capital costs of a project, but the operation and maintenance costs can be far larger over time. For example, the cost of sustaining sanitation services for twenty years can be 5-20 times the upfront cost of building a latrine (Burr & Fonseca, 2011).

For implementation programmes, we follow Burr & Fonseca's (2011) terminology of CAPEX (capital expenditure), OPEX (operating expenditure) CAPMANEX (capital maintenance expenditure) to think about the different types of costs. Consider a simple initial example for a borehole with hand-pump. In the BAU scenario, drilling contractors are unsupervised and drill until they hit water, stopping soon afterwards to minimise costs. In the BPEICV scenario, in contrast, supervision takes place (which increases CAPEX) and the borehole is drilled 50% deeper to reach the bottom of the aquifer, also increasing CAPEX. Under both scenarios, a drought is hypothesised in the fifth year after construction and OPEX costs (at 5% of CAPEX) are incurred every year along a ten-year time horizon.

Under the BPEICV scenario the benefits are constant. However, under BAU the drought causes groundwater levels to fall, precipitating mechanical failure of the pump. After two years (during which benefits are zero) an NGO rehabilitates the borehole and incurs CAPMANEX costs at 25% of the original CAPEX. The service and its benefits resume at the original level.

This is just a simple example to demonstrate the basic logic of costs under BAU and BPEICV programme designs. It is expanded in more detail in the Tanzania section below. For capacity development and knowledge programmes, other approaches are discussed.

3.3.3 Approach to modelling benefits

For benefits, the approach is similar to existing CBAs in DFID business cases. Two main benefits are valued: (a) the value of health benefits modelled as DALYs averted;[21] and (b) the value of time savings resulting from water supply or latrines nearer the home. Global studies suggest that these comprise the largest proportion of benefits of WASH interventions. Additional benefits, not modelled here but possible to value, include health care costs avoided and missed school days. Other benefits which are harder to value are related to increased dignity, gender equity and personal safety. The scale and pricing of these benefits present difficult methodological challenges.

The two main sources of benefits identified above are modelled as follows:

Health:

- Use WHO data on DALYS to work out (i) overall DALYs per capita, (ii) % overall DALYs due to diarrhoea.
- Apply those to the number of beneficiaries (water or sanitation) to get overall pre-intervention diarrhoea DALYs in the beneficiary population.
- Use a hypothesised % reduction in diarrhoeal disease burden due to the intervention to calculate DALYs averted – this should be based on recent health evidence (see DFID WASH evidence paper), with a 30% reduction being a useful benchmark.
- Work out the economic benefit of DALYs averted by valuing a DALY using an accepted method. 50% of GDP per capita is one useful benchmark, but there are many more ways of assigning this value not discussed here because of the focus on adaptation options.[22]

Time savings[23]

- Use an estimate of average household size to get the number of beneficiary households.

[21] DALYs are Disability-Adjusted Life Years, a measure of a year of life lost due to disease.

[22] This is an important decision since health benefits usually make up the majority of benefits under a WASH programme. The pricing choice here therefore has a big influence on the outcome. Furthermore, valuing a DALY has complex moral and ethical dimensions – essentially, we are putting a shadow price on life. The aim of estimating an annual wage to value a DALY is not uncontroversial. There is no space to discuss these issues in detail here. If the wage basis for DALY pricing is accepted, on the argument that it approximates economic value added per year, we must estimate rural wage rates (another approach is to look at the opportunity cost of reducing DALYs through different health programmes). This is no easy task, with heterogeneous informal work and significant income inequality meaning that there are few hard and fast rules. Again, to keep things simple, we use 50% of GDPPC. This can be justified by saying that in most developing countries a majority of the population works in agriculture, and a large proportion of GDP comes from that sector. Taking 100% of GDPPC may be an overestimate there may be significantly higher value added in other sectors employing lower proportions of the population, and 50% is a balanced reduction. Other values are tested in then sensitivity analysis.

[23] These are time savings due to not walking to collect water, though the same could equally be estimated for sanitation in terms of time not walking to practice open defecation (OD). Again, we try to keep things simple. It is worth noting that, in terms of climate change, increased drought may affect water travel time but not OD travel time. On the other hand, increased flooding could have a large impact on both.

- Make an assumption about pre- and post-intervention total daily water collection time per household (a conservative estimate is 40 minutes down to 20 minutes for rural areas), using the daily difference to work out hours of time saved per year.
- Calculate the value of an hour of a poor person's time, using 50% of GDP per capita divided by 365 and a twelve hour day, and multiply that by hours saved to get overall economic benefit.

As far as modelling the benefits of adaptation options in particular, the simplest approach is generally to scale the above benefits up or down depending on other assumptions, rather than attributing additional benefits. This is best explained in individual examples. However, one example could be all benefits going to zero during a period of water infrastructure down time (during which people revert to unimproved sources). On the sanitation side, raising latrines could make them more resilient during flood events, meaning that benefits are not lost or return to their original level more quickly after a flood.

3.3.4 Basic process and methodological alternatives

Building on the basic outline discussed above, our approach was therefore as follows:

- Prepare a CBA of the BAU programme scenario (i.e. DFID's current WASH programme in that country, based on outputs in the business case).
- Prepare a CBA of the BPEICV programme scenario by supplementing the BAU version with low-regrets adaptation options.
- Calculate BCRs and NPVs for each case, and compare the change in NPV (in absolute terms and as a % increase in BAU NPV) attributable to the adaptation option(s).
- Carry out sensitivity analysis, for example through using alternative values for key prices (e.g. value of DALY) and programme determinants (e.g. flood frequency). The aim is to assess whether outcomes are robust to changes in key variables.

There are different indicators of interest. The change in NPV (ΔNPV) when the adaptation options are added is useful because we are testing the implications of changes to programme design. However, knowing whether the NPV is predicted to go up by 20% under BPEICV is no more or less useful than knowing whether the BCR is 3.4 or 3.2, and both are shown in the examples below. Both relative and absolute changes in the economic performance of interventions are important and should be looked at alongside one another.

3.4 Country examples

3.4.1 Summary of country examples

Adaptation options appraised using CBA are summarised in Table 4. Two types of CBA are demonstrated:

- **BPEICV programme analysis** – comparing a BAU programme scenario to a BPEICV programme scenario including selected adaptation options. Within this, one can either
    - Start from programme outputs (e.g. Malawi example)
    - Start from programme outcomes (e.g. Sierra Leone example)
- **Discrete option analysis** – assessing a single intervention under different scenarios

The rationale for this is to demonstrate the different kinds of method that can be used to approach economic analysis of adaptation options. Different approaches require different levels of effort and data input.

Table 4: Adaptation options explored in this note

	Type of CBA	Adaptation option	Type of option
Malawi	BPEICV programme analysis	Study of groundwater levels, surface water flows, and climate variability	New intervention
		Recurrent hydro-meteorological data collection and publication	New intervention
		Catchment protection	New intervention
	Discrete option analysis	Lined and raised pit latrines	Upgrade
Sierra Leone	BPEICV programme analysis	Flood risk mapping in programme areas	New intervention
		Vaulted latrines instead of pit latrines	Upgrade
Tanzania	Discrete option analysis	Drilling boreholes to bottom of aquifer with proper supervision	Upgrade

A summary of CBA results is presented in Table 5. In all countries, and for each type of analysis, adaptation options boost the BCR compared to the BAU programme design. Moreover, the adaptation options are all predicted to increase the NPV of the programme by a significant percentage. Sensitivity analysis is undertaken in the relevant country sections below.

Table 5: Summary results for CBA

		BCR under BAU	BCR under BPEICV	% change in NPV between BAU and BPEICV
Malawi	Full BPEICV programme analysis	2.81	3.11	27%
	Discrete option analysis	2.11	2.86	23%
Sierra Leone	Simplified BPEICV programme analysis	2.34	2.73	27%
Tanzania	Discrete option analysis	1.42	1.68	69%

3.4.2 Malawi example

The Malawi water supply example is the most detailed and includes an approach for isolating additional benefits potentially related to climate change adaptation that could be replicated elsewhere. The key innovation is the incorporation of reduced water point functionality over time, using this to drive changes in the model under different scenarios. As shown in Table 6, two of the Malawi adaptation options relate to better understanding of water resources which are sensitive to changes in both weather and climate over time.

In this example, the causal chain between adaptation options and changes in benefits is quite long and complicated, but serves as a useful example for the valuation of ‘softer’ investments in water resource information and management.

Table 6: Costs of adaptation options related to DFID Malawi's programme of boreholes and piped schemes

	Rationale	Cost assumption	Cost drivers
Recurrent hydro-meteorological data collection and publication (sector level)	Poor hydro-meteorological data means little understanding of groundwater levels and river flows. This leads to poorly-planned water infrastructure and higher non-functionality. Governments often have the infrastructure but not recurrent data collection and publication are not funded	£24,300 OPEX every year, of which the majority is recurrent data collection, and the rest its publication	Based on monthly data collection at Malawi's existing network of 135 stations, including assumptions about staff time, vehicle running costs, and publication costs
Study of groundwater levels, surface water flows, and climate variability (sector level)	Benefits from the above recurrent data will only be reaped when there is an emerging time series of at least 5 years available. In the meantime, investment in a discrete sample study of groundwater levels and surface water flows could increase understanding.	One-off CAPEX of £300,000 in first year of programme	Based on a broad estimate for the cost of this kind of study
Catchment protection (project level)	Increased deforestation is causing soil erosion, leading to problems with gravity schemes due to higher run-off as the soil's water retention capacity reduces, including: (i) more extreme river highs and lows, (ii) flashier short-run river flows, (iii) silting up of intakes from soil erosion. These three factors can lead to reduced system capacity or damaged intakes.	£33,800 CAPEX per piped scheme initially (spread over 3 years of programme), and then £587 OPEX per year, with CAPMANEX of the full initial capital cost after 10 years	Based on an estimate of a 6km2 catchment for a scheme of 20,000 people, assumptions were made about the costs of public education, labour time, saplings and barbed wire.

In order to model impacts on WASH services, we must estimate potential changes in WASH programming as a result of the information. This is achieved through modelling different water point functionality scenarios.

The rationale is that improved data on water resources will result in better planning, siting and construction of rural water infrastructure. For example, if fluctuations in groundwater levels and surface water flows were better understood (both in seasonal and drought conditions), more informed siting and construction would result in lower failure rates. This implicitly links functionality with underlying water resources. Resources are, in turn, linked to climate because existing variability affects resource conditions and increasing variability and change will only amplify these effects.

Rural water supply programmes suffer from problems related to the functionality of infrastructure, which usually reduces amongst a given number of water points over time. This occurs for multiple reasons (see below). In the Malawi example, assumptions about the causes of non-functionality are used to identify specific benefits 'lost' under BAU which could be recouped under BPEICV. In addition, we have used a longer time horizon of 20 years instead of the usual 8-10 years used in DFID BC CBAs, made possible by incorporating functionality over time and OPEX. This is best explained using two graphs.

Figure 2: Percentage of water systems functional in 2006, in six districts of Tanzania, by year of construction

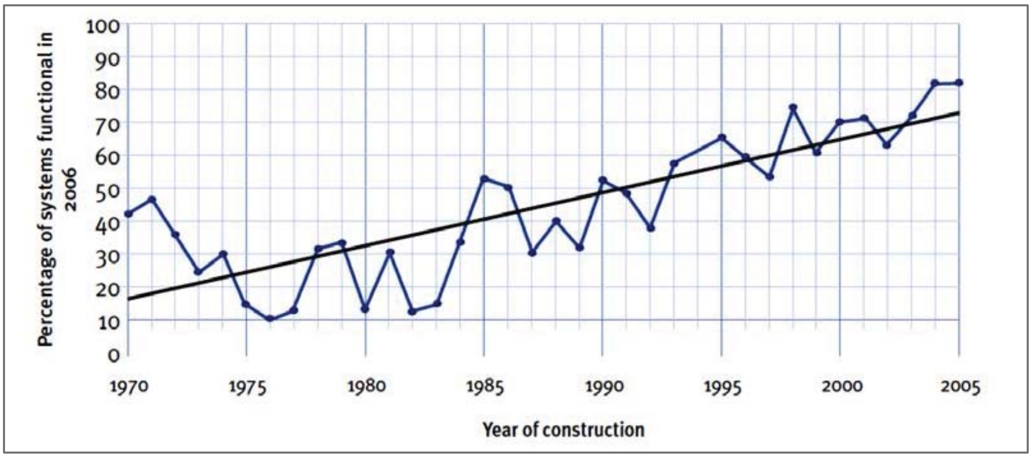
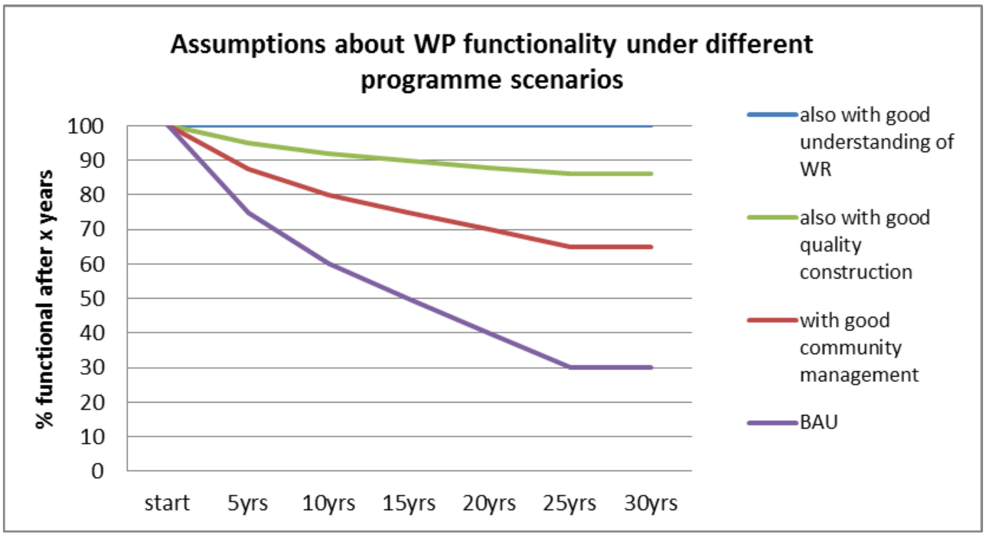


Figure 2 above is based on WaterAid data for water points in six districts of Tanzania, with year of construction on the x-axis. It represents some of the only time series data on functionality available. Using this data, the "half-life" of installed water points can be estimated, i.e. the number of years it takes for half of a set of water points to become non-functional. As highlighted in the graph above, 50% of water points constructed in 1990 were functional in 2006, meaning that the half-life of water points in these areas was about 15 years.

Data from Figure 2 above is used to produce the bottom-most line in Figure 3:- hypothesised functionality under the BAU programme design. Based on estimates of the three main causes of non-functionality in boreholes with hand-pumps, the other three curves are calculated. These are poor community management (50%), poor construction and siting (30%), and poor understanding of, and changes in, groundwater levels (20%). This distribution of causes is a simplifying assumption and was developed in consultation with the project team and other sector experts. In reality things are more complicated with water points failing for a combination of reasons, but for present (illustrative) purposes this will suffice. The main point of Figure 3 is to model how water point functionality over time might increase if the different causes of non-functionality were "solved".

Figure 3: Hypothesised functionality of water points over time under different scenarios



The innovation comes in using these assumptions to drive changes in benefits over time. We assume that as a water point becomes non-functional, the benefits resulting from the service it provides stop. OPEX costs also reduce by the same proportion as systems go out of service.

This helps us isolate the benefits of the adaptation options linked to water resource conditions. We can do this by estimating benefits related to changes in functionality between the second-most and top-most line in the graph above, i.e. the benefits that would come if the resource-related causes of source failure were reduced, in this case through better data on resources. Again, this is climate-related because climate variables affect the water resources on which water services depend. This is likely to become more pronounced with the increased variability that is projected with climate change.

For the analysis of BPEICV for the water supply interventions in the Malawi programme, there are three key options, set out in Table 7 below. The table provides brief details of costing, Full details are given in online appendices (PDFs of the spreadsheets) available on the project page of the ODI website.[24] Table 8 shows the assumptions underpinning the analysis.

Table 7: Benefits of adaptation options related to DFID Malawi's programme of boreholes and piped schemes

	Benefit assumption	time delay	multiplier effect on sector
Recurrent hydro-meteorological data collection and publication (sector level)	Re-capture half of the water resources-related benefits which were lost under BAU related to all the programme's water interventions, i.e. those benefits related to the area above the "also with good quality construction" line in Figure 6	Starts after 5 years	5x
Study of groundwater levels, surface water flows, and climate variability (sector level)	Capture 5x the benefits of recurrent monitoring	Immediate, reducing by 50% every year after 5 years (i.e. tending to zero after 10 years)	0
Catchment protection (project level)	Re-capture half of WR-related benefits lost under BAU related to the programme's piped schemes	Immediate, increasing as area above red curve increases	5x

Malawi results

Figure 4: below shows estimated BCRs for the Malawi programme under BAU and BPEICV for the base case and various other cases which form the sensitivity analysis. The different sensitivity analysis assumptions are set out in Table 8. Finally, graphs showing the flows of costs and benefits under the two programme designs are shown in Figure 5: These results are then discussed.

[24] See here - http://www.odi.org.uk/search/site?f[0]=im_field_programme%3A40&f[1]=bundle%3Aprojects

Figure 4: CBA sensitivity analysis results for Malawi

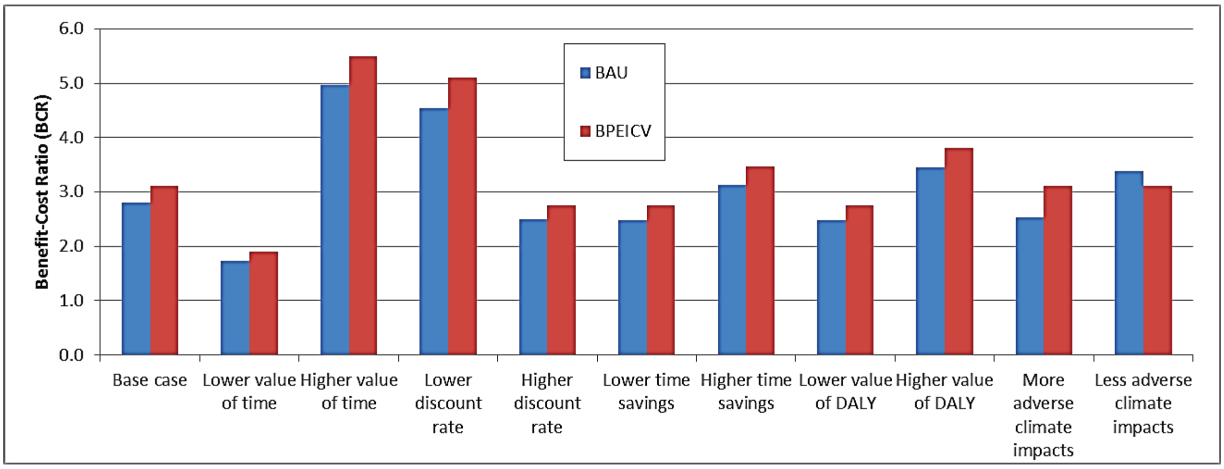
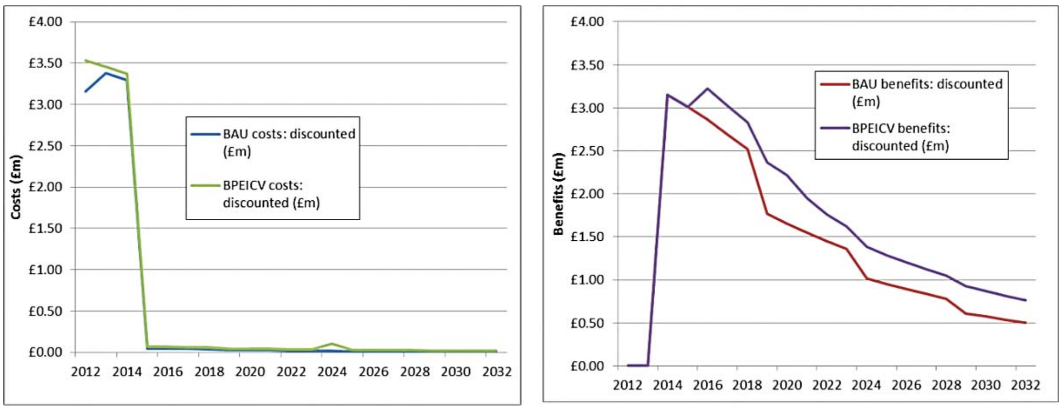


Table 8: Sensitivity analysis assumptions and results

			NPVs		BCRs	
	Base case	Sensitivity case	ΔNPV	% ΔNPV	BAU	BPEICV
Base case	n/a	n/a	£5.0	27%	2.8	3.1
Lower value of time	50% GDPPC	25% GDPPC	£2.7	36%	1.7	1.9
Higher value of time	50% GDPPC	100% GDPPC	£9.5	23%	5.0	5.5
Lower discount rate	10%	3%	£11.6	29%	4.5	5.1
Higher discount rate	10%	12%	£4.0	26%	2.5	2.8
Lower time savings	40mins to 20mins	40mins to 30 mins	£4.3	28%	2.5	2.8
Higher time savings	40mins to 20mins	40 mins to 10 mins	£5.6	26%	3.1	3.5
Lower value of DALY	50% GDPPC	25% GDPPC	£4.3	28%	2.5	2.8
Higher value of DALY	50% GDPPC	100% GDPPC	£6.3	25%	3.4	3.8
More adverse climate impacts	n/a	BAU benefits decrease by 10%	£7.8	50%	2.53	3.11
Less adverse climate impacts	n/a	BAU benefits same as CCA	-£0.9	-4%	3.38	3.11

Figure 5: Graphs demonstrating discounted costs and benefits under the BAU and BPEICV designs



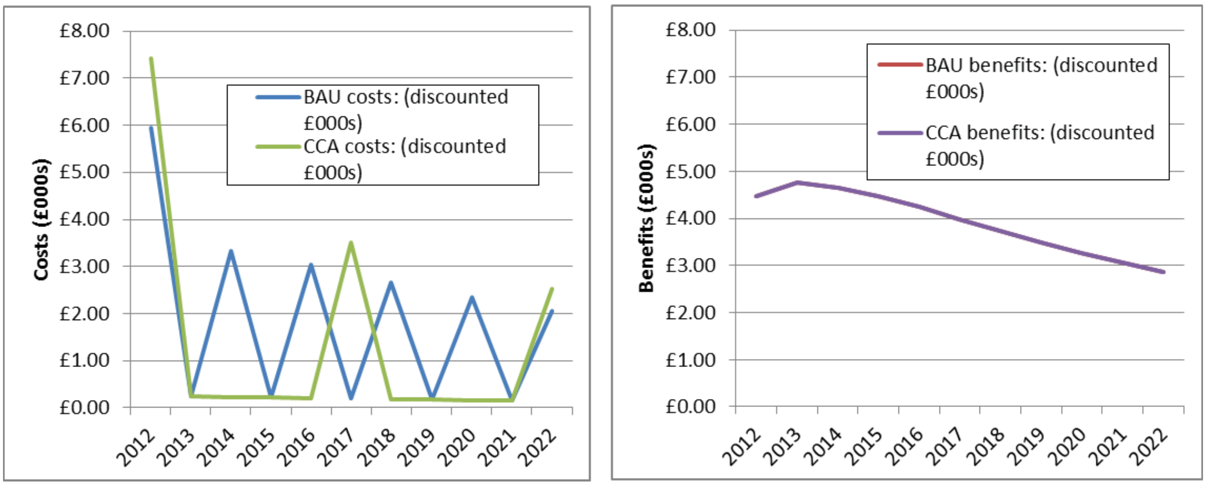
As can be seen from the graph of BCR (Figure 4), the BPEICV programme design consistently performs better than the BAU programme design, except in the case of less adverse climate impacts. However, in all cases the difference is similar and quite small. This is due to the fact that the focus is on low regrets adaptation options, and also that the same assumptions drive benefits in both BAU and BPEICV. Therefore, the gap between the two is often similar. This is not to say that high regrets options would not perform better if a broader range of climate scenarios were considered, but the aim here is to keep things simple.

The graphs in Figure 5 illustrate more clearly where the differences between BAU and BPEICV come from in the base case. BPEICV costs (see left-hand graph) are initially higher due to the additional expenditure on the adaptation options. Furthermore, there is another rise in BPEICV costs in 2024 due to the full assumed CAPMANEX of the catchment protection costs ten years after the project (as described in Table 5 above). In terms of benefits (see right-hand graph), consistently higher benefits are seen under BPEICV soon after project completion. This is mainly due to benefits from higher water point functionality following implementation of the adaptation options.

Malawi sanitation results

For the Malawi sanitation example, only the graphs of discounted costs and benefits are shown, for clarity (0). As can be seen, this analysis is simpler because identical benefits are assumed in BAU and BPEICV. The main thing driving the differences in the results is assumptions about flood damage. This is assumed to be a flood-prone area and, under BAU, unlined latrines collapse every two years during flooding. Some materials are salvaged and the latrine is immediately rebuilt, retaining the same benefits, at a cost of 50% of the original CAPEX. This explains the increase every two years in the BAU costs line. Under BPEICV, latrines are built with a brick lining and raised on a mound so the pit is higher above ground, at a cost 22% higher than under BAU (see CCA costs line in year of original construction). This adaptation option results in the latrine collapsing only in larger floods every five years, where the latrine is again rebuilt at 50% of original CAPEX (see uptick in green line). This demonstrates a different, and perhaps simpler, way of thinking about adaptation options, i.e. a way to maintain constant benefits, but at different initial and ongoing costs. A more detailed analysis would look at the impact of flooding on the benefits as well, but in this case it serves to demonstrate one simple methodological option.

Figure 6: Charts showing costs and benefits of sanitation interventions under BAU and BPEICV



3.4.3 Sierra Leone example

The Sierra Leone example, like the Malawi water example, is programme based but it takes programme outcomes as its starting point rather than outputs. The full costs of the WASH service delivery component of DFID's support to the Freetown Urban WASH Consortium (FUWC) are calculated, along with an attributable portion of non-programme costs (such as salaries and office space). Benefits are calculated based on the numbers of beneficiaries in the programme, and comprise health benefits and time savings discussed above. For the BPEICV programme design, two adaptation options are proposed, for which the assumptions are set out in the tables below.

To drive the differences in the model, it is assumed that significant floods take place every five years in the informal settlements where the programme is situated. As can be seen from Table 9 below, it is assumed that under BAU flood damage is severe and most benefits from the interventions are lost, but are slowly recouped (because of time taken to regain assets and rebuild infrastructure), returning to 100% after three years. Under BPEICV, the flood risk mapping and improved latrine design are assumed to mean that flood damage is less severe and systems return to delivering full benefits after two years instead of three.[25] In addition, the necessary CAPMANEX after the flood is assumed to be 30% of original CAPEX under BAU but 15% under BPEICV, due to lower damage.

Table 9: Assumptions about benefits lost due to flood damage in Sierra Leone

	F	F+1	F+2	F+3
BAU	30%	50%	75%	100%
BPEICCV	60%	80%	100%	100%

Table 10: Costs of adaptation options in Sierra Leone

	Rationale	Cost assumption	Cost drivers
Flood risk mapping in programme areas (programme level)	During rainy season, flooding is common in the slum areas of Freetown. Better understanding of flood risk could reduce the risk of damage to water supply infrastructure	£75,000 for a discrete flood risk study in programme areas	Based on a broad estimate for the cost of this kind of study at programme level. Cost could be adjusted based on assumptions about its scale and level of detail
Latrine with small vault instead of pit, above ground for regular emptying (project level)	Flooding also affects sanitation infrastructure. Moving to an above-ground small vault latrine design would reduce damage to latrines during flooding. It would also facilitate more regular emptying and therefore a better market for faecal sludge management	30% mark-up on the Freetown Urban WASH consortium's budget for communal pit latrines	Basic estimate of a mark-up on existing technology option, to account for additional materials needed

[25] If extended, this analysis could include fully "flood-proof" latrines that survive all predicted flood events, in order to evaluate whether they are worth the additional expense

Table 11: Benefits of adaptation options in Sierra Leone

	Benefit assumption	time delay	multiplier effect on sector
Flood risk mapping in programme areas (programme level)	Benefits are still reduced after the 5-year flood event, but not to the same scale as under BAU, and benefits return to original levels faster. CAPMANEX required after flooding is lower under BPEICV	Benefits return to original levels 2 years after the flood instead of 3 years	0
Latrine with small vault instead of pit, above ground for regular emptying (project level)	As above	As above	0

Sierra Leone results

Figures 7 and 8 below shows estimated BCRs and the streams of costs and benefits. Since the sensitivity analysis assumptions were similar, that table is not repeated.

As with Malawi, we see that the BPEICV programme design generally performs better under sensitivity analysis. The differences in costs and benefits are explained by the assumptions in the tables above. Initial programme costs under BPEICV (green line) are higher due to the adaptation options. However, lower costs for rehabilitation are seen under BPEICV (due to the assumptions about CAPMANEX described above). On the benefits side, the red line in the right-hand graph spikes lower after flood events, indicating that a higher proportion of benefits are lost, and recovery takes longer. These are all hypothetical examples, of course, which illustrate the kind of things one might expect no or low-regrets adaptation options to address.

Figure 7: CBA sensitivity analysis results for Sierra Leone

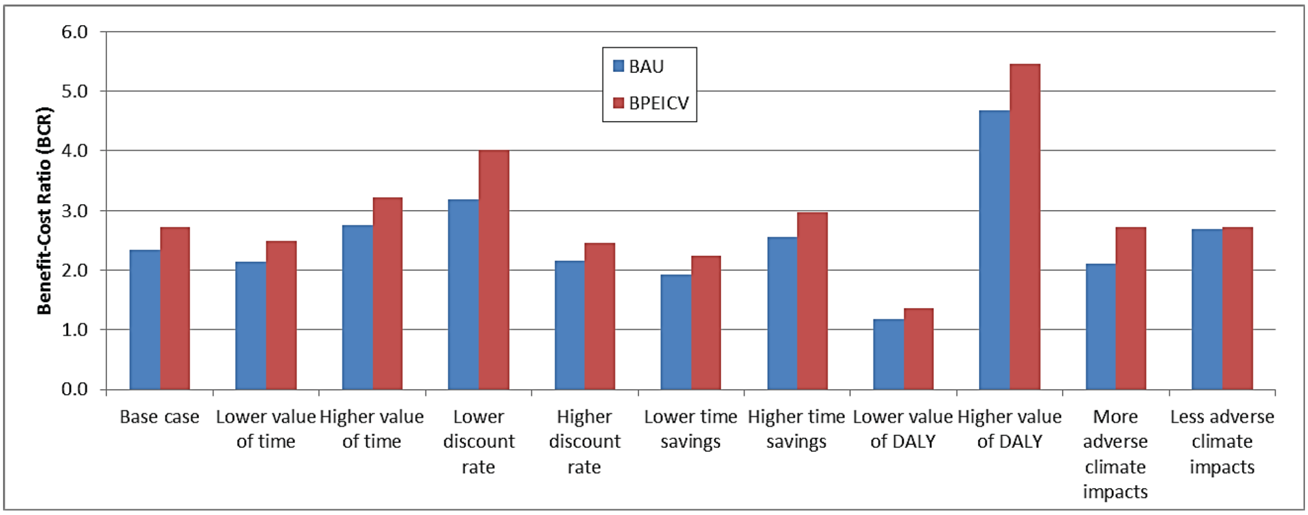
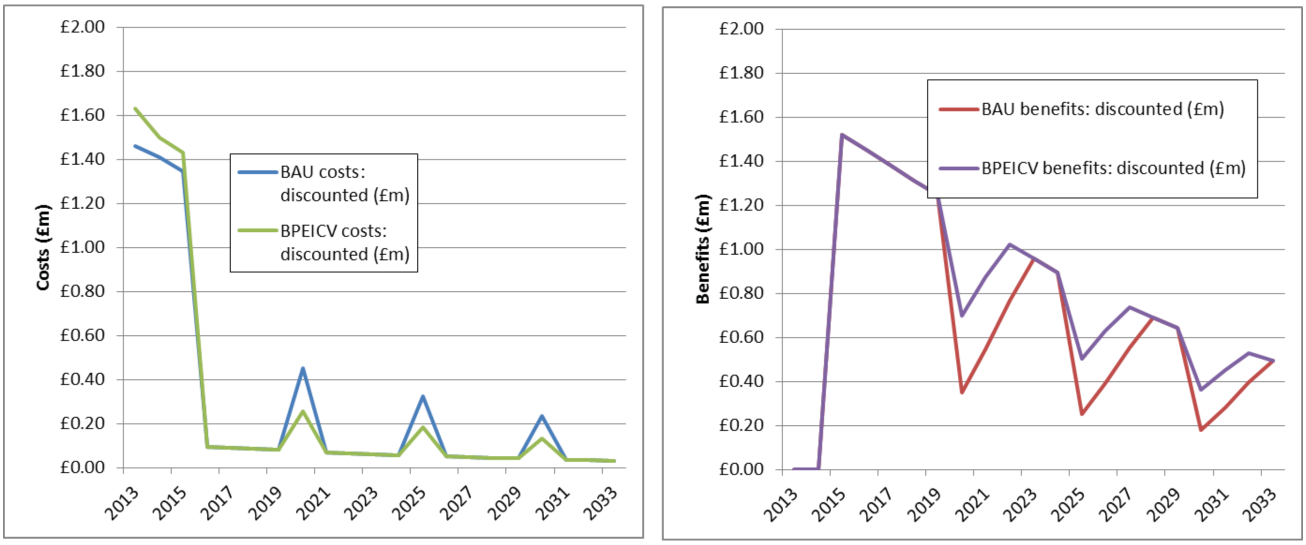


Figure 8: Graphs demonstrating discounted costs and benefits under the BAU and BPEICV designs for Sierra Leone



3.4.4 Tanzania example

For Tanzania, a discrete adaptation option is analysed on its own rather than as part of a programme. In this case the intervention is drilling boreholes to a greater depth, with adequate supervision to ensure contractor compliance.

Table 12: Costs of adaptation options in Tanzania

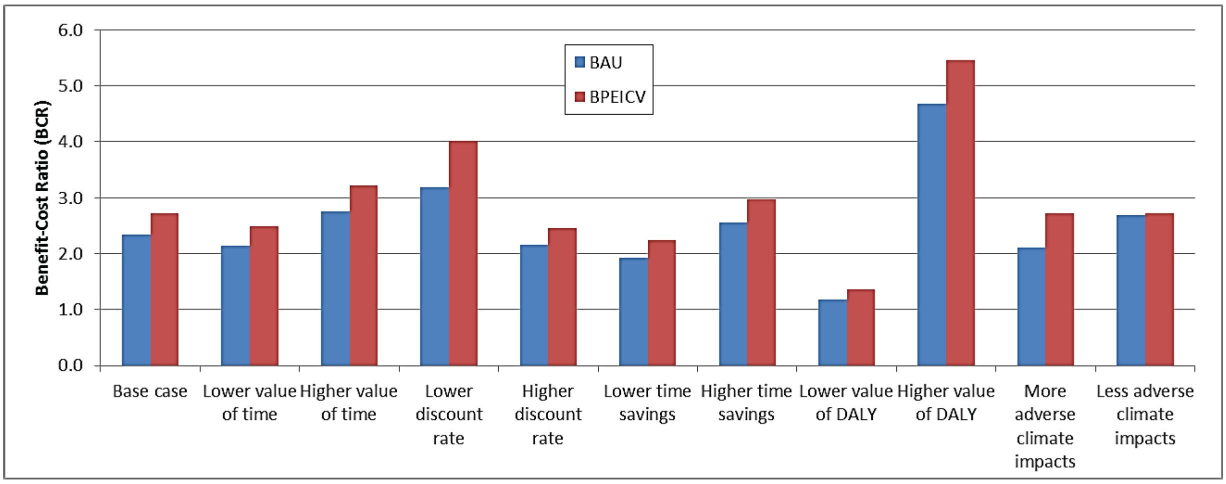
	Rationale	Cost assumption	Cost drivers
Drilling boreholes to bottom of aquifer with proper supervision	Many boreholes drilled only until the contractor strikes water or soon after. If groundwater levels fall during a drought, the borehole may stop producing water and fall out of use. Better supervision of contractors, and changes to contract design to alter incentives, could ensure that drilling continues to the bottom of the aquifer.	Drilling 25% deeper (e.g. to 50m instead of 40m) increases drilling costs by 12.5%. Proper supervision costs about £300 per borehole	Costs of deeper drilling based on WASHCost data for Burkina Faso; costs of supervision based on UNICEF Bills of Quantities for Malawi

Table 13: Benefits of adaptation options in Tanzania

	Benefit assumption	time delay	multiplier effect on sector
Drilling boreholes to bottom of aquifer with proper supervision	Under BAU the borehole is assumed to fall into disrepair during a drought event after 3 years. This reduces benefits to zero for 2 years, and then the hand-pump is replaced at a 25% CAPMANEX cost. Under BPEICV however, the benefits remain the same.	n/a	n/a

The figures below show estimated BCRs and the streams of costs and benefits. The differences in costs are explained by the assumptions in the tables above. The borehole is assumed to be out of use for two years, hence zero OPEX costs for those years. However, the CAPMANEX causes a spike in costs under BAU in 2017. During the down time, benefits are reduced to zero (see lower line).

Figure 9: CBA sensitivity analysis results for Tanzania[26]



[26] Full details of the different sensitivity cases are given in the Malawi section below

Figure 10: Discounted costs and benefits under the BAU and BPEICV designs for Tanzania

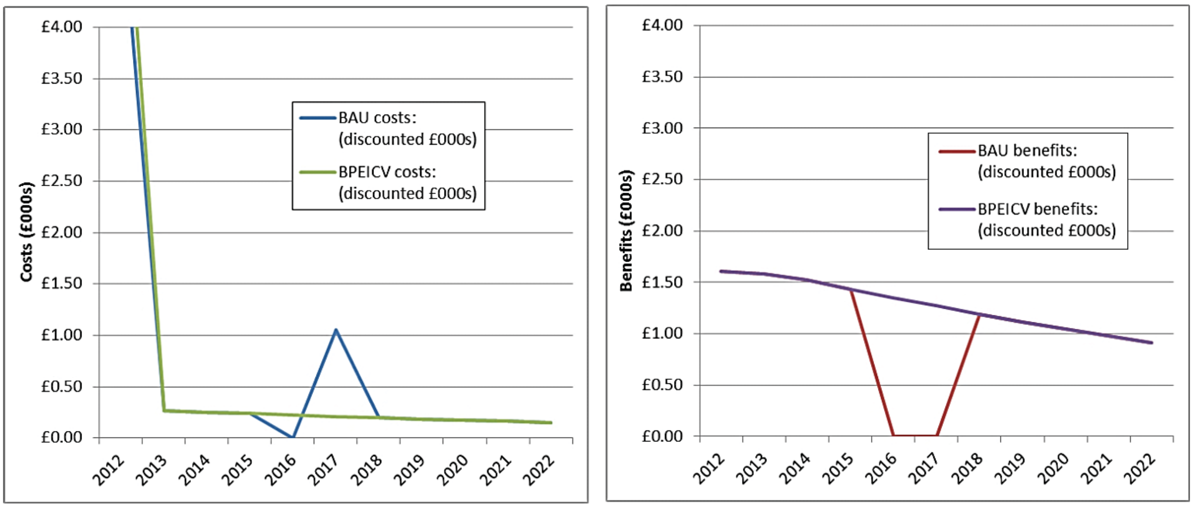
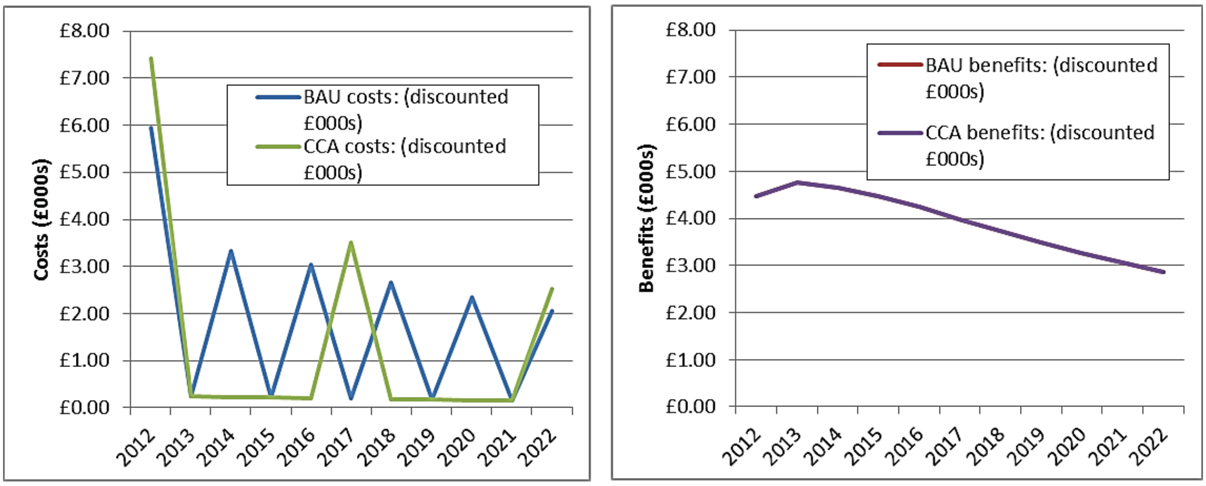


Figure 11: Charts showing costs and benefits of sanitation interventions under BAU and BPEICV



3.5 Discussion of overall results

This section aims to give an introduction to the kinds of analysis that can be used to appraise adaptation options in economic terms. As noted above, CBA could be supplemented by additional sensitivity and robustness methods for analysing the implications of climate change, but it was used here for coherence with existing DFID approaches to project appraisal. At present only a few DFID business cases use CBA.

The analysis could be useful for mainstreaming climate finance, such as increasing thinking around existing programmes to take climate variability into account. Findings suggest that fairly modest additional costs at the start of the programme could lead to better performance and greater resilience overall.

There are many different ways of approaching this problem even within CBA. We have demonstrated a few of these, namely full BPEICV programme analysis starting from outputs, the same starting from outcomes, or analysis of discrete options on their own. Furthermore, one can simplify the analysis by letting benefits be constant and looking at what happens to costs under different scenarios. In general, however, allowing both costs and benefits to vary is preferred as it is more realistic.

There are three key points worth highlighting from the results. Firstly, time horizons and discount rates matter in economic analysis. The Malawi water and Sierra Leone examples adopted a twenty year time horizon, which is longer than most DFID business cases (those reviewed used an 8-10 year horizon). Typically, DFID business cases also use a 10% discount rate.[27] This makes quite a big difference to future costs and benefits, as can be seen for Sierra Leone, where the benefits lines incline sharply downward. In infrastructure development, while ongoing OPEX and CAPMANEX are important, it is the immediate CAPEX which is the largest component of costs. This takes place in the undiscounted present, not the future. Extending these time horizons beyond twenty years, perhaps to thirty or forty would require serious thought, due to the various CAPMANEX events that would be necessary to ensure a permanent service. Simply extending the analysis forward as is would not be sufficient. The WaterAid Tanzania data shown in Figure 5 suggests that historically, most infrastructure has been almost *completely* defunct after twenty years.

Secondly, assumptions matter. This is a fact of economic analysis in general. We simplify the world in order to model and understand it. Assumptions must be justified. This is something that there has not always been space to do within this chapter. Our more detailed annexes available on the ODI website give a lot more detail on where the assumptions have come from, especially for costs. On the benefits side (particularly the assumptions about flood events, system failures etc.) many of these assumptions simply come from expert judgement. In the absence of hard data for many of these phenomena, this is the only possible source of information. The best way to deal with potential biases in this area is to convene an expert group and come to a consensus decision. There may be better ways to model the scenarios than we have done. For example, rather than modelling constant benefits and regular CAPMANEX, it might be more realistic to think about infrastructure lying dormant for a few years, or even indefinitely. We welcome feedback from interested stakeholders on how to improve these approaches.

Thirdly, our tentative findings suggest that no- or low-regrets adaptation options are a good way forward for the WASH sector. This does of course assume that programme designers know what these might be, but here the risk screening approach can help. However, few sector specialists would argue with the need for better supervision of drilling contractors, or much better hydrometric monitoring. The problem is finding the necessary finance and capacity to deliver them.[28] This was our reason for drawing a comparison between BAU and BCEICV. This may make it harder to identify the specific "additional" climate *change* related factors, but in all of these countries, variability is already causing problems and is expected to increase.

We have dealt with the additionality question to the extent that is possible while trying to keep things simple and practical, given that the audience for this work is DFID country offices and implementing partners. Many of these stakeholders do not have access to economic modelling skills within their immediate teams. In all the cases above, the adaptation options perform even better relative to BAU if more significant adverse events are modelled, as demonstrated by the (admittedly simple) sensitivity analysis.

Our most detailed illustration is developed from the DFID Malawi business case. In this example, we used modelling of water scheme functionality to identify the key part of

[27] The Green Book specifies a rate of 3.5% for UK projects, but on p.99, it states "For international development assistance projects, a discount rate derived from estimates of the social time preference rate appropriate to the recipient economy should be used." (HM Treasury, 2003)

[28] One further role for CBA is to explore how incremental expenditure on adaptation options could give better returns than simply increasing the scale of existing WASH programmes.

potential benefits that were water resource related, and therefore most vulnerable to climate change. This allows specific benefits from interventions beyond BAU to be isolated. This represents a significant innovation in the economic analysis of WASH interventions taking into account climate change. In future examples such as this can be explored further, using alternatives to conventional CBA where appropriate.

4 Conclusions and next steps

The rapid increase in awareness and concern about climate change is feeding through into sector-specific analyses of impacts and guidance on adaptation and resilience. Despite the proliferation of toolkits and decision-support systems, however, remarkably little has been written on the practical substance of adaptation. In the WASH sector, Vision 2030 (Howard & Bartram, 2010) is one of the few studies to have addressed both the types of risks posed by climate change, and what can be done to mitigate them. This report has attempted to fill a slightly different, programme design gap: how to identify key risks at a programme level by looking at climate change alongside other pressures, and how to then identify and appraise adaptation options using CBA.

A key conclusion is that adaptation should start with the measures that tackle the weather risks that countries already face, since climate change will exacerbate these risks. A key argument is that many of these measures, such as improved siting and construction of water points, or changes in latrine design, are relatively simple, if capacity exists to implement. A focus on vulnerability rather than prediction is also pragmatic given present uncertainties with climate projections, particularly for rainfall, and difficulties in translating rainfall projections through hydrological systems to impacts on the ground.

A number of relatively straightforward measures that could increase the resilience of services were identified during country consultations in Malawi, Sierra Leone and Tanzania. These emerged from discussion around the risk screening approach developed by the project with sector stakeholders from government, donors and NGOs. In addition, some more complex and longer-term priorities emerged, including catchment and water resources management, and investment in underpinning monitoring systems. Indeed one of the core priorities identified in each country consultation was the need for better water resources assessment and management at both national and watershed scales.

The report illustrates how CBA can be used to compare costs and benefits under different assumptions around likely benefit streams from health and time saving gains, using a mix of primary and secondary data. The value of CBA lies in its ability to provide a more secure and transparent basis for programme decision-making, narrowing the field for pure judgement. As noted in Section 3, however, robust CBA requires robust data on what would happen to WASH results 'with' and 'without' adaptation.

Given the time limitations on the current project, we provide only a preliminary set of CBA examples that could be improved considerably with better data and sensitivity analyses. Nonetheless, our tentative findings suggests that some relatively simple step changes in programme planning, design and construction could realise positive returns, even over the near-term (10-20 years), and despite higher upfront costs. In the CBA illustrations provided, the positive BCRs emerge from a comparison of 'business as usual' programme design with 'best practice (options) under existing and increasing climate variability'. The comparison is a potentially useful one in broader policy terms as it helps define, and place a monetary value on, 'additionality'. That is, the investment needed over and above normal development assistance to help countries tackle climate change in the WASH sector.

What needs to be done to develop these approaches to risk and economic assessment further? There are three main priorities:

1. The risk screening approach presented and applied in this report could be developed further for individual WASH sub-sectors along the lines of WSP's Country Status Overview. As it stands, the national and programme-level assessments consider all elements of WASH together in a 'one-shot' exercise that can be conducted fairly rapidly by a small team. An obvious development would be to provide a breakdown between rural water supply, urban water supply, rural sanitation and urban sanitation, accepting the fact that there will overlaps. The sub-sector breakdown could replace or supplement Step 2 – the programme level assessment.
2. The economic analysis could be strengthened and extended in a number of ways. Maintaining the focus on relatively simple adaptation options such as those described here, the aim would be to develop some specific (ground-truthed) infrastructure damage/service failure functions linking climate hazards with areas/people affected and costs incurred. Future investment scenarios, with and without adaptation options, could then be prepared and tested using different frequencies of extremes, or increasing the damage function to represent more intense events in future. Additional sensitivity analysis could then explore the circumstances in which upfront investment in more 'climate-proof ' WASH infrastructure might be justified, compared with periodic repair or rehabilitation of less robust, lower cost systems.
3. While attempting to broaden the adaptation discussion in this report beyond the merely technical, we recognise that the risks and options identified are far from comprehensive. For example, the report does not discuss the risks posed by sea level rise in coastal areas and the impacts this could have on WASH services. It does not cover bigger infrastructure investments in water storage, treatment and conveyance. And it does not discuss the indirect impacts of climate change on resources, infrastructure, demand for services or access to those services. These topics are worthy of further attention.

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Appendix A – Vision 2030 Update: Key Literature

This appendix provides an annotated bibliography of work focusing explicitly on climate change adaptation and WASH in Africa since 2009.

A1: Ten prominent, general publications on climate change adaptation and WASH

This section cites 10 prominent pieces of general literature on climate change adaptation and WASH (CCA & WASH) since 2009. We define 'prominent' here to mean literature published by global influencers: UN agencies, development banks, governments, donors and large NGOs. Note that prominent literature specifically on Africa is cited in the sections below. This review was undertaken using Google Scholar and Search.

Adaptation of WASH services delivery to climate change, and other sources of risk and uncertainty

Batchelor et al., 2011, IRC

Summary

This report discusses how WASH professionals can integrate the need for climate adaptation into their ongoing work. It recommends WASH professionals to treat climate change as one of many sources of risk and uncertainty, that there is no single strategy for adaptation, and that effective adaptation will almost always require improvements in general WASH governance as well, particularly to strengthen planning processes. It outlines a practical approach for managing risk and uncertainty by: identifying WASH governance issues for potential 'hot spots', visioning and scenario building, and preparing and implementing plans. It also overviews a variety of tools for identifying, prioritising and managing risk and uncertainty.

Climate change and WASH services delivery – is improved WASH governance the key to effective mitigation and adaptation?

Batchelor et al., 2009, IRC

Summary

This paper discusses the nature and scope of possible climate impacts on WASH services delivery in developing countries. It first reviews the current state of knowledge on climate change and water, then discusses the potential impacts of climate change on WASH services, and then discusses how the WASH sector could prepare for these impacts. It gives four recommendations in this regard: improving WASH governance systems, adopting and implementing IWRM, adopting principles of adaptive management and strengthening sector capacity. It underscores that a focus on improving general WASH governance and decision-making processes to take explicit account of risk and uncertainty is better for the sector's resilience than separate and additional adaptation interventions.

How to integrate climate change adaptation into national-level policy and planning in the water sector: a practical guide for developing country governments
Venton, 2010, Tearfund

Summary
This guide discusses an approach to integrating CCA into the water sector in developing countries. In incorporates four main tasks: 1) establish an understanding of climate change risk and key actors, 2) strengthen national policy frameworks, 3) develop and implement a climate-resilient action plan for the water sector, and 4) track performance, adjust to changes and make improvements. It is targeted at national government stakeholders, particularly water ministries. For each task, it provides justification, a suggested approach, a list of stakeholders to involve and other key considerations.

Guidance on water supply and sanitation in extreme weather events
Sinisi and Aertgeerts, 2010, UNECE and WHO

Summary
This guide aims to provide an overview on why and how adaptation policies should consider the new vulnerabilities and risks for health and the environment which arise from water and sanitation in adverse weather events. Its eight chapters focus on: extreme weather events for water and sanitation in Europe; basic disaster preparedness and early warning; communication in extreme weather events; vulnerability of coastal areas and bathing waters in extreme weather events; impacts of climate change and extreme events on waterborne diseases and human health; water safety plans as an approach for managing extreme weather risks; adaptation measures for water supply utilities in extreme weather events; and adaptation measures for drainage, sewerage and wastewater treatment operations. While the focus is Europe, its advice is broadly applicable.

Climate change and urban water utilities: challenges and opportunities
Danilenko et al., 2010, WSP World Bank

Summary
This report assesses climate vulnerability and adaptation on urban water utilities. It highlights that climate impacts are increasingly important to the design of infrastructure investment programmes, but that its variability and uncertainty challenge water utilities in their daily operations and planning, especially since they are dealing with a wide variety of other challenges already. Thus, their adaptation measures taken to date have often been ad hoc, with a need to address vulnerability more systematically. It highlights that knowledge sharing and twinning between utilities can help formulate more strategic responses, while adopting integrated urban water management can help utilities better consider the interactions between water resources, infrastructure, operations and planning.

Water and climate change: impacts on groundwater resources and adaptation options
Clifton et al., 2010, World Bank

Summary
This report discusses climate impacts and adaptations for groundwater supply and management, emphasising the lack of attention paid to this topic. It first discusses these impacts on groundwater recharge, discharge, storage and quality, then focuses on its implications for water supply for communities, agriculture and ecosystems. It then discusses adaptation options for groundwater systems and how to build adaptive capacity and avoid maladaptation. It highlights that adaptations to reduce the vulnerability of groundwater systems to climate pressures are often the same as those needed to address non-climate pressures, such as overuse.

Technologies for climate change adaptation: the water sector
Elliott et al., 2011, UNEP and UNC Water Institute

Summary
This report reviews 11 adaptation technologies and practices for use in the water sector, discussing their appropriateness for different situations and how to incorporate them into other activities. It discusses the following topics for each technology/practice: basic description; contribution to climate change and development; institutional and capacity building requirements; costs, barriers and opportunities for implementation; and links to external resources and case studies. The 11 items reviewed are: boreholes/tubewells for domestic water supply during drought; desalination; household drinking water treatment and safe storage; improving the resilience of protected wells to flooding; increasing the use of water-efficient fixtures and appliances; leakage management, detection and repair in piped systems; post-construction support for community-managed water supplies; rainwater collection from ground surfaces – small reservoirs and micro-catchments; rainwater harvesting from rooftops; water reclamation and reuse; and water safety plans.

Adapting urban water systems to climate change: a handbook for decision makers at the local level
Loftus, 2011, ICLEI

Summary
This handbook is targeted at city governments and water utilities and aims to enable them to increase their awareness of how the potential impacts of climate change will affect their urban water systems and to build their capacity to develop a long-term strategy for adaptation. It first outlines the vulnerability of urban water systems to climate change, both on scientific and social / institutional dimensions, then presents a strategic planning framework for adaptation, along with case studies from ICLEI member cities.

Adaptation strategies guide for water utilities
USEPA, 2012

Summary
This guidebook was prepared by the US EPA to assist drinking water and wastewater utility owners in understanding and addressing climate change risks. It provides a glossary of adaptation options and worksheets for adaptation planning, giving topic briefs for the various types of climate challenges: droughts, water quality degradation, floods, ecosystem changes, and changes to service demand and use. It provides tailored advice for both drinking water utilities and wastewater utilities. Although it was written for the US context, its lessons and best practices are widely applicable.

Climate change adaptation: the pivotal role of water
UN-Water Policy Brief, 2010

Summary
This brief reviews climate impacts and the link between WRM and climate change, though is not specific to Africa. It then discusses climate adaptation from the perspective of water and gives several guiding principles for adaptation and water resilience: mainstreaming adaptation in the broader development context; strengthening water governance and the integration of land and water management; improving and sharing knowledge and information; building long-term resilience; cost-effective, adaptive water management and technology transfer; and additional and innovative funding. It also cites Vision 2030 when discussing that water services are often not climate resilient and that systematic assessments of this degree of existing resilience is needed.

A2: Vision 2030 citations in literature
This section cites relevant literature on CCA & WASH in Africa that directly cited Vision 2030 (either the report itself or the related journal article). A brief summary of each is

included. This is not an exhaustive list of every article that cited Vision 2030, as there were several articles that cited the study, but whose content was not related to CCA & WASH or was focused on regions other than Africa – these were not included here. This review was undertaken primarily using internet search engines (Google Scholar, Google Search) and academic databases from Bristol University and Cranfield University. Google Scholar's citation tracking function was used for the Vision 2030 journal article, and the titles of both the report and journal article were searched in these databases.

How to climate proof water and sanitation services in the peri-urban areas in Lusaka

Heath et al., 2010, WSUP, Cranfield University

Summary

This report evaluates the impacts of climate change on water and sanitation technologies in two areas in Lusaka, Zambia; one which is predicted to experience a decrease in precipitation, the other an increase. Potential short, medium and long term adaptations are identified. Vision 2030 is cited as the key document used to inform the report. Though a field visit with interviews, focus groups, and a location-specific vulnerability assessment was undertaken, both the vulnerabilities of technologies and the recommended adaptations are taken directly from Vision 2030.

How to climate proof water and sanitation services for the urban poor

Heath et al., 2010, WSUP, Cranfield University

Summary

This report evaluates the impacts of climate change on water and sanitation services, with Lusaka, Naivasha and Antananarivo as case studies. It focuses particularly on climate impacts on low-income urban communities, and then reviews potential adaptation responses, including sources of funding. It cites Vision 2030 extensively, reviewing its findings on WASH sector climate vulnerability and resilience and making use of its vulnerability assessment methods for its three case studies.

Testing a rapid climate change adaptation assessment for water and sanitation providers in informal settlements in three cities in sub-Saharan Africa

Heath et al., 2012, Environment and Urbanization

Summary

This paper presents a Rapid Climate Adaptation Assessment (RCAA) for water and sanitation providers that generates recommendations on climate proofing for local service providers, utilities and local governments. The RCAA converts regional climate predictions into recommendations for local adaptations. The methodology used was developed in Lusaka, Zambia (see aforementioned report also by Heath et al.) then trialled in two other case study cities: Naivasha, in Kenya and Antananarivo, in Madagascar. Vision 2030 is cited as one of the few studies available on water and sanitation for the urban poor, along with CRiSTAL methodology and the USAID methodologies, though this is followed by some critique: "*Vision 2030 gives a comprehensive overview of the resilience of water and sanitation technologies but lacks information on replication or assessing vulnerability. The other methodologies overview community vulnerability and adaptation but lack a water or sanitation focus. To fill the gap, this paper presents a Rapid Climate Adaptation Assessment (RCAA), developed specifically for water and sanitation supply for the urban poor.*" So this report is trying to improve on Vision 2030 by offering a more location-specific approach.

Integrating human health into wetland management for the Inner Niger Delta, Mali

Cools et al., 2012, Environ. Sci. Policy

Summary

This paper presents a methodology and framework to integrate human health risks and opportunities into assessing the appropriateness of wetland management options, particularly in a data-poor context. The feasibility of different management options are assessed, and are scored using the concept of adaptive capacity, considering four criteria: affordability, organisational capacity, cooperation and robustness. The paper references a finding from Vision 2030 that '*very few technologies and management systems for drinking water supply and sanitation services are resilient to climate change*', and goes on to say this will result in increased challenges faced in wetland cities in developing countries. This is the only reference to Vision 2030, although climate change is discussed again a number of times. One of the indicators in the framework for assessing wetland management options is 'robustness to flow variability', with flow variability being a result of climate change (among other factors). So climate change and its effect on adaptability of WASH services and management has been considered, though indirectly.

Financing Water Quality Management

Kauffmann, 2011, Organisation for Economic Co-operation and Development (OECD)

Summary

This paper examines the recent trends in the development of wastewater infrastructure and discusses the investment needs and potential sources of funding, though is not specific to Africa. Overall the paper is primarily concerned with the financial implications of future WASH implementations. The paper references a finding from Vision 2030 that '*few water and sanitation technologies are resilient to climate change, but those that are need to be prioritized in future investment*'. This is the only reference to Vision 2030. A number of other papers related to climate change are referred to. The year 2030 is used as a point of reference throughout the paper, as in Vision 2030.

Global health and environmental change: linking research and policy

Kovats and Butler, 2012, Current Opinion in Environmental Sustainability

Summary

The paper discusses linkages between human health and policies to address environmental change, and the additional burden that climate change will cause on global health strategies, though is not specific to Africa. The paper contains a short section on 'Water for Health', which reproduces statistics and information from other references. This includes a quote from Vision 2030, '*though climate change represents a significant threat to sustainable drinking-water and sanitation services… climate change may be a driver for improvements that have been insufficiently delivered to date*'.

Climate change, water resources and WASH: a scoping study

Calow et al., 2011, ODI/BGS Working Paper

Summary

The paper focuses on the links between climate change impacts and adaptation for WASH and WRM, though not specifically for Africa. It overviews global and regional climate scenarios, discusses potential impacts on WASH and WRM and assesses operational responses for pro-poor adaptation planning for WASH and WRM. It professes to build on the work of Vision 2030 by looking at the climate resilience of different WASH technologies.

Achieving water security: lessons from research in water supply, sanitation and hygiene in Ethiopia

Calow et al., 2013, Practical Action Publishing

Summary

This book summarises the findings from the DFID RiPPLE programme in Ethiopia. It includes chapters on: Ethiopia's water resources, policies and institutions; WASH sector monitoring; Multiple-use water services; Rural sanitation and hygiene promotion; Water service sustainability; Water for livelihoods; Implications of climate variability and change for planned adaptation; and Critical reflections. It mentions Vision 2030 in several locations, as a source of evidence for the climate-water sector relationship.

Water, sanitation and hygiene: the missing link with agriculture

Tsegai et al., 2013, ZEF Working Paper

Summary

This paper reviews the link between WASH and agriculture, though is not specific to Africa. It discusses the impacts, priorities, advances and challenges in the WASH sector, then links argues for the recognition of a 'WASH-agriculture nexus'. Within this nexus, it overviews the impacts of irrigated agriculture on health and how to better integrate WASH and agriculture. It cites Vision 2030 when discussing water supply and health links, and when discussing the place of climate change within this nexus.

Climate change and the human rights to water and sanitation

UN OHCHR Position Paper, 2010

Summary

This paper discusses how to design and implement climate change policy responses to respect the legal obligations surrounding the human right to water and sanitation, though is not specific to Africa. It overviews climate impacts on water availability, quality, accessibility, affordability and acceptability, and then gives recommendations based on the restrictions and opportunities offered by the human rights framework. It cites Vision 2030 when reviewing climate impacts on WASH infrastructure.

Resilient techniques to improve water availability, with a focus on drought-prone areas

Fewster, 2010

Summary

This report explores the current body of knowledge on resilient techniques in water supply where water availability is limited, particularly in drought-prone areas, though is not specific to Africa. It then prepares a technical basis for the evaluation of WASH projects developed in areas potentially exposed to drought. It cites Vision 2030 several times, both its technology fact sheets and the broader report, when discussing resilient water supply technologies.

Addressing climate change impacts on infrastructure: preparing for change

USAID, 2013

Summary

This report discusses climate impacts and adaptations on a variety on infrastructure sectors, including potable water systems and sanitation systems, though is not specific to Africa. For the former, it describes climate impacts on water supply, water treatment and water storage/distribution systems separately, then describes adaptation solutions for each phase of the project cycle, which include water capture and storage, improving water conservation, and protecting water quality. For the latter, it describes climate impacts on wastewater treatment, latrines, and septic and leach fields separately, then describes adaptation solutions, which include relocating, separating storm & wastewater sewers, and improving treatment. It cites Vision 2030 in its 'further reading' section.

Integrated urban water management
Bahri, 2012, GWP TEC

Summary
This background paper overviews the concept of integrated urban water management, showing how it is nested with broader IWRM and can contribute to water security by aligning the urban water sector with rural water supply, agriculture, industry, energy and the environment, though is not specific to Africa. Rather than having water supply and sanitation systems managed separately, and in isolation from land-use planning and economic development, IUWM calls for the alignment of urban development and basin management to achieve sustainable economic, social and environmental goals. It cites Vision 2030 several times when reviewing the climate impacts on various aspects of the water / sanitation sector.

Vulnerability assessment of surface water supply systems due to climate change and other impacts in Addis Ababa, Ethiopia
Elala, 2011, Uppsala University

Summary
This report undertakes a vulnerability assessment of surface water supply systems under climate change in Addis Ababa. It identified more key vulnerabilities: increasing population, increasing per capita water demand, overexploited land, and increased distribution losses, then made recommendations on adaptation. It cites Vision 2030 when reviewing climate impacts on the water sector and to justify its work via its claim that few systematic vulnerability/resilience assessments on the water sector have been done.

Strategic planning for water security in developing countries
Smout, 2013, WEDC – Loughborough University

Summary
This report proposes a strategic planning approach to water security with a 15-40 year time horizon, considering various scenarios and focusing on 'no regrets' actions to build resilience. It draws on research from the EU SWITCH project from Egypt. It cites Vision 2030 vulnerability scoring of various water supply technologies under different scenarios.

Nile River Basin: hydrology, climate and water use
Melesse, 2011, Springer

Summary
This book reviews climate and water issues for the Nile River Basin, including sections on: hydrology and water budget; satellite rainfall estimation; GIS and remote sensing in watershed modelling; climate variability and hydrologic response; and WRM, allocation and policy. It cites Vision 2030 when discussing climate impacts on the water sector.

Energy, water and climate change in Southern Africa
Prasad et al, 2011, University of Cape Town

Summary
This report assesses the water-energy nexus in the context of climate change in Southern Africa. After reviewing this nexus in the four study countries, it then investigates water supply adaptation technologies, opportunities for renewable energy for rural water services, water and energy policies and the state of integrated planning of water and energy resources. It cites Vision 2030 when discussing the resilience of water supply technologies and reproduces its resilience matrices for the three rainfall scenarios on the different technologies.

The 'mainstreaming' approach to climate change adaptation: insights from Ethiopia's water sector
Oates et al., 2011, ODI Background Note

Summary

This report discusses the concept of mainstreaming climate change adaptation into development interventions, drawing technical and political lessons from the Ethiopian water sector context. It lists a number of strategic and operational requirements for effective mainstreaming of adaptation in the water sector, then assesses Ethiopia's progress towards them. It cites Vision 2030 by highlighting its vulnerability assessment of various WASH technologies.

Rainwater harvesting from rooftops

ClimateTechWiki, 2010

Summary

This wiki page reviews the rainwater harvesting technology, though is not specific to Africa. It cites Vision 2030 when saying that over 60 million people use rainwater harvesting as their main source of drinking water in 2006, and that this figure is projected to increase to 75 million by 2020. It highlights rainwater harvesting as a climate-resilient drinking water supply technology, due to its water storage capabilities.

Vulnerability of bank filtration systems to climate change

Sprenger et. al., 2011, Science of the Total Environment

Summary

The paper explores the resilience of bank filtration systems in two scenarios; drought and flood. The findings are that bank filtration systems comprising an oxic to anoxic redox sequence ensure maximum removal efficiency, and bank filtration for drinking water supply is more resilient to climate change than ground water abstraction or surface water abstraction alone. The article only references Vision 2030 to support the statement that climate change will have a major impact on water supply. Bank filtration is not one of the technologies covered in Vision 2030 so no direct comparison can be made between the two studies. It is unclear whether the paper uses Vision 2030 results to contrast the vulnerability of direct surface water abstraction to bank filtration systems.

A3: General literature on climate change and WASH

This section cites other relevant literature on CCA & WASH in Africa since 2009 that do not reference Vision 2030. A brief summary of each is included. This is not an exhaustive list, and to maintain a narrow scope, only studies with a clear focus on Africa were included this time (unlike some of the general studies included in the previous sector). Likewise, only studies with a clear focus on WASH were included, excluding any studies focusing solely on water resource assessment / management issues. This review was undertaken primarily using internet search engines (Google Scholar, Google Search) and academic databases from Bristol University and Cranfield University. Key words used for searches included climate change, water supply, sanitation, WASH, risk, sustainability, vulnerability, resilience, adaptation, Africa.

What impact will climate change have on rural groundwater supplies in Africa?
MacDonald et al., 2009, Hydrological Sciences Journal

Summary
This paper reviews the nature of groundwater resources in relation to improved rural water supplies and considers the impact of climate change on groundwater availability, access and use. It finds that increased demand on dispersed water points, as shallow unimproved sources progressively fail, poses a much greater risk of individual source failure than regional resource depletion does.

Climate change adaptation in a developing country context: The case of urban water supply in Cape Town
Ziervogel, et al., 2010, Climate & Development

Summary
This article focuses on the processes impeding and facilitating adaptation to climate change within the urban water sector in the City of Cape Town, South Africa. It explores water management at the city scale, highlighting how actors currently respond to water stress and the challenges they face in integrating climate change information into water management.

Does South Africa's water law and policy allow for climate change adaptation?
Stuart-Hill and Schulze, 2011, Climate & Development

Summary
This report discusses whether South Africa's regulatory frameworks and laws on water are sufficient to support climate adaptation, and to incorporate climatic uncertainties into the decision-making process. It concludes that they are indeed sufficient.

Potential impact of climate change on improved and unimproved water supplies in Africa
Bonsor et al., 2011

Summary
This book chapter explores the question of how rural water supplies in Africa will be affected by climate change. It concludes that, while climate change will be important in determining future water scarcity, other drivers like population growth and rising food demands will likely provide greater pressure on rural water supplies in the short term.

Assessing the sustainability of rural water supply programmes: a case study of Pawaga, Tanzania
Sanders and Fitts, 2011, Masters project – Duke University

Summary
This report assesses the sustainability of rural water supply for Pawaga, Tanzania. It first overviews the region's characteristics, then discusses operation and maintenance, M&E, financing, community and institutional considerations for the region's rural water supply. It makes a variety of recommendations for improvement of rural water supply programming in the region.

Options for water storage and rainwater harvesting to improve health and resilience against climate change in Africa
Boelee et al., 2013, Regional Environmental Change

Summary
This report discusses water storage and rainwater harvesting for climate resilience and health in East and West Africa, which both experience high rainfall variability. While water harvesting and storage can mitigate the effects of this variability, it can also increase health risk if not done with environmental health considerations in mind. The report suggests that a participatory approach to the planning, design and management of rainwater harvesting and water storage, along with full consideration of possible options, would better allow health issues to be accounted for and for climate resilience to be built.

Water and climate change in Africa: challenges and community initiatives in Durban, Maputo and Nairobi
Perkins, 2013, Routledge

Summary
This book overviews projected climate impacts on the water sector in Durban, Maputo and Nairobi, then discusses the equity and climate justice implications. It then gives examples of ongoing community initiatives to address this challenge. Its chapters include: the importance of CBOs for equitable water governance under climate change; community river restoration in South Africa; civil society engagement in climate change and water in Durban; and several others with less relevance to water specifically.

Climate change as a wicked problem: an evaluation of the institutional context for rural water management in Ghana
FitzGibbon and Mensah, 2012, SAGE Open

Summary
This article discusses climate change complexity and defines it as a 'wicked problem', which will not be solved by the same tools and processes that are complicit in creating them. It then analyses this topic from the perspective of rural water management in Ghana, discussing how climate impacts on water resources are increasing, while existing institutional capacity is weak. It recommends a dynamic approach with complex and adaptive systems thinking – adaptive co-management – to allow the country to adapt its water management system to climate change.

Domestic rainwater harvesting as an adaptation measure to climate change in South Africa
Kahinda et al., 2010, Physics & Chemistry of the Earth A/B/C

Summary
This article discusses climate impacts on water resources in South Africa, focusing on rainwater harvesting as a resilience and adaptation measure. It then presents a methodology to enable water managers to incorporate climate change considerations during the design of rainwater harvesting systems – for calculating optimal storage tank size under different climate scenarios.

Approaches towards practical adaptive management options for selected water-related sectors in South Africa in a context of climate change
Schulze, 2011, Water SA - WRC

Summary
This article places the South African water sector and water-related sectors in the climate change context. It first reviews climate terminology and projected impacts on the South African water sector, then discusses adaptive management options for national water planners, municipalities, rain-fed agriculture, the insurance industry and aquatic ecosystems. For each, it lays out adaptation considerations for enhancing adaptive capacity, technological and structural responses, knowledge / skills/ participation, policy instruments, risk sharing/spreading, and the change of use / activity / location, along with cross-references for each to other resources.

Africa Adaptation Programme identification of climate-resilient water and sanitation technological options for schools in Ethiopia

Swan Mgmt Plc, 2012, UNICEF

Summary

This report discusses a variety of climate-resilient technology options for the WASH sector in Ethiopia. It first discusses the projected impacts of climate change on Ethiopia, then reviews some general principles for technology options based on their urgency of need, level of impact, replicability, level of effort to implement, level of skill requirement and cost of implementation. It then describes ~24 technologies, including sanitation technologies, land management and agriculture methods and energy options, which it implies are climate-resilient, though does not specifically justify why each was selected.

Appendix B – Guidance Note

What is it?
This Guidance Note provides a reasonably simple and practical way of assessing risks to delivery WASH results posed by climate change and other pressures, and then illustrates how some basic economic principles can be applied to help identify cost-effective adaptation options.

The Note is split into three parts, or steps. Step 1 describes a simple risk screening approach that can be applied at national level for assessing major country-level risk factors, and the relative importance of climate change compared to other threats and change. Step 2 then looks at the extent to which a country programme addresses these risks, and specifically how 'climate smart' a particular WASH programme is. Step 3 provides guidance on how some basic cost-benefit principles can be used to support an evaluation of adaptation options. The stepped process is illustrated in the figure below.

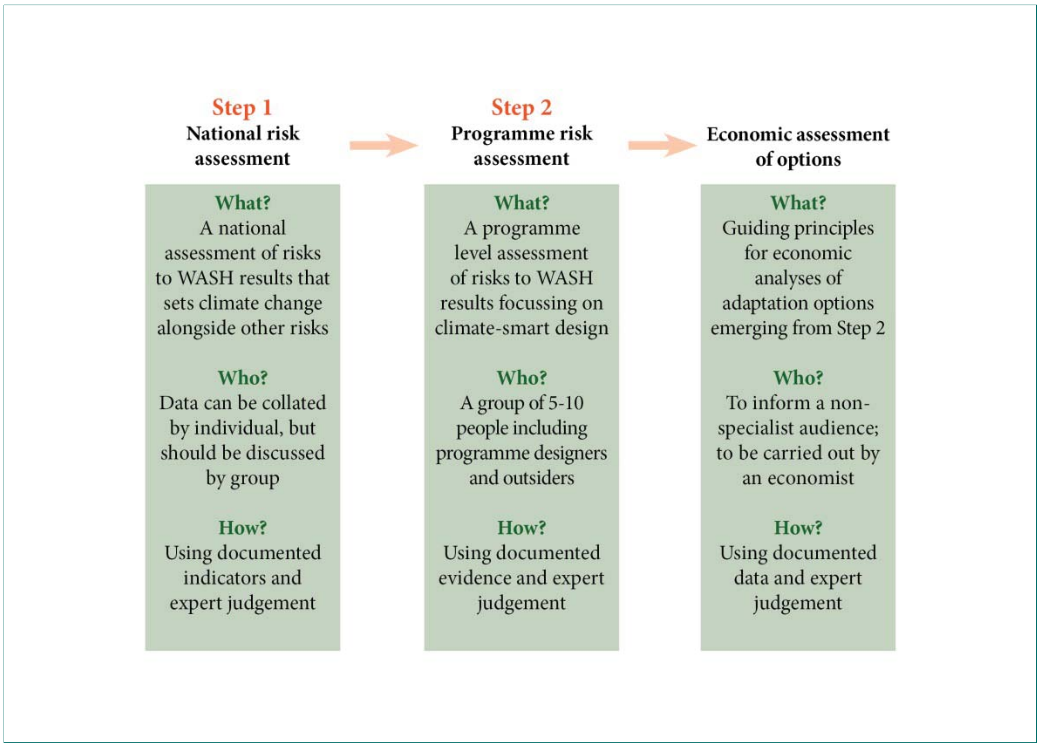
Who is it for?
The Note is intended to inform the planning of country-based WASH projects and programmes by DFID staff and their development partners, including other donors and NGOs. For a development partner or NGO, the Note could form part of a proposal to DFID – to demonstrate that 'due diligence' has been followed in assessing risks and options.

Who should be involved?
Some parts of the risk screening and economic appraisal can be carried out by individuals with a good knowledge of the sector and country context, using readily available secondary data. Ideally, however, Steps 1 and 2 should be carried out as participatory exercises with groups of 5-10 people, combining documented indicators and expert judgement. The group is expected to include both programme designers and 'independent' outsiders. Carrying out the economic analysis requires specialist skills in project-based CBA.

Does it require expert knowledge?
The risk assessment requires knowledge of sector and country context to inform the traffic light assessment. Step 3 of the Note is aimed at both a general audience (to inform) and economists (to apply).

How long will the assessment take?
A lot will depend on data availability and accessibility. However, with a knowledgeable group of people and reasonable access to data, Steps 1 and 2 should take 1-2 hours each.

Figure A1: Risk assessment and appraisal process



Steps 1 and 2 - key questions

The risk assessment set out below is designed to answer the following questions:

- To what extent is the effectiveness of WASH interventions likely to be compromised by climate change, as compared to other trends and hazards?
- Does the proposed WASH programme adequately address (either directly or taking account of the work of others) the impacts of variability and change in present and future climate on water resources and WASH services, and the wider impacts of climate change on the target communities?
- Does the proposed WASH programme adequately address (either directly or taking account of the work of others) the enabling environment and institutional capacity to address climate change risks in WASH programming?
- Are the proposed physical infrastructure improvements sufficiently protected against present and future climate risks?

The first question is addressed in relation to WASH programming in general, and with respect to the national context. This is **Step 1** of the risk assessment.

The remaining three questions focus attention on the content of a specific proposed WASH programme or project, in that same national context. This constitutes **Step 2** of the risk assessment.

Taken together, these two steps enable the assessment team to judge the relative importance of climate change as a threat to WASH programming in the country, compared to other threats and trends, and how 'climate-smart' a particular WASH programme is.

Step 1 – WASH vulnerability in context

What factors make WASH services vulnerable, or conversely, what factors make them resilient[29]? We suggest here that seven factors are important. These are all demonstrably important, and potentially measurable. Table 1 sets out the logic here and it sets WASH service vulnerability to climate and climate change within a wider context of "*external and internal vulnerabilities*", allowing its relative importance to be assessed.

The right-hand column of Table 1 provides a way of mixing documented indicators of vulnerability / resilience with more subjective judgments to arrive at a national assessment of the key vulnerabilities of WASH services. Table 2 sets these out in the form of a rapid assessment 'traffic light style' review, to be undertaken at national or possibly sub-national scale. This is Step 1 in the risk assessment.

Tables 1 and 2 address the general contextual question "*to what extent is the effectiveness of WASH interventions in general likely to be compromised by climate and climate change, as compared to other factors and trends?*"

Table 1 highlights the importance of resilience in public and civil society institutions (policies, organisational capacity and cooperation), economy and finance, physical infrastructure, knowledge (of environmental change) and demographic pressures. The greater the existing variability and expected future change in climate, the more vulnerable a society is likely to be.

Table 2 translates the principles of Table 1 into a semi-quantified assessment of WASH service vulnerability at national level. Most of the factors listed here can be scored using readily available published data. The scores assigned to different ranges of any single indicator are inevitably somewhat arbitrary, but they can be readily adjusted to better fit the country context. It is emphatically not the intention of this first step risk assessment to make inter-country comparisons. The issue addressed is the relative importance of climate change as a risk to WASH services, compared to other contextual risks.

[29] For simplicity vulnerability and resilience are treated as antonyms.

Table A1: National level risk assessment

Factor	Justification for inclusion	Possible Index / indicator
1. Appropriate WASH and climate policies, strong public institutions, good governance.	Public policy and public institutions provide the necessary national guidance for dealing with vulnerabilities and risks.	A general governance indicator combined with assessments of WASH policies and the capacity of WASH institutions.
2. Adequate routine and emergency WASH sector budget allocations, including (especially) recurrent budgets.	Sufficient routine investments and reserves for dealing with emergencies are an obvious pre-requisite for resilience.	WASH public investment as % of GDP; measures of national wealth.
3. Sufficient resilience of WASH infrastructure (designing for appropriate levels of climate variability without attempting to 'climate-proof'.	Design and construction standards confer resilience on WASH physical infrastructure: reliability/yield, water quality protection, infrastructure damage.	Existence of sound design / construction standards; assessment of observation of sound standards.
4. Effective environmental (weather, groundwater, surface water, land use) monitoring networks and institutions.	Given the immense uncertainty over direction and magnitude of environmental change, monitoring is a clear pre-requisite for observing and understanding such change.	Existence of national monitoring agencies; extent of monitoring networks; amount and availability of data.
5. Slow / limited demographic change and environmental degradation.	Rapid population growth, urbanisation and land use change are major causes of vulnerability.	Percentage increase in population predicted between 2010 and 2050 under UNDESA medium variant; equivalent urban increase to 2050; assessment of rate of deforestation and impact of natural resource exploitation.
6. Limited magnitude / impact of climate variability and climate change.	The relative magnitude of changes in secondary climatic variables such as rainfall and its variability, and the projected impacts of CC, to the extent that they are predictable, are the specific focus of the study.	Mean annual projected rainfall change to 2030s; relative magnitude of increased rainfall variability; assessment of special factors leading to vulnerability to temperature changes, snow / ice melt, flood, drought or sea-level rise.
7. Strong civil society and civil society representation.	The levels of education, health and poverty of the general public, and the ability of civil society organisations including the media to speak out on public issues such as CC are key to a nation's resilience.	Human Development Index (HDI); assessment of strength of environmental / campaigning CSOs and media.

Table A2: National level scoring

		Score					
No	**Factor**	**1**	**2**	**3**	**4**	**5**	**Comments**
1.1	Government effectiveness						
1.2	WASH and other policies						
1.3	WASH institutional capacity						
1.4	Cross-sector & trans-boundary cooperation						
2.1	GNI per capita						
2.2	WASH and national budget						
2.3	Adequacy of WASH recurrent budget						
3.1	Technology						
3.2	Design & construction standards						
3.3	Standards observed - implementation						
4.1	Monitoring agencies						
4.2	Monitoring networks						
4.3	Environmental data						
5.1	National population growth						
5.2	Urban population growth						
5.3	Deforestation and environmental damage						
6.1	Mean rainfall change						
6.2	Change in annual 5-day max rainfall						
6.3	Climate change impacts in general						
7.1	Human development index						
7.2	CSOs/media accountability						

Information sources

1.1 The World Bank Governance Indicators (http://info.worldbank.org/governance/wgi/sc_country.asp) include assessments of (i) Voice and Accountability, (ii) Political Stability and Absence of Violence, (iii) Government Effectiveness, (iv) Regulatory Quality, (v) Rule of Law, and (vi) Control of Corruption. In the absence of major political instability, corruption or lawlessness we propose to use the Government Effectiveness percentile rank. Values are then scored as follows: <20% (1), 21-40% (2), 41-60% (3), 61-80% (4), >80% (5). CPIA could be an alternative – there are 4 indicators http://data.worldbank.org/indicator/IQ.CPA.PUBS.XQ - widely used by the WB and donors.

1.2 WASH and related Policy and Guidance documentation (policies, laws, implementation manuals) should be assessed on the following scale: almost non-existent (1); barely adequate (2); satisfactory (3); well-suited to context, well drafted and widely disseminated (4); known, respected and implemented by all agencies (5).

1.3 WASH and WASH-related Ministries (including Water, Health, Environment, Education, Local Government) should be assessed en masse according to the following scale: almost non-existent (1); barely adequate (2); satisfactory (3); well-staffed and organised (4); highly competent and professional (5).

1.4 A judgment should be made about the quality of inter-Ministerial cooperation (e.g. between Water, Health, Education, Agriculture, Lands, Energy, Public Works or their equivalents), and where appropriate, cross-border coordination. The scoring can be carried out according to these descriptors: highly effective (5), effective (4), satisfactory (3), weak (2), very poor (1).

2.1 The World Bank national income categories (low, lower-middle, upper-middle, and high) are used for ratings of 2, 3, 4 and 5 (http://data.worldbank.org/data-catalog/country-profiles). If a country is classified by the UN as 'least developed' (see http://unctad.org/en/PublicationsLibrary/ldc2012_en.pdf) it ranks 1 here.

2.2 The WASHwatch website (http://washwatch.org/) can be used here with caution in the absence of better information. The GLAAS report may also be of use (http://www.who.int/water_sanitation_health/publications/glaas_report_2012/en/index.html). Where quantitative data exist, the ratings are as follows, based on the 2010 GLAAS report: <1.0% (1); 1.00-2.50% (2); 2.51-4.00% (3); 4.01-5.00% (4); >5.00% (5). In the absence of quantitative data, use the scale of grossly inadequate (1); inadequate (2); barely adequate (3); sufficient (4); generous (5).

2.3 It is unusual for recurrent finance to be truly adequate to cover all the post-construction costs of WASH services. This represents a major threat to the sustainability of such services. The general (national) adequacy of such financing should be assessed on the following scale: excellent provision for opex, capmanex and support costs (5), most post-construction costs provided for (4), opex and support costs covered (3), recurrent finance inadequate (2), recurrent finance grossly insufficient (1).

3.1 Vision 2030 identified water and sanitation technologies which are considered more or less vulnerable to climate change. A judgment should be made here about the predominant technologies used in the sector, and their reliance. The Vision 2030 resilience categories may be used as follows: high (5), high-medium (4), medium (3), low-medium (2), low (1). Tables 1 and 2 in the summary document (http://www.who.int/water_sanitation_health/vision_2030_9789241598422.pdf)may be used.

3.2 The existence and use of sound engineering design standards each need to be assessed using the professional judgment of one or more informed Advisers. The rating scales are as follows: no standard documentation exists (1); minimal documentation exists (2); adequate guidance exists (3); good guidance exists which is widely disseminated (4); guidance is excellent and known by all relevant agencies and households (5).

3.3 Standards of design and construction in practice are extremely poor (1); poor (2); adequate (3); good (4); excellent.

4.1 Strong Government agencies for monitoring of weather, surface water, groundwater, and water quality should exist. A professional judgment about the capacity of these agencies (en masse) should be made, using the following rating: extremely weak and grossly under-resourced (1); functioning but very weak (2); just adequate (3); competent and effective (4); extremely competent and professional (5).

4.2 Monitoring networks should be in place, generating reliable data. Ratings here are: networks virtually non-existent (1); very rudimentary networks (2); partially adequate networks (3); well-functioning but incomplete networks (typically lacking groundwater monitoring) (4); comprehensive networks for all functions (5).

4.3 Data availability should be rated as follows: non-existent or very hard to access (1); limited data, but difficult to access (2); adequate data with relatively ready access (3); good records and easily accessible (4); excellent data, summaries, time-series, maps and reports all freely accessible(5).

5.1 Percentage increase in population predicted between 2010 and 2050 by UNDESA medium variant (http://esa.un.org/wpp/unpp/panel_population.htm). Ratings are as follows: >3.00 (1); 2.51-3.00 (2); 2.01-2.50 (3); 1.51-2.00 (4); <1.50 (5).

5.2 Percentage increase in urban population predicted between 2010 and 2050 by UNDESA (http://esa.un.org/unup/unup/index_panel1.html), rated as follows: >4.00 (1); 3.51-4.00 (2); 3.01-3.50 (3); 2.51-3.00 (4); <2.50 (5).

5.3 Judgment of level of threats to the natural environment posed by deforestation, soil erosion, mining, industrial development, water pollution, or any combination – risk level: extreme (1); high (2); moderate (3); small (4); negligible (5).

6.1 Using the UNDP/Oxford University Climate Change Country Profiles (http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/) or the World Bank climate portal (http://sdwebx.worldbank.org/climateportal/index.cfm), derive the best estimate of mean annual precipitation anomaly for the 2030s (% change relative to 1970-99) and change in annual maximum 5-day rainfall for 2030s relative to 1961-90. For mean annual precipitation change (positive or negative), ratings are as follows: >10% (1); 8.01-10.00% (2); 6.01-8.00% (3); 4.01-6.00% (4); <4.01% (5).

6.2 For annual maximum 5-day rainfall anomalies, ratings are as follows: >10mm (1); 8.01-10mm (2); 6.01-8.00mm (3); 4.01-6.00mm (4); <4mm (5).

6.3 Reflect any special national climate change vulnerability using qualitative information given in UNDP/Oxford climate change country profiles or other reports / reviews and professional judgment, according to the following rating: extremely vulnerable to CC impacts (1); very vulnerable (2); moderately vulnerable (3); limited likely impact (4); negligible likely impact (5).

7.1 Derive HDI from http://hdr.undp.org/en/statistics/hdi/ and rate as follows: lowest quartile by rank (1); second quartile (2); third quartile (3); fourth quartile (4).

7.2 Use World Bank Governance Indicator for Voice and Accountability (http://info.worldbank.org/governance/wgi/sc_country.asp) to assess strength of civil society, with the following ratings based on percentile rank: <20% (1), 21-40% (2), 41-60% (3), 61-80% (4), >80% (5). Alternatives/supplements could be Press freedom index (http://en.rsf.org/press-freedom-index-2013,1054.html) or EIU's democracy index https://www.eiu.com/public/topical_report.aspx?campaignid=DemocracyIndex12

Step 2 – programme risks

In order to relate the assessment in Step 1 to the risks to specific WASH projects and programmes in that country, a second step is needed. This step attempts to answer questions 2, 3 and 4 in the introduction to the risk-screening approach, for which the reasoning is set out below.

The second step of the risk screening uses the foregoing rationale to create a structured self-assessment checklist (Table 3). A short set of questions is asked of a WASH project or programme to highlight the extent to which it is climate-aware and paying due attention to climate-related risks, with the responses enabling a "traffic-light" scoring – green to indicate that the issue is adequately addressed, amber to indicate that more work is needed, and red to signal that this element has been inadequately addressed. If a WASH programme is too complex to assess as a whole, it can be broken down into component parts, and Table 3 applied to as many projects as is desired.

It is obvious that not every WASH project or programme can (or should) address every issue of governance, capacity, knowledge generation and service delivery. If other organisations, projects or programmes are undertaking important aspects of the needed work, then duplication may not be appropriate. However, if there are serious gaps in any or all of these aspects, the question should be asked, 'why is this project or programme (the one being risk-assessed) neglecting such fundamental matters?'

An assumption underlying this step of the risk assessment is that in most cases a 'WASH project or programme' has limited duration, covers a limited geographical area, meets the needs of a limited population even within that limited geographical area, and possibly is limited in scope by not addressing all aspects of WASH (rural, small town, urban; water supply, sanitation, hygiene). However there is little in Table 3 which is not equally applicable to national programmes, perhaps with a small amount of adjustment of wording. In either case, it is assumed that Government, with or without the services of utilities and private service providers, is the entity which is mandated to assure basic services such as WASH. This is the reason why many of the questions focus on the extent to which projects and programmes – including those implemented by NGOs – contribute to strengthening of the enabling environment and capacity of those permanent service providers and enablers.

It is envisaged that the questions in Step 2, as with Step 1, would be addressed by a group of assessors in a participative manner which involves both programme designers and a few outsiders.

Table A3: Programme level risk assessment

				Score		
Aspect	**Element**	**Question**	**Response and proposed actions**			
Understanding of climate impacts	1. Present climate	Is there good understanding among all stakeholders of existing climate variability, its impacts on water resources and its implications for WASH services?				
	2. Future climate	Is there good understanding among all stakeholders of projected climate change, its likely impacts on water resources and its implications for WASH services?				
Developing capacity, enhancing the enabling environment	3. WASH policies	Does the programme design contribute to the development and promotion of strong sector policies which recognize the multiple pressures on WASH services, including that posed by climate variability and change?				
	4. Technical guidelines and standards	Does the programme design contribute to the development and promotion of WASH guidelines and standards which take adequate account of climate change?				
	5. Monitoring	Does the programme design contribute to strong and effective systems for monitoring of water resources and WASH services?				
	6. Research and learning	Does the research / learning component of the programme include areas related to CC?				
	7. Capacity development	Does the programme include a significant component of general and CC-specific capacity development, addressing the needs of WASH service users, local Government, private sector, NGOs, central Government and development partners?				
	8. Flexibility and responsiveness	Does the programme contribute to the strengthening of flexible national and local planning, budgeting and emergency response capabilities which can effectively respond to gradual and rapid onset change?				
Design and implementation	9. Overall design philosophy	In general how does the design of physical infrastructure in the programme take account of climate variability and change?				
	10. Catchment and source protection	Does the programme include adequate measures for source and catchment protection?				
	11. Impact of major abstractors	Does the programme take due account of the indirect impacts of climate change and other socio-economic and demographic trends				

	on local water availability	on WASH, especially those felt through (increasing) agricultural, industrial and urban water abstractions?	
	12. Water supply system design and construction	How does the design and construction of water source works take account of present and future variability of water levels and / or flows? Does the sizing of service reservoirs and larger water storage structures take due account of projected changes in the timing and magnitude of available flows? How is the design of piped distribution systems informed by climate considerations? How does the design of water treatment systems allow for future possible changes in water quality and quantity caused or contributed by climate change? Does the selection of water lifting technology allow for future increases in fossil fuel energy costs? Is there a preference for renewable energy sources?	
	13. Sanitation system design	Does the programme design include modifications to latrines and other on-site sanitation technologies to reduce their vulnerability to floods? In any urban sanitation components of the programme, is due attention being paid to stormwater drainage and solid waste management? How does this address the possibility of higher flood flows in future? How does the design of sewage conveyance and wastewater treatment allow for future climate changes which affect quality and quantity of discharges?	

The following guidance is intended to assist assessors to answer the numbered questions in Table 3.

1. Climate variability (season-to-season and year-to-year, in the absence of longer term climate change) is usually an important factor in determining spring, stream and river flows, groundwater recharge, groundwater levels, water quality, and the likelihood of climate-related damage to WASH infrastructure. Knowledge of climate variability and its links with these outcomes must therefore inform water resource assessment and water supply system design. It is also essential for the design of on-site and sewered sanitation systems. The question here is about the adequacy of the knowledge possessed by project or programme implementers. If there are concerns about this, it may still be that such knowledge exists in the country, but it needs to be disseminated and communicated to those involved with the project or programme. If not, and no-one else is addressing this matter, then it may be that the project should include an appropriate component of research and learning. Not all the impacts of climate variability and change on WASH services are direct. For example, the interaction of climate variability and change with demographic trends, environmental degradation and growing demands for water by other (non-WASH) sectors may have important indirect impacts on WASH services[30].
2. Similar comments apply as to question 1, except that the focus here is on the future. Most if not all countries have been the subject of climate change assessments, although not all are sufficiently down-scaled as to be useful for our purposes, and not all explicitly consider WASH. Furthermore, the significant uncertainties in the direction and magnitude of changes limit the current usefulness of such projections. Consequently the question here is whether, within the limits of the available science, sufficient attention has been paid to the likely future impacts of climate change on WASH services.

Taken together, questions 1 and 2 address the adequacy of the relevant stakeholders' knowledge of the linkages between climate variability and climate change on the one hand, and WASH system vulnerability on the other.

3. In Step 1 of the risk screening, the quality and relevance of the WASH sector policies are assessed in very general terms. To the extent that there are weaknesses or shortcomings in the national policies (including in stakeholders' awareness and application of their content), the question here in Step 2 concerns the contribution to be made by the assessed project or programme in enhancing those policies and their implementation. As with the other questions in Step 2, if the project is not planning any relevant actions, the assessors should ask, "why not?". The answer may be that others are doing so. However, all programme experience is relevant to better policy formulation and dissemination, so one would expect at a minimum that programme implementers will be playing an active role in existing sector dialogues, technical working groups and networks.
4. In a similar manner to question 3, this question has been partially addressed (in very general terms) in Step 1. Once again, to the extent that there are gaps, weaknesses or shortcomings in technical standards and guidelines, the question concerns the contribution to be made by the programme in enhancing those procedures and helping to ensure that they are applied consistently.

[30] An obvious example in India is the interaction of growing demands for groundwater for irrigation, combined with low cost energy supply, leading to over-abstraction of deeper groundwater at the expense of WASH services which were dependent on shallow groundwater.

Questions 3 and 4 of Step 2 should both draw on the knowledge which is highlighted in questions 1 and 2, namely the known and anticipated, direct and indirect, impacts of climate variability and climate change on WASH services.

5. While the monitoring of WASH services is highly topical and being widely addressed, the corresponding hydro-meteorological or water resources monitoring is often hugely neglected or only carried out in an incomplete manner. There are major uncertainties surrounding climate change modelling and the corresponding projections of future climate. At the same time the detail of climate variability and change experienced to date is gathered largely through anecdotal evidence. It is therefore essential that monitoring systems for rainfall and other meteorological variables (typically temperature, wind speed, solar radiation and relative humidity), river flows and river water quality, and groundwater levels and quality are strengthened. WASH projects and programmes which work at the local level (as opposed to national) may not be able to focus on this subject in a comprehensive manner, but they can and should support national efforts within their limited geographical areas. If such national efforts are inadequate, then the programme may be able to advocate for change, for example in the scale of Government budgets for water resources monitoring.
6. Here we make two assumptions: (a) that all WASH programming should include an element of research and learning, and (b) that climate variability and change potentially or actually affect the delivery of sustainable WASH services. The first of these assumptions should go without saying, even in 'straightforward' WASH service delivery projects – there should always be the opportunity to learn and to document that learning. Regarding the second, the impacts of climate variability and change on WASH services may be direct – e.g. increasing frequency of flooding of on-site sanitation – or indirect – e.g. through the impact of climate on livelihoods, reducing the ability and willingness of households to pay for water services or invest in sanitation. Understanding these positive and negative, direct and indirect, impacts should be part of all climate-aware WASH programmes.
7. One of the major constraints to effective programme implementation is the capacity of the individuals (including their knowledge, experience and attitudes) and the organisations (including their culture, standards, resources and resource deployment, leadership) responsible for delivering services. If weaknesses in these areas are not addressed systematically through projects and programmes, then the likelihood of service standards rising, and implementation becoming more responsive to climate hazards and threats to sustainability from other sources will remain low. Capacity development efforts need to focus on all stakeholder groups, starting with the service users, but extending through all those public, private and civil society agencies providing support to the delivery and management of WASH services.
8. Well-coordinated planning and budgeting processes are essential if those mandated to deliver WASH services are to be effective. Processes which are responsive to gradual and more rapid change, as well as to sudden crises, will increasingly be needed as changes in demographics, demand for services, environmental status and climate become increasingly important over the coming decades. WASH programmes need at least to engage constructively with others' attempts to harmonise and coordinate approaches, and ideally to advance these processes proactively.

The next and final section of Step 2 focuses on ways in which projects and programmes address the resilience of the physical infrastructure which delivers WASH services. In the case of delivery by (local) government and their partners, it is only through their knowledge of climate impacts, operating environments that are truly enabling, and strong organisational capacity that resilient infrastructure will generally emerge. In the case of programmes implemented by NGOs, knowledge and capacity can be mobilised, and less advantageous aspects of the operating environment can often be circumvented; but in this case despite the implementation of climate-resilient infrastructure, little may change in the wider sector.

9. Although certain aspects of WASH system design explicitly and systematically take account of (shorter-term) climate variability – for example the use of statistical return periods for the design of storm drains and culverts, dam spillways and so on – other components such as protected springs, wells, boreholes and latrines, are often designed in a more *ad hoc* manner. In anticipation of significant changes to climate in the longer term, some judgment needs to be made as to when in the future the magnitude of such change is likely to move beyond the typical range of shorter-term variability – when the 'signal' is distinguishable from the 'noise'. That judgment will determine whether design procedures need to be fundamentally re-thought. The purpose of this question is therefore to ask whether standard design procedures are (a) adequate, (b) in need of some modification in light of existing climate variability, or (c) need to be over-hauled in the light of major and relatively certain changes in climate.
10. The combination of expanding populations, increasing pressures on the natural environment, existing climate variability and anticipated climate change means that the immediate environs of water sources as well as their more extensive catchments must be adequately protected. It is common for the drying up of springs, wells and boreholes, and the deterioration of surface flows and water quality to be blamed on 'climate change', without recognition of the complex interactions of the wider set of factors just mentioned. Nevertheless, it is important to include this aspect in a risk assessment of WASH programming, and it is a matter which all WASH programmes should consider carefully.
11. Urban water abstractions may have significant impacts on other downstream water uses and users. In contrast, rural domestic water abstractions generally have very limited impacts on water resources and other water users simply because they are small in quantity and widely distributed geographically[31]. However, major abstractions for agriculture, industry and urban water supply, and their growth, which can be in part affected by climate variability and change, may indeed impact on both rural and urban water supply. This needs to be considered and addressed in WASH programming.
12. The question here relates the climate knowledge identified in questions 1 and 2 to its practical outworking in water supply system design. It should be answered with examples showing explicit linkages between climate and design and construction considerations – for instance the choice of return periods and safety factors used in design of source works, rules about the timing of construction of groundwater sources. Not all of the system components (source works, storage structures, conveyance, water lifting and water treatment) are applicable in all cases, and it should be made clear, for example if certain components such as water treatment are absent from the programme.
13. The question here focuses on sanitation both in the narrow sense (excreta disposal) and in the wider sense of environmental sanitation, including storm water drainage, vector control and solid waste management. It should be answered in a similar manner to question 12, namely with examples linking knowledge identified through questions 1 and 2 with specific design / construction examples.

[31] There are exceptions to this generalisation and if that is the case in the specific programme area, the associated risks should be considered carefully.

Step 3 – Economic analysis of adaptation options

This section gives advice on how to undertake economic analysis of adaptation options in the WASH sector. It is necessarily short and simple, referring to more detailed guidance source where appropriate. The target audience is WASH project managers in the early stages of programme design – some existing understanding of cost-benefit analysis (CBA) is assumed.

Further reading:

- One good overview of CBA is provided by the Asian Development Bank's (2013) *Cost-Benefit Analysis for Development: A Practical Guide*.
- The World Bank's Water and Sanitation Programme will soon produce a useful toolkit under the Economics of Sanitation Initiative (Hutton, 2014 forthcoming).
- An ODI report (Oates et al., 2013) contains a chapter on CBA of adaptation options in WASH, with examples from Malawi, Sierra Leone and Tanzania.
- DFID produced a topic guide on adaptation decision making under uncertainty (Ranger, 2013) which is very useful in supplementing CBA
- DFID and WHO's Vision 2030 report (2009) sets out key aspects of the resilience of WASH infrastructure in the face of climate change

Economic appraisal, particularly CBA, is a formal part of many institutions' procedures for evaluating proposals and business cases. This note aims to support programme *design*, therefore it is implicit that this analysis is taking place in the early stages of this process. Final decisions should not yet have been made – economic appraisal should be thought of as a tool in considering the implications of different options, rather than as a 'green light' for pre-determined ideas.

This part of the guidance note is framed around three key decisions

- Decision 1 – level of analysis
- Decision 2 - broad methodological approach
- Decision 3 – Incorporating climate variability and change

Decision 1 – level of analysis

Economic appraisal can be conducted at the intervention level, the project level, or the programme level. This decision is important because it affects the detail of analysis that can be undertaken, and also the way in which climate dimensions can be brought in.

Considering the **intervention level,** such as the installation of a borehole with hand pump in a rural community, may be useful for really focusing on the nuts and bolts of technical design. This might be, for example, the implications of different technology choices or community management models. However, it can be hard to aggregate such analyses from the level of a single community to a £30 million rural WASH programme which may contain thousands of different interventions in water, sanitation, hygiene, capacity development and policy work.

Considering the **project level,** such as a 6-month set of borehole drilling activities in a single district, allows a focus on different questions. These could include project management (e.g. models for supervision of contractors to ensure appropriate siting) or different climate assumptions for that particular area (e.g. district-level flood return periods and data on groundwater levels). Broader programme costs can be estimated and attributed more easily than at the intervention level.

Finally, considering the **programme level,** such as a 5-year rural WASH programme across 20 districts, allows the more macro-level questions to be considered. For example, this could be the implications of working with different implementing partners (each bringing their own approaches and costs), different models for capacity development of local government, or key externally-commissioned activities.

The different questions for different levels can of course be mixed, as is carried out in Oates et al. (2013). The main argument of this section is that it would be impossible to analyse 2,000 different individual interventions for a programme-level appraisal. Some level of approximation and homogenisation is needed, which may mean losing the granularity that an intervention-level focus could bring. It may be that at the early stages of design, an intervention-level approach could be best, whereas towards the end (when a formal appraisal may indeed need to be submitted), a programme-level approach incorporating that learning would be more appropriate.

Decision 2 – broad methodological approach

In any modelling activity such as CBA, the more things one allows to vary, the more complicated the analysis becomes. You should therefore consider what is really important, i.e. which variables you are most interested in, and primarily allow those to vary. Less important factors can be held constant at a justifiable level. Across different scenarios, the simplest approach is to **vary costs** (for constant benefits), the next simplest is to **vary benefits** (for constant costs), but overall it is most realistic to **vary both costs and benefits**. The latter option isn't necessarily that much more difficult to implement – it just requires more explanation as to what is going on, and is to be strongly preferred

For example, it may be that you have a strong idea of the costs of a project, and are more interested in looking at the implications of different flooding scenarios or different frequencies of WP breakdown. In this case, you would therefore have a single 'programme design' in terms of costs, and make different assumptions about benefits over time in order to see the implications of that.

In this case, it would not be that difficult to allow both costs and benefits to vary. For example, you could allow floods if a certain level of damage at different frequencies, say every 3, 5 or 10 years. An example for urban Sierra Leone in Oates et al. (2013) takes the opposite approach – a single flood frequency is assumed, but different WASH programme designs are modelled to be more or less resilient in the face of flooding. Those that are less resilient see longer down time (with no benefits during that period), and greater capital maintenance (CAPMANEX) costs are incurred in order to return benefits to the original level. The main point to make is that you should make your assumptions clear, and back them up with hard data wherever possible, though expert judgement is acceptable.

Decision 3 – incorporating climate variability and change

Incorporating climate variability and change into CBA can take some thought, and there are various ways of doing it. First, it is important to emphasise that both variability and change matter for the WASH sector. Existing climate variability, for example in rainfall (with its subsequent effects on groundwater levels and river flows) has long been a key factor in WASH programme design. Rainfall depths, intensity and timing are all important. Each can influence flood and drought events, as well as water quality. It is important to recall that, in all the examples in this note, other key factors interact with climate to influence WASH sector outcomes, particularly population growth, water demand and land use. Most are probably more important than climate.

In almost all cases for those likely to be using this guidance note, actual climate modelling (e.g. down-scaling of global models) will be unnecessary and excessively costly. It is enough to incorporate different climate scenarios by considering the effect of climate variables on WASH. For example, in considering urban flooding, one could model 3 different flood frequency and intensity scenarios based on an interpretation existing climate predictions.

A good overview of climate predictions for many developing countries is provided by the UNDP Climate Change Country Profiles, developed by McSweeney (2010) at the University of Oxford. However, it is important to emphasise the uncertainty inherent in these predictions. A key message of the UNDP profiles for specific countries, as well as broader IPCC climate modelling, is that variability is predicted to increase across the board. It may therefore be pragmatic to plan for existing and increasing variability.

This is the approach taken in Oates et al. (2013) is based on two programme designs: one denoted Business as Usual (BAU) and the other Best Practice under Existing and Increasing Climate Variability (BPEICV). The rationale for this is that a cautious adaptation approach in the face of uncertainty is to focus on low regrets options. These are interventions which robust to a range of possible future climates, i.e. they are relatively insensitive to climate uncertainty.

This approach to incorporating climate into CBA can be summarised as **comparing multiple low regrets options for a single increasing climate variability scenario**. It follows a classic CBA approach, focusing on low regrets options which are climate-*related* and would become more important in the face of existing variability. Both costs and benefits are allowed to vary, and the focus is on the difference that adaptation options would make to net economic benefits over time. Climate is incorporated obliquely, but there is only one climate scenario, with is modelled against the two programme design options (BAU and BPEICV) because programme design is the variable of focus. Various examples of this approach are included in Oates et al. (2013).

Another approach could be considering a **single design under multiple climate variability and change scenarios.** This is best demonstrated with an example such as catchment protection. Gravity schemes are vulnerable to more variable river flows due to silting and intake damage, which is worsened by poor catchment management. One approach to incorporating climate could be modelling different frequencies and levels of both flash flooding and low flows (which reduce water quantity in the dry season) throughout the year. Costs are assumed constant, but benefits allowed to vary through three climate scenarios. The analysis could first be carried out for the gravity scheme on its own, and then separately again with the incorporation of catchment protection activities (which, if properly implemented, could reduce deforestation and run-off). As mentioned above, it is important to consider the other risks to WASH infrastructure, such as population, land-use and water demand.

A third approach, increasingly called for by adaptation economists (Ranger, 2013) is to amend CBA by focusing on additional sensitivity methods which can incorporate the deep uncertainty that climate change brings. This can be summarised as **resilience and robustness approaches.** It is argued that, with the 'deep' uncertainty that surrounds climate predictions, conventional economic tools like CBA can become useless, because the mathematical optimisation inherent in their workings are sensitive to uncertainty. A resilient intervention is one that achieves its objectives today, but is also robust (i.e. high benefits under a variety of scenarios) and adaptive (i.e. can be altered to changing future conditions). Robustness can be tested with lighter-touch additions such as sensitivity and switching values analysis, as well as more in-depth alternatives to CBA such as Robust Decision Making and Real Options Analysis. Ranger (2013) provides useful examples of these approaches.

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DFID welcome comments and suggestions, and any feedback on these documents should be sent to the ICF Secretariat (ICFSecretariat@DFID.gov.uk).

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