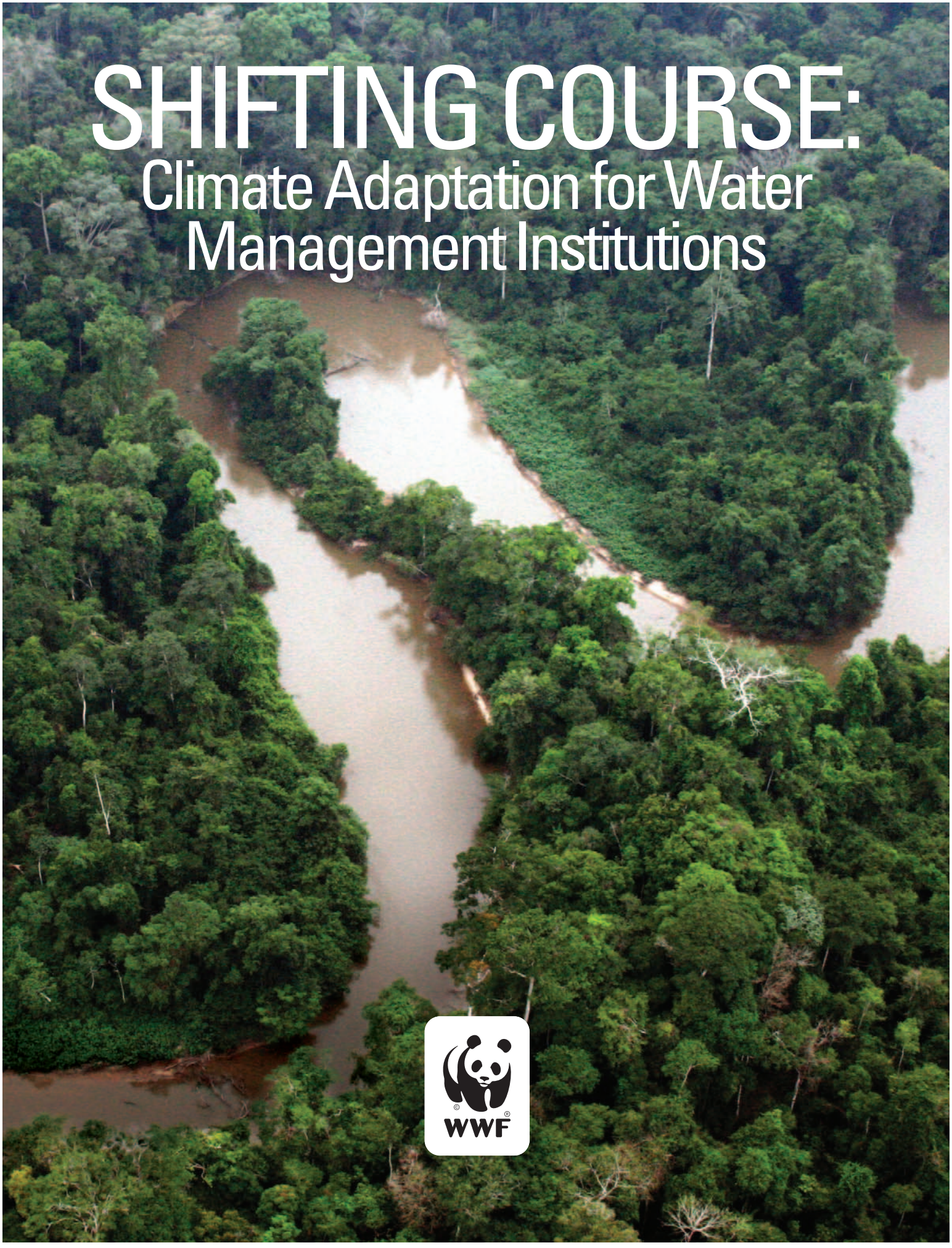

SHIFTING COURSE:
Climate Adaptation for Water Management Institutions

WWF

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Jonathan Cook
Sarah Freeman
Eliot Levine
WWF-US

Margot Hill
University of Geneva

www.adaptiveinstitutions.org

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HSBC

Foreword

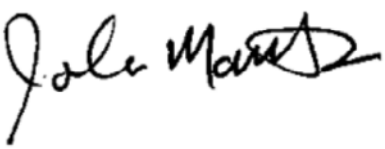
Institutions have been a basic building block of the way societies organize human interactions with our environment. Over decades, centuries, and millennia, institutions have been critical for responding to climate variability and uncertainty about future change. Ensuring that institutions are climate-adaptive is vital not only for the resilience of those institutions themselves, but also for how our economies and societies might adapt in the future. When climate, ecosystems, economies, and societies are all shifting rapidly, the resilience of institutions—in coping with change or re-organizing when needed—will determine our ability to be good stewards to the ecosystems that we value so dearly.

Human history has many examples of both successful and unsuccessful responses to climate variability and change. Therefore, the question may be framed simply: What are the qualities of institutions that make them successful in adapting to climate change?

This question sparked great interest and lively debate at a conference session organized by WWF, IUCN, and Conservation International during the 2010 Stockholm World Water Week. The enthusiasm of participants became the initial inspiration for *Shifting Course: Climate Adaptation for Water Management Institutions*, which is the first systematic contribution towards developing, sharing and operationalizing guidance for how to make institutions more climate-adaptive.

Both headlines around the world on extreme climate events as well as the basic physics of climate tell us that climate change is water change. Responding to drought, floods, storms, glacier retreat and sea-level rise all depend on managing water adaptively. For this reason, while this report focuses on water resources institutions, it provides a basis for understanding how a broader range of institutions can respond to the complex set of issues related to climate change adaptation. The report provides an overview of the current state of thinking on climate-adaptive institutions. It outlines a set of relevant principles, and describes the importance of these principles and how they relate to one another through discussion of five case studies.

Shifting Course is the first step in a journey towards ensuring that our institutions are better prepared to respond to the fundamental challenges posed by climate change, and that therefore our societies can be resilient to climate change. The test now will be how effective we are in moving from understanding the issue to taking concrete action that will safeguard communities, economies and ecosystems.



John Matthews, PhD
Director, Freshwater Climate Change
Conservation International

Mark Smith, PhD
Director, Global Water Programme
International Union for Conservation of Nature

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1. Introduction

Institutions are fundamental in helping communities, ecosystems, and economies to manage and adapt to climate change. But while institutions have long dealt with climate-related stresses, accelerating rates of change and increasing uncertainties are moving environmental processes beyond human or ecological frames of reference.

This report attempts to provide an answer to the question: *What qualities do institutions possess that make them capable of successfully adapting to climate change*? While there is no panacea, we believe that there are common principles that underpin climate-adaptive institutions. Given that alterations in hydrological patterns are the cornerstone of how we will experience climate change impacts, we look specifically at water institutions.

Section 2 seeks to develop a better understanding of the challenges that actually face water institutions. How is climate change affecting water resources? What are institutions, and why are they important for managing change? And what are the key climate-related challenges facing institutions that manage water?

Section 3 explores some of the existing literature on adaptation that may be useful in considering the question of what makes an institution adaptive. Section 4 posits 15 principles of climate-adaptive institutions, and analyzes them through five case studies (included in Appendix 2) from different geographical and institutional contexts. Section 5 offers some concluding thoughts about next steps for research and action.

2. Climate Change, Water and Institutions

2.1 Climate Change as Water Change

Although the climate debate is often centered on temperature, water is what will determine whether a community (a village, city, or region) or ecosystem can survive and thrive.[1] Water is the medium through which climate change impacts are being felt[2] and will be experienced. Climate change will ultimately come down to changes in water **timing** (when water is delivered – seasonality, monsoon, etc.), **quantity** (how much water is available – floods and droughts), and **quality** (how well the water is suited for consumption or use). That means that water has become an important potential platform upon which to shape sustainable climate change solutions.

Climate change is a threat multiplier.[3] Water managers, farmers, and other stakeholders are used to dealing with seasonal and yearly variation, but climate change will shift weather and water patterns with greater frequency and to greater extremes. Future situations will be substantially less manageable and less predictable,[4] exacerbating underlying stresses and presenting new risks. Increased drought and flood recurrence and duration, higher variability of precipitation patterns, increased hurricane intensity, changing trends in snowpack, and generally accelerating rates of glacier melt will be experienced.[5]

This alteration (shifts in timing and averages) and intensification (increasing number and severity of extreme events) of the hydrological cycle will change seasonality, and water temperatures and alterations in precipitation patterns will affect water quality. Dissolved oxygen levels, concentration of pollutants and levels of toxic algae, and sedimentation will all change, which mean impacts on aquatic species that will not only have health and sustenance implications but also economic consequences.

1 Matthews & Le Quesne, 2009; Le Quesne, et al, 2010
2 IPCC, 2007
3 Downing, 2009
4 IISD, 2006
5 IPCC, 2007. This often leads to increased runoff in the short term, followed by decreased runoff in the long term.

Box 1: Key Concepts

Vulnerability is the extent to which a system is susceptible to and unable to cope with conditions that adversely affect its well-being, such as climate variability and extremes.[i] Vulnerability is made up of three components[ii]: *Exposure* is the degree to which something experiences a climate change–related stress; *sensitivity* is the degree of impact that a stressor has on something; *adaptive capacity* is the ability to respond to, create, and shape variability and change in the state of the system.[iii]

Resilience is the ability of a system to absorb disturbances while retaining the same fundamental structure, function and identity, including the capacity to adapt to stress and change, through either recovery or reorganization in a new context.[iv]

Adaptation is a "process, action, or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage, or adjust to some changing condition, stress, hazard, risk, or opportunity."[v] Adaptation strategies therefore aim to reduce vulnerability and increase adaptive capacity.[vi]

Maladaptation is adaptation that does not reduce vulnerability, but instead exacerbates it.[vii] A simplistic example would be responding to higher summer temperatures by turning up the air conditioning. By definition, increasing greenhouse gas emissions is maladaptive.[viii] Promoting only the kinds of adaptation that reduce vulnerability and build resilience is a challenging and complicated process.[ix]

i Plummer & Armitage, 2010
ii IPCC, 2001
iii Chapin et al, 2009
iv Chapin et al, 2009
v Smit & Wandel, 2006, p282
vi UNECE, 2009
vii Rappaport, 1977
viii Barnett & O'Neill, 2010
ix Wilbanks & Kates, 1999; Adger et al, 2005; Orlove, 2005

Responding to these changes is essential: Even if greenhouse gas emissions cease tomorrow, the time lag in the climate system is likely to imply an increase in global temperatures by at least 2°C by the end of the century.[6] Concepts such as vulnerability, resilience, adaptation, and maladaptation help us to characterize this challenge and potential responses to it (see Box 1).[7]

2.2 Institutions

What Are Institutions?

Institutions are broadly defined as rules, or sets of rules, that structure social interaction by shaping or constraining actor behavior.[8] In the context of natural resource management, institutions can be seen as laws, regulations, policies and property rights that define ownership, disposition and use rights to a natural resource, as well as the policies for protection and exploitation of a resource.[9] In a narrower sense, institutions are commonly perceived as being synonymous with organizations (e.g., national ministries, sub-national agencies, multi-stakeholder management entities and planning departments).

For the purposes of this report, we focus on formal institutional bodies.[10] We are interested specifically in institutions that influence how people interact with water resources. However, we recognize that informal institutions undoubtedly influence these more formal institutions. While some overlap is unavoidable, we attempt to demarcate and highlight the broader institutional processes where relevant. In this report and the accompanying case studies, we focus our discussion of water institutions primarily on entities that are responsible for the management and provisioning of water resources either at the basin level or within a political boundary (e.g., water boards, commissions, agencies, public/private providers and the like).

Why Are They Important?

Institutions have the potential to demarcate responsibilities between actors, mediate trade-offs between actors and interests, minimize jurisdictional overlaps or deficiencies, cross political and natural boundaries, match responsibilities, and serve as authorities and facilitators of action.[11] Institutions can play a vital role in the way a country or region adapts to climate change, and can be fundamental for building resilience in communities and markets, and in protecting ecosystems and biodiversity.

Water institutions are at the center of how society interacts with its water, and provide a variety of ecosystem goods and services. They maintain environmental integrity and smooth the variability in water supply and delivery to meet human needs (in the past due mainly to seasonality and weather patterns, but now due also to climate change). They have at their disposal hard infrastructure such as dams and levees, and can also bring into play rules and laws that govern scarce resources, such as withdrawal permits, ownership rights, treaties and rule curves.

Water institutions are thus critical to how we manage climate change, which makes it important to ensure that those institutions are themselves resilient to climate change. Water institutions carry out a number of functions that are likely to be affected by climate change,[12] including allocating water resources; implementing and managing water infrastructure; defining and implementing flood management policies; and protecting, monitoring and assessing the quality and quantity of water resources. In particular, there are several key climate change-related challenges that will affect these functions and to which these institutions must respond.

6 IPCC, 2007
7 Smit & Wandel, 2006
8 North, 1990; Knight, 1992
9 Ostrom, 2007
10 Institutions are often defined as being formal or informal. Formal institutions tend to have their rules enforced by a state actor and are openly codified and officially accepted (e.g., legislation, resource ministries, basin management organizations). Informal institutions convey socially shared rules that may be self-enforcing or enforced outside of official channels (e.g., legislative norms, bureaucratic norms, judicial norms, traditional culture and personal networks). Informal institutions can be as influential and shape behavior as effectively as formal institutions, and thus they often play an important a role in natural resource management (Helmke & Levitsky, 2003).
11 GWP, 2000
12 IPCC, 2007

2.3 Key Challenges

Spatial scale. Though scientists may see an entire watershed as one ecological unit, many institutions that make decisions on water-related projects often operate within political boundaries that do not reflect the physical boundaries of a watershed.[13,14] Furthermore, the individuals within the same watershed may identify themselves as upstream or downstream, or as citizens of one country or another. Additionally, adaptation plans tend to be focused at the national level, while the impacts of climate change are largely felt at a local level. Spatial scale is particularly challenging because of recurrent imbalances in power, such as the interplay of natural and economic resources between upstream and downstream water users. Adding to the complexity of decision making is the fact that some residents are widely separated from the immediate consequences of water change, while others are intimately connected to every day's rain or irrigation. Addressing these challenges is vital in navigating toward more sustainable and adaptable water institutions.[15]

Temporal scale. Climate change can be viewed as the "great accelerator,"[16] speeding up processes of change and moving environmental change beyond human or ecological frames of reference. Climate change exacerbates the usual variation, rendering future situations less manageable. In addition, some societies or governments are in such a state of flux that they cannot make any decisions that last longer than a few months. Institutions face the challenge of managing resources consistently while also being adaptive to the increasing variability of climate change.

Societal scale. Adaptive actions are inextricably linked with regulatory structures, property rights, and social norms.[17] Issues like gender, class, educational opportunities, and traditions cannot be ignored when designing adaptive responses to climate change. Institutions must improve the vertical integration of adaptation[18] and solve the disjuncture between the scale at which adaptive actions tend to take place and the scale at which decisions about adaptive actions tend to take place.

Non-stationarity. The increasing uncertainty of future conditions, or "non-stationarity,"[19,20] implies that water institutions cannot approach the future based on the assumption that it will replicate the relatively stable conditions of the past Institutional processes that were designed in a context of stationary climate may not be equipped to address significant uncertainties around future climate.

For instance, increased uncertainties in hydrological patterns at regional and local scales will challenge institutions that have codified rules on allocation amounts, periods or sectoral distribution based on parameters that may no longer be relevant. Without a degree of flexibility, greater uncertainties and the increasingly indeterminate nature of risks and large-scale events[21] (e.g., years of drought followed by extreme flooding) from climate change may severely challenge the fixed rules and regulations that define many water institutions and may lie beyond current planning practices. Box 2 gives a well-known example from the western United States.

Synergistic impacts. We have moved into the "anthropocene,"[22] a period in which human actions play a major role in shaping biospheric processes[23]. Physical processes can no longer be examined in isolation; human processes have become the dominant driver.[24,25] For that reason we must look at the effect of climate change not just on the natural world, but on social-ecological systems, which represent the interrelated nature of the resources and ecosystem services upon which humanity relies, as well as the human activities that influence

13 De Stefano et al, 2010
14 Wolf et al, 2003
15 Hill & Engle, in review
16 IISD, 2006
17 Adger et al, 2005
18 Dovers & Hezri, 2010
19 Milly et al, 2008
20 Kiang et al, 2011
21 Dovers & Hezri, 2010
22 Crutzen, 2002
23 Olsson et al, 2004 (a)
24 Folke et al, 2005
25 Olsson et al, 2004

Box 2: The 'Law of the River'

The Colorado River Basin spans seven U.S. states and is a critical source of water for the U.S. and Mexico, and for countless species and habitats throughout its reach. Over the past century, an intensely negotiated and debated institutional arrangement has developed for governing the water resources within the basin, in the form of laws, agreements and compacts known as the "Law of the River." This institution underlies most physical infrastructure, water rights, and other planning and policy decisions for allocating the scarce water resources of the Colorado River. The original allocations between the various governing bodies involved were determined based on a historically "wet" year in 1922. Recent studies indicate that the Colorado River is currently over-allocated and will become increasingly "water stressed" as climate change influences the timing and amount of water available for humans and ecosystems.

While the institutional makeup that governs water along the Colorado River has generally proved effective for meeting multiple competing needs throughout its existence, the increasing threats of climate change and regional population growth suggest that the institution will need to adapt to these shifting realities. This is not an easy task for an institution that has operated for almost 100 years. There is some indication, however, that flexibility can occur within the institution in the face of these increasing stresses. For example, following the extreme drought period of the early 2000s, policy-makers and scientists worked to amend the original 1922 Colorado River Compact to renegotiate and clearly identify allocation guidelines during periods of water shortage. This amended agreement is known as the 2007 Colorado River Shortage Agreement. Adaptive mechanisms of this nature will be needed to ensure the flexibility of the institution to continue to prepare for and respond to the threats of climate change.

Sources: NRC, 2007; Cayan et al, 2010; Seager & Vecchi, 2010

these ecological dynamics.[26] Climate change should therefore be seen as an "exacerbator" of the existing challenges that already confront water institutions.[27] Population growth, development and diminishing water supply due to current climate variability are already stressing the availability of high-quality water resources. Climate change generally represents an overarching pressure that causes these underlying stresses on water institutions to become even more pronounced as impacts intensify.[28]

To summarize: Many of the institutions that manage rivers, wetlands, lakes, and glaciers use approaches that were developed over a relatively stable period. Most are not ready for these growing challenges.[29] And, of course, we must recognize that institutions exist in a social reality and that climate change is not their only responsibility. Water institutions often find themselves in a tug-of-war between responses to competing threats. Sometimes, rather than the lesser of two evils, water institutions find themselves choosing between the lesser of two goods: What if reducing greenhouse gases means increasing the use of hydro power, which takes water from the environment? What if releasing water to the environment means that farming becomes less sustainable? Climate change means that the way we evaluate water institutions must change as well. We must ask different questions and use different frames of analysis to determine if those institutions are working effectively.

26 Berkes et al, 2003
27 De Stefano et al, 2010
28 Lettenmaier et al, 2008
29 IPCC, 2007

3. Stepping Stones

We need adaptive institutions that can respond effectively to the climate-related challenges outlined above. This section briefly discusses several areas of existing research that are useful stepping stones toward addressing that need. The water resources and research communities have in recent years focused on better understanding adaptive processes[30] and ways to build institutional adaptive capacity in the water sector (e.g. integrated water resources management, adaptive management and adaptive governance).[31]

Adaptive capacity has been defined as the ability to respond to, create, and/or shape variability and change[32]; or as the preconditions needed to enable adaptation, including social and physical elements, and the ability to mobilize these elements.[33] A number of studies have proposed that more flexible, participatory, experimental, collaborative and learning-based designs and approaches will increase the adaptive capacity and sustainability of water systems.[34]

30 Pahl-Wostl et al, 2007

31 Yohe & Tol, 2002; Adger et al, 2005; Brooks et al, 2005; Smit & Wandel, 2006; Eakin & Lemos, 2006

32 Chapin et al, 2009

33 Nelson et al, 2007

34 Kallis et al, 2006; Cromwell et al, 2007; Pahl-Wostl et al, 2007; Tompkins & Adger, 2004; Pahl-Wostl 2007

Adaptive governance is closely related to adaptive capacity; it is a move from the conventional view of institutions as "static, rule-based, formal and fixed organizations with clear boundaries" to a view of institutions as "more dynamic, adaptive, flexible… for coping with future climatic conditions."[35] If adaptive capacity is an end goal, then adaptive governance can be seen as a means to that end. Within the context of river basins, for instance, greater attention is needed to understanding and managing a transition from current management regimes to more adaptive regimes that "take into account environmental, technological, economic, institutional and cultural characteristics of the basin."[36]

Adaptive management is a well-established approach that focuses on methods such as learning by doing, social learning and scenario planning. These methods allow greater flexibility, which improves the connectivity between different processes and scales. Good adaptive management builds a community of institutional learning that takes place at the collective rather than the individual level,[37] drawing from the memories and experience of the entire institution and carrying this wisdom forward into the future.

35 IISD, 2006, p5

36 Pahl-Wostl et al, 2007, p49

37 Berkes & Folke, 2001

4. What Makes Institutions Climate-Adaptive?

4.1 Principles

In the previous section, we discussed some areas of existing research which provide a starting point for identifying the characteristics of climate-adaptive institutions. While there is no template for how future water institutions should look,[38] we have identified a number of principles for climate-adaptive institutions (Table 1), informed by the literature[39] and cases, that seem to be consistent across many situations and which may be useful for the process of making institutions more adaptive to climate change.

Most of these principles could apply to natural resource management institutions in general; however, here we specifically emphasize their applicability to water institutions. The principles should be viewed as working hypotheses: characteristics that are assumed to be important for climate-adaptive institutions. We expect that these hypotheses will be developed further through a growing body of comparative case study research and testing in the future.

We roughly divide the principles into those that are internal, external, or both.

> *Internal (I):* Conditions within an institution over which it has a certain degree of control and that support/hinder it to adapt.
>
> *External (E):* Conditions outside an institution and its capacity to control them, but that support/hinder it to adapt.

We have further refined and evaluated these principles in the context of water institutions through a set of five case studies, which are listed and briefly summarized in Table 2. The cases were selected for their perceived geographical and institutional diversity.

The full versions of these case studies are included in Appendix 2; reading the full cases is highly recommended, since the following discussion only draws upon them briefly.

In the following sections, we provide illustrations from the case studies where these principles are demonstrated (or not) with greater (or lesser) adaptive success. Each case study author was asked to fill out a table analyzing their case in terms of each principle, and to select and further analyze the three most important principles for that case. A sample principle analysis table is included in Appendix 1.

4.1.1 External Regime

The institution is granted authority and a mandate to act appropriately. Authority to enforce, or "teeth," is required to ensure that mandate is carried out effectively, both internally and externally. Contradictory or overlapping policies, regulatory frameworks, mandates or other external conditions may constrict institutions and directly impact their internal operations and ability to adapt.

In the SEA case: The São Paulo Climate Change Policy was the driver for an internal restructuring of the Secretariat of Environment, since the state government has the mandate to coordinate and implement the policy. The existence of such a legal framework is an important prerequisite for the development of an appropriate institutional framework and for the establishment of underlying conditions such as financing. The new state administration has utilized the Pacto das Águas ("Water Deal") in order to begin preparing for the impacts of climate change. The Pacto was considered a powerful platform by the past government, and the new administration has just established a permanent structure to advance this statewide effort.

38 Meinzen-Dick, 2007

39 Yohe & Tol, 2002; Cash et al, 2003; Olsson et al, 2004 (b); Brooks et al, 2005; Folke et al, 2005; Pelling & High, 2005; Eakin & Lemos, 2006; Pahl-Wostl, 2007; Pahl-Wostl et al, 2007; Medema et al, 2008; Huitema et al, 2009; Bussey et al, 2010; Engle & Lemos, 2010; Gupta et al, 2010; Engle et al, 2011; Wilby & Vaughan, 2011

Table 1: Principles of climate-adaptive institutions

#	I/E	Principle	Description
1	E	External Regime	External environment (e.g., policies, legal frameworks, etc.) supports or does not constrain the institution's ability to adapt proactively and effectively to climate change; and grants the authority and enforceability to carry out its actions
2	I/E	Flexible Resource Management	Managing resources (e.g. water) more flexibly due to uncertainty and the need to become more adaptable to climatic variability
3	I/E	Resources	Possesses sufficient financial, technological, informational (e.g. data) and human resources; the ability to generate and engage those and future resources effectively; and the ability to allocate or use resources flexibly and swiftly
4	I/E	Legitimacy and Accountability	Is accountable for its actions, transparent in its dealings, and well received and respected within the community. Public perceives the institution as both responsible and trustworthy.
5	I/E	Variety and Diversity	Promotes the development of a diverse, heterogeneous range of proactive strategies, measures and actions
6	I	Monitoring and Evaluation	Uses monitoring and evaluation objectively to assess the effectiveness of the institution's operations and programs
7	I	Identity	Possesses a strong but fluid organizational purpose, vision, set of responsibilities and priorities
8	I	Forward Thinking	Thinks ahead to what the future may bring and tries to incorporate some of this thinking into plans, strategies and operations
9	I/E	Iterative Approaches	Encourages cyclical approaches to project, program or policy design and management such that the institution is able to respond to change through an ongoing process of incremental adjustments in a time frame relevant to both the physical and institutional setting
10	I	Mainstreaming	Incorporates climate change adaptation into all institutional operations
11	I/E	Creativity and Learning	Has a culture of experimentation, learning and innovation that encourages the development, testing and adoption of new approaches to climate change
12	I/E	Internal Agency and Autonomy	Some degree of autonomy within the institution that allows individual staff to carry out responsibilities and make decisions in a way that minimizes bureaucratic barriers and delays The institution itself has autonomy to act in adaptive ways; this is dependent on a supportive external regime
13	I/E	Collaboration and Partnerships	Engages in partnerships and collaborative networks with other organizations
14	I/E	Leadership	Has a visionary champion(s) who identifies and implements a strategy for addressing climate change and inspires others to follow that strategy
15	I/E	Transparency and Participation	Operates internally and with external stakeholders in an equitable and transparent manner. Guarantees access to information to all stakeholders, and fosters a culture of openness and fairness in its operations.

Table 2: Case studies

Institution (Abbreviation)	**Location**	**Brief Description**	**Main Drivers of Change**
Murray-Darling Basin Authority (MDBA)	Australia	The Murray-Darling Basin Authority was established in 2007-08 by the Water Act adopted by the Australian federal government. The Act establishes a process for adopting a "sustainable diversion limit" and centralized management through the new Authority, while the states retain local management capacities.	The Murray-Darling Basin has been extensively exploited for human use. The river mouth was closed from 2002 to 2010 due to overextraction and climatic variability. Its ecosystems have been extensively impacted by habitat conversion for agriculture, exploitation for water resources and invasion by exotic species. Its climate is extremely variable, oscillating between droughts and floods, with the recent Millennium Drought leading to the loss of floodplain forests and other wetlands and severe consequences for water quality.
Pangani Basin Water Board (PBWB)	Tanzania	The Pangani Basin Water Board ensures that the Pangani River is managed sustainably while maximizing the resultant economic and social welfare through better water governance and integrated water management principles. The Board is composed of ten members drawn from public institutions, sub-basin water committees and private-sector water users.	There have been decreases in rainfall during the dry season (May–October), increases in evapotranspiration and in rainfall during the wet season, and overall shifts in seasonality. Population growth and the intensification of land use for agriculture and urban growth have led to an overexploitation of water resources and increased the demand and competition for water among land users, industry and ecosystems.
U.S. Army Corps of Engineers (USACE) -Reservoir Operations	USA	The U.S. Army Corps of Engineers is responsible for a variety of water resource–related missions in the United States, including coastal protection, disaster preparedness and response, environmental protection and restoration, flood protection, hydropower, navigable waters, recreational opportunities, regulatory oversight, and water supply.	Increases in heavy downpours, rising temperatures and sea level, rapidly retreating glaciers, thawing permafrost, lengthening growing seasons, lengthening ice-free seasons in the ocean and on lakes and rivers, earlier snowmelt, alterations in river flows, and drastically changing land-use patterns and increasing populations are the key drivers of change. They affect reservoirs operated by the Corps, many of which were designed and constructed before climate change was recognized as a potential influence.
Water and Energy Commission Secretariat (WECS)	Nepal	The Water and Energy Commission Secretariat's core function is to act as an apex institution to coordinate national-level planning within Nepal's entire water resources sector, including formulating policies, strategies, and analysis on various aspects of water resources and energy development; enacting laws pertaining to the development of water resources and energy; and coordinating among existing national water and energy policies.	Increases in temperature are leading to drought, drying up of spring sources, and rapid glacial melt that will reduce long-term dry-season water supplies. The South Asian monsoon is becoming increasingly variable, with fluctuations in seasonality and short-term changes in flows contributing to erosion, landslides, and flooding from intense rainfall events that occur after long periods of drought. WECS will have to plan for this greater supply variability and increased frequency and potency of extreme events, which affect water infrastructure development.
São Paulo State Secretariat of Environment (SEA)	Brazil	The Secretariat of Environment is responsible for implementing São Paulo state's climate change policy. As part of this institution, the Water Resources Technical Advisory Team is coordinating water-related adaptation efforts.	The São Paulo urban area is expected to double in size by 2030. Climate vulnerabilities, such as flooding and landslides, are expected to grow proportionally; a significant portion of the area will be susceptible to extreme climate events such as higher rainfall.

In the PBWB case: The ability of ministries to implement and enforce the 2002 National Water Policy and Water Resources Management Act and to reconcile the interests of traditionally powerful sectors with the interests of the more vulnerable water users has proved to be crucial for the Water Board. Both the policy and act were essential in providing for the different water requirements and benefits to be equitably considered and periodically reviewed within the framework of what is actually available.

In the WECS case: Climate change may have benefited the organization by providing a more powerful institutional mandate and authority (beyond the current critical need for more coordinated water resource management). However, the lack of statutory authority has severely harmed WECS efforts to better coordinate the water sector around a coherent strategic plan in the face of already occurring climate change. Until such statutory authority is granted, WECS will continue to struggle to meet its mandates in the face of a changing climate.

In the MDBA case: The external policy framework that drives the major institutional framework in the basin, the Federal Water Act, is the Ramsar Convention on Wetlands (an international environmental treaty to which Australia is a signatory) because it provides a constitutional mandate for federal government intervention. This has led to equal, if not greater, emphasis on environmental outcomes in the basin, which are often overlooked in institutions that are not necessarily climate-adaptive.

On the other hand, the Australian National Water Initiative states that future climate change–induced reductions will be borne by consumptive users whereas the Authority proposes to share losses between the environment and users, demonstrating the limits to external regulatory factors for enabling adaptive institutions. But the Water Act does not include third-party enforcement provisions. While the federal government must accredit state sub-basin implementation plans and in theory could write its own if the states fail to do so adequately, in practice it is hard to see how the federal government could effectively supplant the states in day-to-day local management.

This means that further compromises are likely with the states: Already, the federal government has compromised through lower water reallocations proposed for the environment, delayed implementation, and increased funding for state water infrastructure projects. Future compromises may include accepting low-quality state catchment plans, redefining environmental outcomes, smaller climate change adjustments, and more funding for questionable state projects. A major gap in the Australian system is a provision for noncompliant states to be taken to court.

4.1.2 Flexible Resource Management

The ability to flexibly manage (e.g., allocate and reallocate) resources like water in the face of variability, uncertainty, and extreme events is vital.

In the MDBA case: Despite some drawbacks, the Australian water market system does enable water to be readily transferred where funds are available, for instance, from irrigation to the environment. The Commonwealth Environmental Water Holder (CEWH) is permitted to buy and sell water entitlements to benefit the environment. For instance, it could sell environmental water for irrigation when the price is high and the ecological need low, so as to acquire water later when that ecological need is high.

4.1.3 Resources

Adequate financial and human resources (experience and expertise), as well as technological and informational resources, effectively and efficiently deployed, allows an institution to quickly react to an event, allocate or use resources more flexibly, or better prepare for unpredictable hydrological situations.

In the MDBA case: A situation is playing out in which a lot of federal government funds have been provided but spent inefficiently. In the current round of reforms, the federal funds have been used to buy political support from state governments by funding populist projects at the expense of changes to most effectively adapt to climate change.

In the SEA case: The new state administration now sees the need not to only set goals for emission reductions, but to advance the adaptation agenda by investing in human resources, training and capacity building within the Secretariat of Environment.

4.1.4 Legitimacy and Accountability

Ensuring that institutions are accountable to the full range of water stakeholders can improve their legitimacy within the scale of operation, allowing greater capacity to fulfill duties in "normal" periods as well as make difficult decisions in more extreme periods.

In the MDBA case: While the Authority and Plan have a clear mandate since the legislative process was adopted with bipartisan support (and the Authority and Plan are accountable to the Federal Parliament), the Authority has squandered its legitimacy through an overly technical, back-room planning process that did not adequately engage stakeholders. Ultimately, in such a large river basin, a federal government authority must gain the consent of more local stakeholders and institutions to effect detailed management on the ground, and the Authority has not yet demonstrated that it has the capacity to do so -- potentially undermining longer-term adaptability to mounting pressures in the basin. The danger is that key stakeholders in the basin resist and frustrate adaptive measures rather than engage new ideas and come to own and help implement the necessary changes.

4.1.5 Variety and Diversity

Acknowledging that there is no single best-fit ideological framework, optimal policy strategy, or set of mutually consistent solutions to a given problem or challenge.

In the USACE case: The pilot study approach reflects the importance of integrating scientific research on climate impacts with on-the-ground projects. In particular, using multiple general circulation models is useful in developing different scenarios (including worst-case scenarios) to aid adaptation planning for reservoir operations. Importantly, this modeling process is being linked with other processes (e.g., scenario development) and is not considered a one-off solution to planning for climate change. However, due to the longer-term time horizons needed to implement the projects, it is too early to tell if these pilots are proving effective.

In the MDBA case: By contrast, overreliance on downscaled modeling may prove unhelpful in the basin, given the wide range of forecast potential outcomes. Focusing on modeling outputs alone may stifle adaptive decision making. Furthermore, the Authority's focus on water quantity, while essential, excludes other important adaptation options, including retention of free-flowing surface and groundwater systems, riparian restoration and reoperation to reduce the impacts from infrastructure.

4.1.6 Monitoring and Evaluation

Monitoring, assessment, evaluation and reporting are important tools for identifying when current policies or programs become ineffective or obsolete, or require change to fulfill their mandates. In addition, monitoring networks provide valuable information (water quality, quantity, etc.) upon which both short- and long-term management decisions should be made, while independent verification through external assessment and evaluation can provide vital accountability for plans and management strategies.

In the MDBA case: Key aspects of water management that enhance monitoring and evaluation are overseen by federal entities such as the independent National Water Commission and other key institutional actors (e.g., the Bureau of Meteorology for water accounting, Australian Competition and Consumer Commission for regulating the water market and the Commonwealth Environmental Water Holder for managing federal ecological water holdings). A particularly positive aspect of these monitoring and evaluation efforts is that they are performed by federal entities, giving them more credibility and accountability.

In the PBWB case: Technical information on the ecological, social and economic status of the basin was vital in supporting the implementation of environmental flow provisions, so that the focus could switch to

stakeholders and the government agreeing on how best to reallocate water. Although this may have seemed a protracted process without prescriptive outcomes, the chosen allocation scenario will be integrated into the basin's water management plan, which is legally binding. A monitoring program that is part of the plan aims to ensure that the desired river state is being achieved and maintained despite climate change.

4.1.7 Identity

The capability to shift organizational purpose, vision, mandate and priorities over time, and to reevaluate strategies and approaches periodically, can allow an institution to adjust and respond to climate change. However, a clear purpose with visible boundaries provides a strong sense of institutional identity. A fine balance thus needs to be struck between flexibility and rigidity.

In the USACE case: The Corps operates under a clear vision and mission that embrace adaptation activities. The Corps' Climate Change Policy and Responses to Climate Change (RCC) Program provide a framework within which to develop concrete activities to implement adaptation solutions.

In the MDBA case: The Authority's "environment first" legal mandate is well directed to sustainability. However, this mandate is somewhat undermined by political compromises that propose to give equal weight to economic and social aspects, thus confusing the culture, identity, purpose and vision.

4.1.8 Forward Thinking

Incorporating uncertainty into planning (e.g., scenario planning for multiple climate futures) can allow an institution to envisage and better prepare for future expected and unexpected climate impacts.

In the USACE case: The Corps initiated the Responses to Climate Change (RCC) Program,[40] which utilizes scenarios as a way to help develop

40 The RCC Program aims "to develop, implement, and assess adjustments or changes in operations and decision environments to enhance resilience or reduce vulnerability of USACE projects, systems, and programs to observed or expected changes in climate developing and beginning to implement approaches and policies to reduce
potential vulnerabilities to the Nation's (US's) existing water infrastructure resulting from climate change and variability."

planning and engineering guidance that ensure future infrastructure is designed to be sustainable and robust.

In the MDBA case: The legislation establishing the Authority and Plan requires the institution to manage a range of future threats to water availability, specifically including climate change (although the Authority is currently struggling to understand this mandate, and political compromises could jeopardize this goal).

In the PBWB case: Technical information generated from a flow assessment study was used to organize ecological, social and economic knowledge of the basin through a set of development scenarios. These scenarios depicted many possible pathways into the future, some of which looked at how climate change might affect the basin's water resources. There is now an increased understanding of the environmental, economic and social implications of different river flow scenarios under expected climatic conditions, and increased capacity to collect and analyze such information across the water and climate change sectors. The focus now switches to a process within which stakeholders and the government will agree on how best to reallocate future water resources, as informed by these scenarios.

4.1.9 Iterative Approaches

An iterative or cyclical approach to planning emphasizes the use of monitoring and evaluation to inform future operations. This allows an institution to absorb new learning and knowledge into existing plans and account for both social and institutional learning.

In the MDBA case: The Basin Plan is to be revised at least once every 10 years, which should greatly aid adaptive management, including the need to revisit areas that were poorly understood or where compromises had been made in the initial Plan.

In the USACE case: Policy suggests that the Corps update reservoir Water Control Manuals every 10 years. However, these updates are often delayed by the lack of congressional funding (sometimes manuals are 50 years old, without having been updated). In addition, attempting to update a manual can result in a long process fraught with conflict among the stakeholders impacted by the reservoir's operations. For example, a recent effort to update the Missouri River's manual took 15 years and cost millions of dollars, in part due to an inability to reach agreement with the various stakeholders.

4.1.10 Mainstreaming

Rather than setting up a separate adaptation program or department, an institution integrates adaptation into different units to fashion a more holistic response to climate change. Mainstreaming also implies applying a systems approach to consider how climate change impacts the different aspects of an institution's activities.

In the MDBA case: Through the Authority, all the states within the basin are forced to integrate adaptation planning and implementation. While they may not be doing the analysis or making the final decisions, they are the ones responsible for developing and implementing the decisions set forth by the Authority. The Authority is required to set a sustainable diversion limit (SDL) for water allocations that provides for climate change, and this SDL is then broken down by sub-basin. Consequently state governments and their tributary catchment management authorities are required to mainstream implementation of climate change adaptation in their water management activities. However, the Authority is still struggling with how to approach and understand adaptation, signaling that it has a long way to go to fully mainstream climate change.

4.1.11 Creativity and Learning

Creates an explicit space for improvisational approaches in which change occurs through experimentation, learning and unplanned responses to contingencies. Increased creativity can allow climate change to be treated less as an obstacle to continued success and more like an opportunity to transform existing processes, structures and operations. Encouraging a culture of social and institutional learning (including from experience) can allow institutions and

actors within them to question embedded ideologies, frames, assumptions, claims, roles, rules and procedures.

In the USACE case: The RCC Program began sponsoring various climate change adaptation pilot studies in 2010. The goals of these initial pilots are to 1) test and evaluate the Adaptation Process Framework proposed by the Council on Environmental Quality; 2) develop and demonstrate innovative methods, strategies, policy and technologies supporting climate change adaptation; and 3) build USACE district capacity in the professional and technical competencies important in climate change adaptation.

Future pilot studies will focus on evaluating and testing approaches, frameworks and guidance for incorporating climate change into USACE district life-cycle decision making. The outcomes from such studies will be invaluable for understanding how the Corps could adapt to climate change. Lessons learned will be incorporated into Corps guidance (including Engineering Regulations and Engineering Technical Letters) and will inform future updates to Water Control Manuals. Current pilot studies have already been useful in identifying issues that should be covered in future guidance.

In the MDBA case: There has been a mixed record of innovation and learning. One criticism has been that the Authority has so far narrowly focused on environmental flows as an adaptation panacea. However, innovative modeling and water accounting approaches have been applied and the environment has been treated as a water end user, with allocations being bought and sold where this is ecologically advantageous.

In the PBWB case: There were considerable challenges for the institution to take into account environmental water allocations. The Environmental Flows Assessment was one of the most pioneering and resource-intensive components of the Pangani River Basin Management Project (PRBMP). The aim was to better understand the hydrology of the river basin, the flow-related nature and functioning of the river ecosystem, and the links between the ecosystem and the social and economic values of the river's resources as a means to adapt to shifting climate and water demands. Additionally, collaborative projects have enabled co-learning from the joint analysis of vulnerability assessments conducted in several villages, for both the institution and water users in general (through dissemination and community consultations).

4.1.12 Internal Agency and Autonomy

A measure of autonomy allows institutions to independently react more swiftly to unexpected climate-related events. Autonomy tends to be granted by the external regime, allowing the institution a measure of independence to pursue adaptive approaches and to enable its staff or departments some autonomy of their own.

In the USACE case: The Corps must have congressional approval for most activities. While this may provide a valuable check and balance, the approval process can also have negative repercussions if it delays reactive adaptation to large-scale events and shocks. For example, the ability of the Corps to alter its reservoir operations to adapt to changing and unexpected conditions is ultimately governed by the congressionally authorized purposes of the reservoir itself as well as the Water Supply Act, the Rivers and Harbors Act, the National Environmental Policy Act (NEPA) and the Flood Control Act. Changes or deviations from published regulation schedules, whether emergency, short term or long term, are possible with appropriate studies and approvals. However, the speed of implementing these adaptive measures depends on the magnitude of the changes. Also, since funding is granted on a project-by-project basis, the Corps lacks the ability to take a more systematic approach to investing in infrastructure across the nation. More flexible institutional behavior might be enabled if Congress gave the Corps authority to take a national view of its infrastructure and to spend limited funds on the infrastructure (e.g. reservoirs) most in need of operation changes.

4.1.13 Collaboration and Partnerships

Well-connected networks tend to enhance communication, favor collaboration, build social

capital and foster innovation. Working with nontraditional stakeholders will be an important part of climate change adaptation efforts in the future. Networks and partnerships for information sharing and research also provide opportunities for the exchange of experiences, mutual learning, and the integration of knowledge into different levels of decision making.

In the USACE case: The Corps does much of its climate change work in partnership with other organizations. Partnerships allow the Corps to capitalize on interdisciplinary expertise, avoid duplication and produce cutting-edge products that they would not have the resources for on their own. For instance, "Climate Change and Water Resources Management: A Federal Perspective"[41] was an interagency report prepared by the four U.S. federal water management agencies (the Corps, U.S. Geological Survey, Bureau of Reclamation, and National Oceanic and Atmospheric Administration) that initiated their approach to climate change. Its purpose was to explore collaborative strategies to improve water management by tracking, anticipating and responding to climate change.

In the PBWB case: Partnerships and collaboration with nongovernmental organizations have increased preparedness for climate impacts, providing support and capacity where it is lacking in local institutions. As part of the different projects, partners have carried out climate change vulnerability assessments in eight different villages, from which a list of adaptation actions were proposed and ranked by the communities. Some of these activities are now being implemented by the government of Tanzania through its local authorities, the district councils.

In the SEA case: The Pacto das Águas is a good example of sharing responsibility with municipalities and of consolidating strategic partnerships and collaborative efforts. Such a decentralized framework empowers the local authorities to take the lead on key aspects of environment and health, and allows a more effective way of achieving ambitious goals that the state alone could not meet effectively. In addition, while the SEA currently lacks both the human and financial resources required to promote sound adaptation at the state level, it has been very effective at reaching out to a strategic set of other institutions and organizations for assistance.

41 Published as USGS Circular 1331 in 2009 (http://pubs.usgs.gov/circ/1331/)

4.1.14 Leadership

Continuous and effective leadership, even in the case of high turnover (e.g., political appointees), is needed to ensure that both short- and long-term plans are made and goals met. Innovative approaches often need to be pioneered by visionary leaders to be effectively mainstreamed by an institution and to drive transformational change toward more climate-adaptive solutions and management practices.

In the USACE case: The clear leadership within the Corps and other entities within the executive branch has enabled a stronger stance to be taken on climate change preparedness and planning.

In the MDBA case: The Authority has the responsibility and autonomy to develop appropriate plans for the basin, but much depends on the quality of its leadership, which has been questioned in this initial planning process. Managing climate change adaptation in a river basin requires leaders who combine skills in science and the humanities and bring excellent capacities to communicate, facilitate and collaborate with the many stakeholders to build a common vision that generates acceptance of necessary reforms.

In the WECS case: The endemic national political instability results in a lack of continuity of leadership for the institution, which makes it extremely difficult to focus on medium- and long-term goals, especially the necessary strategic planning critical to the adaptation process.

4.1.15 Transparency and Participation

Consultation with and participation of civil society and external experts or stakeholders in the decision-making process ensure representation of a broad set of interests and allow for

consensus to be built and conflicts resolved earlier rather than later. However, participatory processes can slow down adaptation efforts if not managed efficiently and effectively.

In the PBWB case: Institutional strengthening in river basin planning has proved to be a key to more climate-adaptive water management by enabling diverse stakeholders to participate in the discovery of options and in joint action. After three years of negotiated steps and social learning, the Pangani River Basin Management Project (PRBMP) has contributed to building resilience in the basin through conflict resolution, capacity building and knowledge sharing. Hydrological models and climate forecasts are now complemented by a participatory governance system that can dynamically respond to uncertain futures.

In the USACE case: Close collaboration with The Nature Conservancy (TNC) around the Green River Lake and Dam in Kentucky ensured that the regulation schedule for the dam better accommodated downstream ecological functioning, thereby improving the resilience of the system. While this particular reoperation was done for environmental reasons, such collaboration could also help with climate change adaptation. However, in the updating of the Missouri River Water Control Manual, extensive participation led to 15 years of negotiation across different stakeholder interests -- which may not have resulted in adaptive expediency.

In the MDBA case: The Authority's planning work is transparent to the extent that technical data is publicly available, the Plan involves formal public consultation and the Authority is accountable to Parliament. Interests of most stakeholders (e.g., indigenous peoples, irrigators, the environment) are considered but perhaps inadequately addressed. However, higher standards of stakeholder participation are expected on more contentious issues (which are likely to increase as climate change impacts mount), and worryingly, the Authority has been found wanting. The multi-government commission was collaborative, but in its transition to a federal government authority this culture of collaboration has been lost, despite the formal public consultation processes. Ultimately, the Authority's mission has been jeopardized because Authority leaders have not cultivated public confidence in their work. This is likely to undermine their ability to implement tough decisions and more transformational policies that could enhance adaptive capacity.

4.2 Synthesizing across Principles

The five cases represent diverse institutional and geographic settings, yet there are some broad comparisons that can be drawn across them from this initial phase of analysis. Generally, the cases suggest that some of the principles might be more important (or at least more common) in influencing the development of climate-adaptive institutions. **External regime, resources, legitimacy and accountability, creativity and learning,** and **collaboration and partnerships** were most frequently identified within the case studies as those principles most important to the institutions in question, either through positive or negative implications for that institution's climate-adaptability. In addition, **variety and diversity**, **forward thinking**, **iterative approaches**, and **transparency and participation** emerged more indirectly through the analysis.

An interesting dynamic came through in relation to collaboration and partnerships, as well as transparency and participation, which has been noted in other studies of adaptation.[42] Participation is a fundamental element of good governance of water resources, but the complicated nature of involving multiple stakeholders in a negotiation process around scarce water resources can have negative implications for speed of adaptive response. While it is vital to ensure that local knowledge, expertise, and interests are not just consulted but actively engaged, an organization that must obtain the consensus of a large number of entities may not be able to respond quickly. The cases suggest that it is important to find a balance between the long-term benefits of negotiated solutions and faster adaptive responses. Similarly, tensions were identified between the principles of of external regime, and internal agency and autonomy. Institutions need not only long-term support from the external regime, but also the internal agency to make independent decisions in a timely manner.

Monitoring and evaluation did not receive as much attention as expected within the case study analysis. The phrase "what you measure, you manage" is highly pertinent here; having reliable water data is a prerequisite baseline from which to develop the institutional knowledge that is vital for adaptation. The decision to carry out water accounting at a national level in Australia is one positive example of this principle in action.

Leadership is another principle that many other studies have cited as a key element in driving institutions to adopt and expand the use of more innovative approaches that could enhance adaptive capacity. The lack of consistent leadership was highlighted as a significant impediment to building capacity in the case from Nepal.

Mainstreaming would imply adopting a systemic approach to climate change and elevating adaptation to an organizing principle.[43] However, in many regions, climate change adaptation is still a relatively new area for institutions, which have yet to even move from scoping and impact assessments to operationalizing adaptation strategies and modes of practice. As such, there were few good examples from our case studies.

Often, it is not one principle that is more important than another, but the interplay of multiple principles that allows institutions to move toward more integrated and adaptive approaches. For example, in Tanzania, over three years of negotiated steps (*iterative approaches*) and social learning, the Pangani River Basin Management Project contributed to making the Pangani Basin Water Board more adaptive through the piloting of WUAs (*creativity and learning*). These pilots were in turn instrumental in creating new governance arrangements whereby water users could further organize in sub-catchment forums. Stakeholders could contribute to decisions by the Water Board, integrating community-level, WUA, district, and regional concerns into basin-level planning (*transparency and participation*). As a result, hydrological models and climate forecasts are complemented by a participatory governance system (*variety and diversity*). This helps the institution dynamically respond to an uncertain future.

By contrast, in Australia's Murray-Darling Basin the ability to implement the Plan to respond to incremental climate changes (e.g., another severe drought) is

42 Engle 2010, Hill 2010, Huntjens et al 2011

43 Dovers & Hezri, 2010

low for a number of reasons. The Plan's mandate is narrowly focused on environmental flows, excluding other adaptation measures (*variety and diversity*); the envisaged 10-year timeline for changes to allocation is too rigid to deal with extreme dry events (*iterative approaches*); the political compromise that allows states to delay implementation of the 2012-13 Plan to 2019-2025 is severely limiting (*external regime*); and the Plan assumes that climate change will be linear and spatially uniform (e.g., citing a 12 percent reduction from 1990–2030 and a 3 percent reduction in 10 years), which has not been the experience from southwest Western Australia. The assumption of linear change illustrates the difficulty of translating complex science into effective policy when decision makers do not adequately understand the limits of the data that they are working with, and in particular, the degree of risk in managing for less likely but more severe climate change impacts. While there are some positive aspects to the MDBA case, there are serious limitations to the Authority's ability to adapt to climate impacts.

These principles point to the importance of creating rather than minimizing choices for water institutions. Helping an institution to "bend rather than break" in the face of new challenges should expand its adaptive capacity. Many of these principles highlight a fine balance between the internal flexibility that allows institutions to adapt to change, and the longer-term need for external mandates and regulated support. By managing resources flexibly, institutions may be able to not only cope with stresses, but also create opportunities for positive transformation out of those stresses.[44]

It is hoped that the development and discussion of the 15 principles in this report is a helpful step in understanding these complex issues for water institutions. Many of these principles support the creation of choices for these institutions by highlighting the importance of a balance between guidance (*external regime*; *legitimacy and accountability*) and leadership (*leadership; identity*) with the requisite flexibility (*flexible resource management, creativity and learning; internal agency and autonomy*) to respond to challenges in an appropriate time scale and suited to local conditions.

44 Folke et al, 2010

5. Recommendations

This report has aimed to identify and discuss a set of principles for climate-adaptive institutions that are broadly applicable across diverse geographic and institutional settings. While it is important not to draw universal causal linkages between these principles and their ability to increase adaptability based on the preliminary case evidence, the principles provide a useful starting point for further work.

From our discussion of the principles in relation to the case studies, we have identified several overlapping areas in which additional work is needed:

- Further case studies would allow more comparative critical analysis on how these issues manifest across different water institutions, and would provide deeper insight into and refinement of the principles that are most valuable across different geographies and scales.

- Indicators linked to these principles would make them measurable as a step towards transforming them into tangible operational guidance for water institutions. Growing awareness of the need for institutions to be adaptive to climate change underscores the importance of investing in the development and monitoring of institutional indicators, not just biophysical or social ones. Some initial work has gone into the development of a range of institutional indicators of adaptive capacity.[45]

- Monitoring and evaluation of these indicators against specific climate events as they occur would allow us to better understand the linkages between these principles and successful adaptation by water institutions.[46]

- Ultimately, a diagnostic tool that can help water institutions to operationalize the principles is essential. Using the cases, principles and indicators to inform meaningful and robust sets of choices for managers and decision-makers would be a crucial step toward improving the adaptive capacity of water institutions.

It has been a productive decade for research, learning and sharing a growing body of knowledge on adaptation. While this report has been an important step towards more adaptive institutions, the pressures of climate change and development on vulnerable water resources increase every day. The time to shift from research to action has arrived.

45 Engle & Lemos, 2010
46 Hill & Engle, 2011

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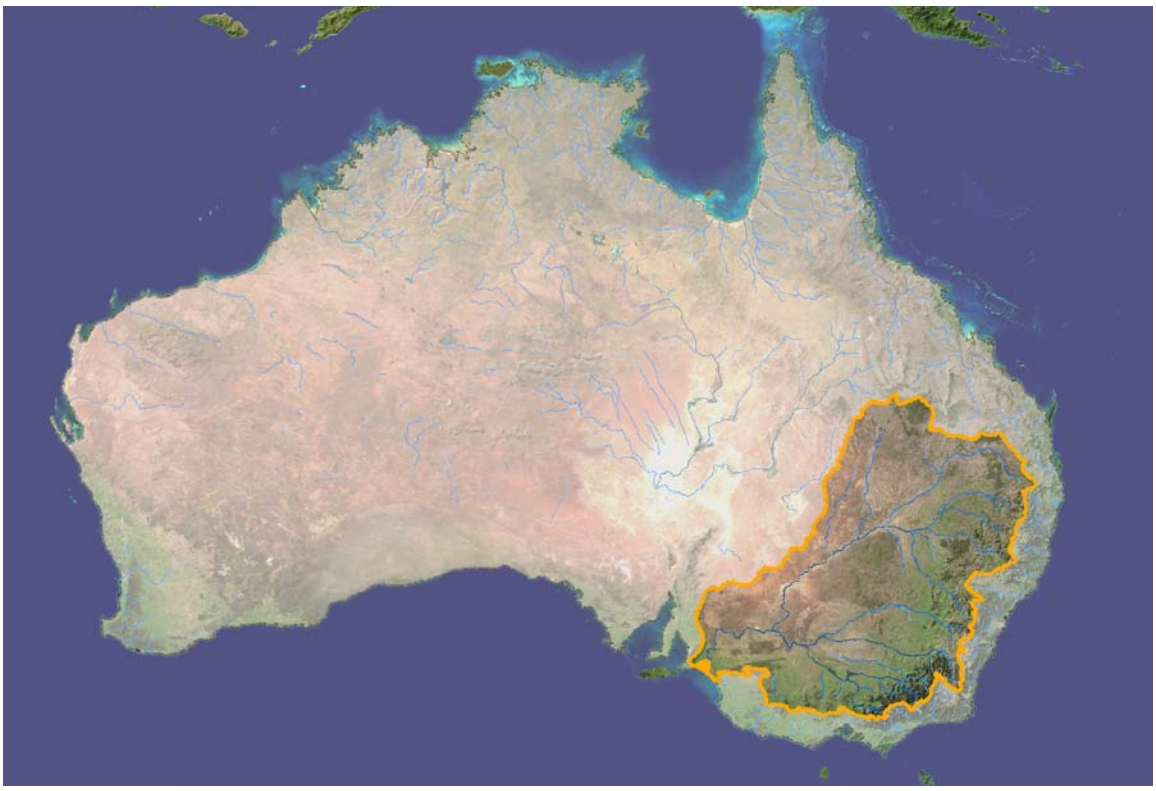
Appendix 1 | Sample Principle Analysis Table

(From Murray-Darling Basin Authority Case, Author: J. Pittock)

Principle	Discussion	Positive, Negative, Mixed	Relevance *(high, medium, low, or N/A)*
External regime	Federal Water Act is largely driven by international environmental treaties (+). There is conflict between who bears the cost of water loss from climate change. The National Water Initiative states that reductions will be borne by consumptive users, whereas the Authority proposes to share losses between the environment and users (-). Negative impacts for water management stem from lack of integrated policies with other sectors (-), e.g., climate change policies favor thirsty renewable energy and carbon sequestration technologies; energy policy favors unconventional natural gas production that impacts on aquifers.	+/-	H
Flexible resource management	Despite some drawbacks, the Australian water market system does enable water to be readily transferred where funds are available, for example, from irrigation to the environment. The CEWH is permitted to buy and sell water entitlements to benefit the environment. For example, it could sell environmental water for irrigation when the price is high and the ecological need low, then acquire water later during periods of key environmental need.	+	M
Resources	A huge amount of government funds have been provided but spent inefficiently, for example, on water "efficiency" measures rather than cheaper water entitlement purchases (-). Where water is being purchased, this is making a major difference (+). In the current round of reforms the federal funds have not been used to incentivize the states to make necessary changes, unlike with the microeconomic reforms to the water sector in the 1990s (-). Market-based incentives have had positive socioeconomic results but adverse environmental impacts due to design flaws (+/-).	+/-	H
Legitimacy and accountability	Australians largely expect state and federal governments to intervene to set high standards for environmental management (McAllister 2008). The legislation establishing the Authority and the Basin Plan process was adopted with bipartisan support, but the Authority has squandered its legitimacy through an overly technical, backroom planning process that did not adequately engage stakeholders. The Authority and the Basin Plan are accountable to the federal parliament. However, the options for enforcing the legislation and the Basin Plan are limited. The Water Act does not include third-party enforcement provisions. While the federal government must accredit state sub-basin implementation plans and in theory could write its own if the states fail to do so adequately, in practice it is hard to see how the federal government could effectively supplant the states in day-to-day local management. This means that further compromises with the states are likely. A major gap in the Australian system is lack of provision for noncompliant states to be taken to court (versus, for example, the European Commission's capacity to prosecute EU member states in the European Court of Justice when they fail to adhere to the Water Framework Directive).	-	H
Variety and diversity	Overreliance on downscaled modeling may prove unhelpful given the wide range of forecast potential outcomes, suggesting that a more robust approach to adaptation is required. The Authority's focus on water quantity, while essential, is overly narrow in excluding other important adaptation options, including retention of free-flowing surface and groundwater systems, riparian restoration, and reoperation to reduce the impacts from infrastructure (Pittock and Finlayson 2011a).	-	M

Monitoring and evaluation	This area is still a work in progress. The existing independent National Water Commission and the establishment of roles for the BoM, ACCC, and CEWH in overseeing key aspects of water management enhance monitoring and evaluation. As federal agencies they are all publicly accountable.	+	M
Identity	The Authority's 'environment first' legal mandate is well directed to sustainability, but this is being undermined by political compromises that claim that economic, social and environmental aspects should have equal weight. The priority afforded to managing water volumes is understandable, but secondary climate change adaptation measures are outside the Authority's mandate or are overlooked, e.g., riparian habitat restoration.	+/-	H
Forward thinking	The Act requires the Authority and Basin Plan to manage a range of threats to water availability, including climate change, although the Authority is struggling to understand this mandate and political compromises jeopardize this goal.	+	H
Iterative approaches	The Basin Plan is meant to be revised on at least a ten-year cycle that should greatly aid adaptive management, including revisiting areas that were poorly understood or where compromises were made in the initial plan.	+	H
Mainstreaming	Adaptation is integrated into the water management (Basin) authority.	+	M
Creativity and learning	The Authority has: (-) narrowly focused on e-flows as the panacea; (+) applied innovative modeling and water accounting; (+) treated the environment as a water end-user where allocations can be bought and sold where this is ecologically advantageous (inc. CEWH); (+) applied external peer review in the initial planning (but this is questioned in the current round); and (+) has the potential to learn from experience through the ten-year planning cycle.	+/-	M
Internal agency and autonomy	The Authority has an independent board and submits draft plans to the parliament for approval. Plan approval is required in both the House of Representatives and the Senate. A lot depends on the quality of the leadership of the Authority, and this has been questioned in this initial planning process.	+	M
Collaboration and partnerships	The multi-government commission was collaborative. In its transition to being a federal government authority this culture has been lost. There have been formal public consultation processes. Ultimately a federal government authority in such a large river basin must gain the consent of more local stakeholders and institutions to effect detailed management on the ground. The Authority has not yet demonstrated that it has the capacity to do so. Legally, a nested/subsidiary governance structure is in place, with the Basin Plan to set high-level, basin-wide standards that the states then apply through their multi-stakeholder (sub-)catchment management authorities and other agencies. Thus the Authority must simultaneously win the trust of state institutions to support implementation and hold them accountable for achieving minimum standards.	-	M
Leadership	Authority leaders have not instilled public confidence in the Authority's work, jeopardizing its mission.	-	M
Transparency and participation	The Authority's planning work is transparent to the extent that technical data is publicly available, the Basin Plan involves formal public consultation, and the Authority is accountable to parliament. The interests of most stakeholders (e.g., Indigenous peoples, irrigators, the environment) are considered, if not adequately addressed. However, higher standards of stakeholder participation are expected on contentious issues, and the Authority has been found wanting.	+/-	M

Appendix 2 | Case Studies



Murray-Darling Basin Authority, Australia

Jamie Pittock, Australian National University, Canberra

Context

The Murray and Darling are the longest rivers in Australia and drain the Murray-Darling Basin (MDB or the Basin), a region in the southeast part of the country of over a million square kilometers that comprises around a seventh of Australia's land mass (Pittock and Finlayson 2011a). The MDB is very flat, old, and salty, and the rivers have some of the most variable flows in the world. The Basin is characterized by high biodiversity—from alpine ecosystems in the Australia Alps in the southeast to semi-desert in the northwest and an extensive area of lakes and estuaries where the Murray enters the Southern Ocean. Large floodplain forests and other wetlands occur over 5.7 million hectares, 637,000 hectares of which are designated as Ramsar wetlands of international importance (sixteen sites total) (Kingsford et al. 2004; Pittock et al. 2010). The northern Basin receives erratic summer rainfall and supplies around 10% of inflows. The southern Basin has been dominated by winter rainfall: runoff derived from the Alps supplying 50% of Basin river flows (Chiew, F.H.S. et al. 2008).

The contested management of this resource dominates institutions in the water-scarce Basin (Connell 2007). The Basin is home to 2 million Australians and supplies water to a million more. Agriculture uses 68% of the Basin's area to produce 41% of total national farm output, valued at more than AUD$14 billion on average per year. Half of this farmland is supplied by irrigation

(ABS et al. 2009). This extensive exploitation for human use has led to over-extraction, with end-of-system flows falling from 41% before development to an average of 16% now. The river mouth was closed from 2002 to 2010 due to over-extraction and climatic variability (CSIRO 2008; Pittock et al. 2010). Further complicating the situation, indigenous communities are increasingly reasserting their traditional rights to the resources of the Basin (Weir 2011; Jackson 2011).

Climate Change

The Basin's ecosystems have been extensively impacted by habitat conversion for agriculture, exploitation for water resources, and invasion by exotic species. Currently, and in the medium term, these factors have a greater influence than any forecast impacts of climate change (Pittock et al. 2010). The Basin's climate is extremely variable, oscillating between drought and flood. Because much of the Basin's inflows are derived from the Mediterranean climate zone in the southern Basin, inflows are at great risk from increased temperatures and evapo-transpiration (Cai and Cowan, 2008).

A major government climate and hydrological modeling program has produced forecasts of water availability in the Basin for the period up to 2030. Under these models inflows are predicted to change between +7% and -37% of current availability and outflows to change between +20% and -69% (CSIRO 2008). This range of possible outcomes has created challenges for effective adaptation. During the historically unprecedented 2002-2010 Millennium Drought, by 2010 inflows had fallen by 63%, and the river mouth had closed and was being maintained by dredging. In the southern Basin there is emerging evidence of higher temperatures and declines in snowfall, snow melt, and autumn and spring rainfall as the subtropical ridge moves farther south, off the continent (Cai and Cowan 2008; Murphy and Timbal 2008; Timbal 2009; Timbal and Jones 2008; Schofield 2011; Fredericksen et al. 2010). Also during the Millennium Drought, higher temperatures, water exploitation, and reduced inflows resulted in loss of floodplain forests and other wetlands and increased salinity, cyanobacteria blooms, and the oxidation of sulphate sediments to form acid. Climate change is likely to exacerbate these impacts (Pittock and Finlayson 2011a; Pittock et al. 2010).

Institutional Description and Response to Climate Change

The Basin is governed through a complex set of institutions that emerged from 18th-century debates over how to manage the transboundary river system under a federal system of government (Connell 2007). Connell describes eight periods of institutional reform in basin management, beginning in the late 19th century with a focus on water allocations and river transport and broadening late in the 20th century to focus on water quality and quantity and other natural resources. The focus was radically reformed again in 2007 in response to the Millennium Drought and the prospect of climate change (Connell 2007). From 1994 to 2007, the six state governments and the Australian federal government shared oversight through a consensus-based Murray-Darling Basin Commission. Unfortunately, the commission was criticized for being slow and for taking lowest common-denominator decisions (Connell 2007). Numerous national policy decisions for more sustainable water management have been made, including those to regulate inflow interception activities (such as farm dams and plantations) and for adequate environmental flows, but none have substantial incentives or penalties for compliance and as a result have been inadequately implemented by state governments (NWC 2009; Young 2010; Pittock and Connell 2010).

Climate Change is water change, and therefore water management is a key component of adaptation (Bates 2008). In the Basin, management of non-climate and climate change impacts on water are inextricably linked (Pittock et al. 2010). The natural variability in the climatic and hydrologic cycles has required Australian water to be managed adaptively, for example, through high per-capita levels of storage (Pittock and Connell 2010). However, the Millennium Drought revealed that some agriculture portfolio drought adaptation measures conflict with water portfolio climate change adaptation measures. For example, subsidies for storing more water on farms and drought subsidies to encourage farmers to stay until conditions return to "normal" (versus a scheme to purchase water entitlements from irrigators) decrease river flows (Pittock and Connell 2010).

As a result of lessons learned from problems in the United States, Australia's water entitlements system is largely based on the principle of ownership of a share in the available water resource in a particular period—more generous in wet periods and reduced proportionally in dry periods—rather than the less flexible prior appropriation ("first in time, first in right") or riparian ("any reasonable use by riverside landholders") doctrines (Pittock and Connell 2010). After the 1990s Australia moved to harmonize water entitlements between states and to separate water and land titles in order to establish water markets that would reduce transaction costs. This allowed low-value water users to sell entitlements to higher-value users (Connell 2007; Productivity Commission 2010; Young 2010). Following the capping of surface water diversions in the Basin based on 1994 levels, water trading has enabled economic growth with limited water and greatly reduced the economic impact of drought (Grafton 2011). However major flaws and loopholes in the regulatory framework for the water market have temporarily increased water diversions and had adverse impacts on the environment, such as conjunctive management of groundwater and inflow interception activities, that are still being rectified (Young 2010).

In response to the stress of the Millennium Drought, the federal government adopted a new Water Act in 2007-08 (the Act) with a constitutional mandate drawn largely from implementation of the Convention on Biological Diversity and the Ramsar Convention on Wetlands (Pittock et al. 2010). The Act establishes a process for adopting a "sustainable diversion limit" and centralized management through its new Murray-Darling Basin Authority (the Authority), which has a difficult relationship with the states because they retain local management capacities (Connell 2007; Commonwealth of Australia 2008). The Authority has been charged with producing a Basin Plan (after consultation with stakeholders) for the consideration of the federal parliament in 2012. The Basin Plan will set new sustainability standards for managing water in the Basin (including measures to address anticipated climate change impacts) that the states are then to implement through approximately twenty sub-basin plans that must be accredited by the federal government (MDBA 2010). It is anticipated that the Basin Plan will be revised on up to a ten-year cycle. In 2010 a science-based but compromised Guide to the Basin Plan was published, proposing a reallocation of 3,000-4,000 GL (27%-37% of the current diverted water) to the environment. However, due to irrigation industry backlash, further compromises that will jeopardize the effectiveness of the Basin Plan are being considered (Pittock and Finlayson 2011b).

At the same time as the establishment of the Authority, three other institutions were created that may enhance adaptive management through greater accountability and polycentric governance. Water accounting was nationalized through the Bureau of Meteorology (BoM) to ensure adequate and consistent data for management. The water market is now regulated

by the Australian Competition and Consumer Commission (ACCC). Most important for the environment, federal government water entitlements are now owned and managed by the Commonwealth Environmental Water Holder (CEWH). Connell argues that this mechanism for central management of growing environmental water holdings may obviate flaws in the Basin Plan institutions (Connell 2011). In particular, the CEWH model makes environmental water a legal entitlement equal to commercial holdings, rather than the previous approach by the states where the environment was supposed to be supplied by "rules-based" (leftover) water that largely disappeared through administrative reallocation in times of scarcity (CSIRO 2008; Connell 2007).

The Authority is required to specifically consider climate change, but bases its response on the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) median-impact scenario rather than on the equally likely and more risky extreme dry scenario (Pittock and Finlayson 2011b; CSIRO 2008). In the Guide to the Basin Plan, the Authority proposes to manage climate change risk in three ways: reallocating 3% of diversions to the environment in the first Basin Plan period, relying on the proportional reduction of water entitlements in dry periods, and revising the Basin Plan every ten years (Pittock and Finlayson 2011b; Schofield 2011). This limited approach to managing risk has been criticized for failing to adequately anticipate and manage the types of severe impacts experienced in the Millennium Drought (Pittock and Finlayson 2011b).

Discussion of Most Important Climate-Adaptive Principles

Resources

Also parallel to the organizational reforms have been efforts by the federal government to acquire more water for environmental flows—including for reduction of climate change impacts—through the expenditure of around AUD$14 billion (AUD$1.00 ~= USD$1.06) in the past decade. Initially the conservative federal government invested only in agricultural water efficiency and in "environmental works and measures" (environmental "water demand management") that proved to be uncertain, expensive, and inefficient in its efforts to return water to the environment (Pittock and Lankford 2010; Productivity Commission 2010; Grafton and Hussey 2007). A new federal administration in 2008 allocated AUD$3.1 billion to purchase water entitlements and AUD$5.8 billion for agricultural water efficiency projects (DEWHA 2010). Since then, the federal government has acquired around a quarter (750 GL bought in average annual entitlements to June 2011) (DSEWPAC 2011) of the water required to reach a sustainable level of extraction, and it could achieve an adequate outcome if the "efficiency" funds were reallocated (Pittock et al. 2010; WGCS 2010).

In the current round of reforms, federal funds were used to gain agreements from the states through reforms by infrastructure grants for agricultural water efficiency of dubious value (Pittock and Connell 2010; Grafton and Hussey 2007). However, these funds have not been adequately used as outcomes-based incentives for the states to make necessary changes—unlike with the microeconomic reforms to the water sector in the 1990s (Pittock and Finlayson 2011b). Market-based incentives through water trading have had positive socioeconomic results but adverse environmental impacts due to design flaws (Young 2010; Grafton, 2011). Consequently, there have been adequate resources for effective adaptation, but these need to be better targeted to be effective.

External Regime

As mentioned previously, the Federal Water Act largely draws its mandate from implementation of the Convention on Biological Diversity and the Ramsar Convention on Wetlands, which establish high “environment first” standards, such as the requirement in most circumstances to maintain the “ecological character” of wetlands—even in the face of climate change (Pittock et al. 2010). This has created conflict with irrigators and politicians who favor trading environmental measures for socioeconomic benefits, and it may lead to the Basin Plan being contested in the courts.

The federal government has attempted to codify who bears the water loss anticipated due to climate change, but conflicting policies are proposed. The National Water Initiative states that after dealing with historical over-extraction that additional reductions will be borne by consumptive users, whereas the Authority proposes to share losses equally between the environment and users (MDBA 2010; Commonwealth of Australia 2004; Pittock and Finlayson 2011b). This issue is unresolved and is becoming more complicated (or the risk is being spread) as the environment is increasingly being supplied by a mixture of entitlement- and rules-based water (as discussed above).

Finally, there is a significant threat to water in the Basin thanks to poorly integrated policies of other sectors, such as climate change mitigation measures (Pittock 2011). For example, federal government climate change policies favor thirsty renewable energy and carbon sequestration technologies; energy policy favors unconventional natural gas production, which will have substantial impacts on aquifers (Pittock 2011; NWC 2010). While the National Water Commission has strongly argued for better policy integration (with little success), the Authority has been largely silent on these questions. More effective integrated governance is needed to minimize adverse impacts of policies from other sectors.

Legitimacy and Accountability

Australians largely expect governments to intervene to set high standards for environmental management, especially for water (McAllister 2008). The legislation establishing the Authority and the Basin Plan process was adopted with bipartisan support, but the Authority has squandered its legitimacy through an overly technical, backroom planning process that did not adequately engage stakeholders.

The Authority and the Basin Plan are accountable to the federal parliament. However the options for enforcing the legislation and the Basin Plan are limited. The Water Act does not include third-party enforcement provisions. While the federal government must accredit the state sub-basin implementation plans and, in theory, could write its own plans if the states fail to adequately do so, in practice it is hard to see how they could effectively supplant the states in day-to-day local management. This means that further compromises are likely with the states. A major gap in the Australian system is the lack of a provision for noncompliant states to be taken to court (versus, for example, the European Commission’s capacity to prosecute EU member states in the European Court of Justice when they fail to adhere to the Water Framework Directive). More effective accountability mechanisms would aid the Authority’s implementation of the Basin Plan and allow the Authority to be more climate-adaptive.

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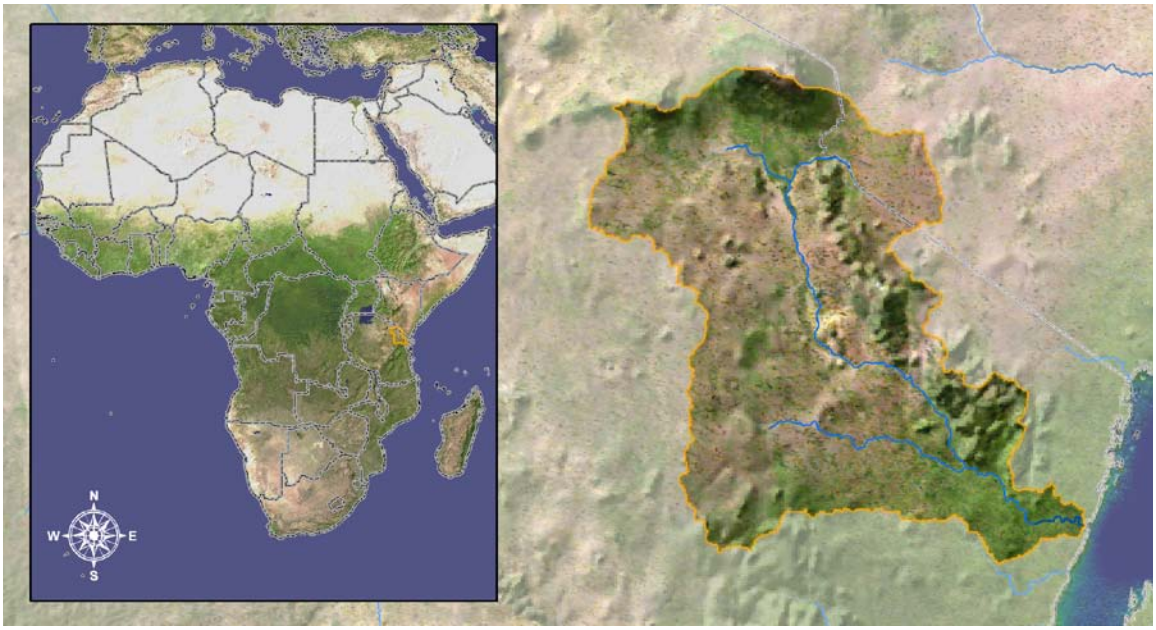

Pangani Basin Water Board, Tanzania

Stefano Barchiesi*, with John P. Owino§, Katharine Cross§, D. Mark Smith*

** IUCN Global Water Programme*
§ *IUCN Eastern and Southern Africa Regional Office (ESARO)*

Context

The Pangani River Basin in East Africa covers 44,000 square kilometers and is home to about 2.6 million people. The Pangani River begins as a series of small streams on the southern sides of Mt. Kilimanjaro and Mt. Meru and passes through the arid Masai Steppe before reaching its estuary and the Indian Ocean at the coastal town of Pangani. Along its 500 km course the Pangani River is a lifeline for biodiversity, people, and industry, and is fundamental to the economic development of the region.

The Pangani Basin is one of the most productive areas of Tanzania, and is very important to the national agriculture (both commercial and subsistence). The river is a source of drinking water for people and livestock and supports irrigated agriculture, which represents the largest water use in the basin. The Nyumba ya Mungu Reservoir is used for the generation of hydropower (8 MW), and as a fish nursery is also an important source of employment. At the coast, the Pangani Hydropower Station (68 MW) is vital to industry and the economy in the town of Pangani and along the coast. Irrigation and hydropower generation use almost 90% of the Pangani's surface flow.

Population growth, urban growth, and the intensification of land use for agriculture have led to an overexploitation of water resources and increased the demand and competition for water among

land users, industry, and ecosystems. The increasing water stress (<1,200 m^3 per person per year) is thus a source of conflict. Small-scale users in villages often compete against larger and more powerful claims by industry. Downstream users, such as cities, industry, and hydropower companies, are negatively affected by upstream land users, such as farmers and pastoralists, who reduce the availability and quality of water.

Protected areas in the upper basin play an important role in conserving globally important biodiversity resources and help provide water to downstream users. But those areas are not enough to maintain water flow and multiple ecosystem services for the entire basin. Ecosystems such as wetlands, riverine forests, and mangroves need a minimum flow of water to provide wildlife products—including fish, plants for medicinal use, reed, timber, and fruits—and other products that are of great importance for the livelihoods of rural populations. The ecosystem services that are considered most important in the Pangani Basin are water treatment by wetlands and the estuary function as a nursery area for fish.

Climate Change

A detailed climate change modeling study for the Pangani River Basin[47] shows that climate change impacts are expected to include: 1) decrease in rainfall during the dry season (May–October); 2) increase in evapotranspiration, mostly in October, by approximately 10 mm; 3) increase in rainfall during the wet season (November–March); 4) minimum temperature increase by approximately 2°C (range of 1° to 3°C) during all months; and 5) maximum temperature increase by 1° to 3°C in July–November. The seasonality of stream flows in the Pangani is therefore likely to change because of hotter and drier periods (especially toward the end of the dry season). The magnitude of this change will vary across the sub-catchments, and its impact will depend on water extraction and the characteristics of each sub-catchment.

In addition, the previously mentioned water use conflicts are expected to increase in the future as climate change aggravates water stress.[48]

Institutional Description and Response to Climate Change

The Pangani Basin Water Board (PBWB or the Board) was established in 1991 and works in accordance with Tanzania's Water Resources Management Act of 2009. The Board is comprised of ten members drawn from public institutions, sub-catchment water committees, and private-sector water users, and it is served by a technical secretariat. Its goal is to develop a comprehensive, integrated, and holistic approach to water resources management. The PBWB

47 PWBO/IUCN. 2010. Climate change modelling for the Pangani Basin to support the IWRM planning process. Pangani River Basin Flow Assessment. Pangani Basin Water Board, Moshi and IUCN Eastern and Southern Africa Regional Programme. V+36 pp. Available at: http://cmsdata.iucn.org/downloads/climate_change_modelling_by_uct.pdf.

48 When the flows for the basin are adjusted to account for the projected changes in rainfall, the water development scenarios predict a reduction in the water available for urban demands, irrigation, and hydropower generation. They also predict reductions in flooding of the ecologically important midland swamps and fish catches and river health in general [PBWB/IUCN (2011). Pangani River System - Future of the Basin Report. Moshi, Tanzania: PBWB and Nairobi, Kenya: IUCN Eastern and Southern Africa Regional Programme. 39 pp.].

must ensure that the Pangani River is managed sustainably while economic and social welfare is improved through better water governance and integrated water resources management (IWRM) principles.

In 2002 the Ministry of Water launched a new National Water Policy (NAWAPO) that recognized the important link between a healthy environment and productive livelihoods. Water for basic human needs is given the highest priority for water allocation, followed by water for maintenance of ecosystems. Determining water requirements for the environment thus became a priority for the government.

Both NAWAPO and the 2009 Water Resources Management Act were formulated in response to the emerging situations of water stress and subsequent conflicts among water-user groups such as we have seen in the Pangani Basin. To tackle uncoordinated abstractions and climate-jeopardized water supplies, the latter amendment also provides for the establishment of water user associations (WUAs) and sub-basin and catchment water committees. Under the umbrella of the PBWB, these groups provide stakeholder participation in water resources management within the same institutional structure that governs the river basin.

Through dialogue and decentralized governance, water users have been empowered to participate in IWRM and climate change adaptation processes. Participatory forums and technical information have equipped the PBWB with the tools, knowledge, and capacity to devise an adaptive water management plan to equitably provide freshwater for the livelihoods of current and future generations as well as for the environment.

In order to implement the National Water Policy, the government has promoted environmental flow assessments that integrate how climate change might affect Tanzanian rivers over time. The Pangani River Basin Management Project (PRBMP) has been assisting the PBWB with such e-flow assessments (studies) and scenario development. Since 2005, the PBWB has undertaken a series of studies to understand water flows in the Basin through the PRBMP. Technical support has been provided by IUCN (the International Union for Conservation of Nature), SNV – Netherlands Development Organization, and a local NGO, PAMOJA, with financial assistance from the Government of Tanzania, the United Nations Development Programme/ Global Environment Facility (UNDP/GEF), the European Union, and the IUCN Water and Nature Initiative (WANI), Through this initiative the PBWB has also identified a number of scenarios (possible future development pathways for the Pangani Basin) to assess different allocation choices and how each would change the river flows from the headwaters all the way to the estuary, as well as assess how the livelihoods of the people who depend on those waters would be affected.

Discussion of Most Important Climate-Adaptive Principles

External Regime

The success or failure of mainstreaming climate change into water management often depends on whether climate change has a place in national legislation. The ability of ministries to implement and enforce these laws and to reconcile the interests of traditionally powerful sectors with the interests of the more vulnerable water users is crucial. Tanzania's National Water Policy

and Water Resources Management Act were thus essential because they provided for the various water requirements and benefits to be equitably considered and periodically reviewed within the frame of what is actually available.

Legal frameworks and institutional mechanisms also need to be flexible and innovative to allow for information sharing on water and climate change-related issues and to build consensus around the different stakeholders' perspectives and priorities. The PBWB was not a self-organizing institution in its own right. But after more than five years of negotiated steps and social learning, the PRBMP has contributed to a more adaptive PBWB by piloting the formation of WUAs in the Pangani Basin as per the Water Management Act. The pilots were instrumental in creating the new governance arrangements and in allowing water users to further organize in sub-catchment forums and to periodically submit their concerns or recommendations over water decisions to the Water Board. In this way, concerns at the community, WUA, district, and regional levels are all integrated into basin-level planning.

Decentralizing the negotiations over water allocations in river basin planning has proven to be key for better climate-proof water management. A diversity of stakeholders is now legitimately participating in the discovery of options and in joint action. As a result, hydrological models and climate forecasts are complemented by a participatory governance system that can dynamically respond to uncertain futures.

Creativity and Learning

The PBWB was originally not knowledgeable about environmental flows, but after technical advice and financial support from the PRBMP, a team was established, and its capacity was developed by international trainers. The Environmental Flows Assessment (EFA) was one of the most pioneering and resource-intensive components of the PRBMP. Setting out to better understand the hydrology of the river basin, the flow-related nature and functioning of the riverine ecosystem, and the links between the ecosystem and the social and economic values of the river's resources, the EFA revealed that breaking the link with the natural infrastructure that regulates hydrological cycles would decrease the success of future adaptation to a shifting climate and water demands. The technical information generated by the EFA about the basin was then used to organize the available ecological, social, and economic data into a set of development scenarios — the many possible pathways into the future.

It was certainly a challenge to implement the 2002 National Water Policy requirement that provides for the basins to take into account environmental water allocations. But it also left some degree of autonomy with river basin boards to allow their staffs to experiment and learn by experience. In the Pangani, implementation meant demonstrating environmental flows as a tool for adaptation; this became the pivot around which to test wider IWRM solutions. Environmental flows science provided the evidence for flow management, and the flow management process in turn acted as a catalyst for the required governance reforms and institutional development.

Focus is now switching to stakeholders and the government agreeing on how to best reallocate water. Although this may seem to be a protracted process that yields no prescriptive outcomes, the chosen allocation scenario will be integrated into the basin's water management plan, which is legally binding. A monitoring program that has been laid out as part of the plan will ensure that

the desired river state is being achieved and maintained irrespective of climate change.

Collaboration and Partnerships

Engagement of relevant stakeholders early in the process of building environmental flows and climate change decision-making tools also resulted in greater buy-in to the decisions made and created new partnerships that helped build stronger water management institutions. The new alliances thus created between water managers, policy makers, community members, and scientists provide a means of jointly solving watershed management challenges at a sufficiently large scale to avoid unintended trade-offs in water benefits.

The PBWB and IUCN are also collaborating with the Climate Change and Development Project and the Global Water Initiative to identify and implement adaptation strategies in the Pangani Basin. Climate change vulnerability assessments have been carried out in eight different villages, from which a list of adaptation actions were identified, ranked by the communities, and implemented. Once again through hands-on learning, the adaptive capacity of the PBWB and other country institutions has been strengthened as technical staff analyzed the vulnerability assessment information gathered during community consultations and knowledge about the basin's vulnerability was disseminated among water users.

Increasing information about possible future climate change scenarios has brought the water and climate change sectors together. There is now a better understanding of the environmental, economic, and social implications of different river flow scenarios under possible future climatic conditions, along with an increased capacity to collect and analyze such information. The water sector's vulnerability to climate change is now better understood by those at risk. Pilot actions are bridging the gaps between basin- and national-level processes. And, perhaps most important, the lessons learned from establishing WUAs and the sub-catchment forums in the Pangani are being scaled up to strengthen national support and inform other communities, basins, and countries.

U.S. Army Corps of Engineers Reservoir Operations

Maria Placht, Institute for Water Resources, USACE [49]

Context

The U.S. Army Corps of Engineers (the Corps) is responsible for a variety of water resource-related missions in the United States, including coastal protection, disaster preparedness and response, environmental protection and restoration, flood protection, hydropower, navigable waters, recreational opportunities, regulatory oversight, and water supply.[50] The Corps also strives to be a good steward of the environment in these areas, especially through ensuring environmental flows for ecosystems.

This case will focus on the area of reservoir operations, which encompasses several of the above missions. Through its Civil Works program the Corps manages hundreds of reservoirs nationwide. Corps personnel focus the resources of these reservoirs to meet a wide variety of purposes, including navigation; flood storage; generating power for homes and businesses; supplying water for nearby communities; and providing recreational areas for camping, fishing, boating, and hiking.

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49 Views, opinions and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy or decision unless so designated by other official documentation.

50 http://www.corpsresults.us/

Climate Change

According to the U.S. Global Change Research Program's 2009 Report, "Global Climate Change Impacts in the U.S.,"[51] climate-related changes observed in the United States include increases in heavy downpours, rising temperatures and sea levels, rapidly retreating glaciers, thawing permafrost, lengthening growing seasons, lengthening ice-free seasons in the ocean and on lakes and rivers, earlier snowmelt, and alterations in river flows. Trends vary by region, with some areas, such as the Southwest, experiencing prolonged droughts. Other areas, including the Midwest and Southeast, have experienced an increase in total volume of precipitation, increase in heavy precipitation events, wetter springs, and drier autumns. Recent storm events (the 2008 Midwest floods; the 2011 Mississippi floods) show a shift toward summer flooding in these areas.

The effects of global climate change could extensively impact reservoir operations in the United States. Significant changes to reservoir inflows may lead to increased frequency of major floods as well as reservoir deficits in the traditional low-flow late summer period. Increased rainfall may have positive effects (reservoirs could store more water), but could also result in uncontrolled water release and downstream damage. With unpredictable precipitation it may be more difficult to balance the storage space in reservoirs, especially if there is a seasonal shift in rainfall. In other areas of the country, duration and severity of drought periods could result in an inability to maintain minimum release rates. The Corps is already seeing increased delivery of sediment to reservoirs from heavy rains. This results in loss of water storage area and makes it difficult to respond to floods and conservation needs.

Institutional Description and Response to Climate Change

The key instruments governing the operation of USACE reservoirs are Water Control Plans and Reservoir Regulation Schedules. Both are included in the reservoir's Water Control Manual. These instruments outline how the project will meet the congressionally authorized purposes and other laws relating to the operation of federal facilities. The content, structure, and basic principles for the development and documentation of water control management strategies, rules (and changes to and deviations from adopted rules), and associated agreements are documented in the Water Control Manual. The Corps must periodically review (and approve in accordance with congressionally authorized purposes) its Water Control Manuals and update them according to evolving conditions in the watershed and riverine system and project purposes. However, funding is scarce for such reviews, and many manuals are decades old.

Climate change is one of many uncertainties affecting water resources management. Corps reservoir operations are being affected by land use changes that affect hydrology, and population increases and other demographic changes affect water demand. The presence of endangered species—and the associated legal requirements—and invasive species can also impact operations, given each reservoir's impact on hydrologic variability. The Corps' current understanding of climate change together with other global changes indicates that virtually all of its infrastructure will require adaptation.

51 http://www.globalchange.gov/what-we-do/assessment/previous-assessments/global-climate-change-impacts-in-the-us-2009

The Corps initiated its Responses to Climate Change (RCC) Program in 2008, formalizing a program that began in the 1990s. This program's mission is "to develop, implement, and assess adjustments or changes in operations and decision environments to enhance resilience or reduce vulnerability of USACE projects, systems, and programs to observed or expected changes in climate."[52] The program is developing and beginning to implement approaches and policies to reduce potential vulnerabilities to the nation's existing water infrastructure that result from climate change and variability. This program's goal is that future infrastructure be sustainable and robust in a range of potential climate changes.

The RCC Program relies on a multitude of partnerships with other federal science and water management agencies and other stakeholders (both domestic and international). For example, the Corps works within the Climate Change and Water Working Group, an informal scientist-to-scientist confederation across federal agencies and the water management community. The Corps also participates in interagency work groups to develop a national strategy for climate change adaptation and in the Climate Change Adaptation Task Force, an interagency forum for discussing and monitoring the implementation of the federal government's adaptation approach.

The Corps translates the recommendations and research conclusions from its various partnership initiatives (and various guidance and instructions from the White House) into Engineering Technical Letters and Engineering Regulations. Corps district offices then follow this field-level project guidance in their planning and operations. If the guidance is not followed, the project may not be approved by USACE Headquarters.

The Corps addresses emerging issues that have not yet been incorporated into long-standing guidance with temporary guidance called Engineering Circulars (ECs). An example is the recent EC on "Incorporating Sea-level Change Considerations into Civil Works Programs." The Corps is constantly developing these types of guidance, yet thus far there has not been an EC related to addressing climate change considerations for reservoir operations.

Discussion of Most Important Climate-Adaptive Principles

Creativity and Learning

The RCC Program began sponsoring various climate change adaptation pilot studies in 2010. The goals of these initial studies are: 1) test and evaluate the Adaptation Process Framework proposed by the Council on Environmental Quality;[53] 2) develop and demonstrate innovative methods, strategies, policy, and technologies supporting climate change adaptation; and 3) build USACE district capacity in the professional and technical competencies important in climate change adaptation. Each pilot study concentrates on a central question to focus the participants

52 http://corpsclimate.us/about.cfm

53 In 2010 the Council on Environmental Quality proposed a flexible Adaptation Process Framework to help agencies identify climate-based vulnerabilities, reduce those vulnerabilities through adaptive actions, and build greater resilience to climate change throughout agency missions and operations. The proposed framework has three components: 1) a set of principles to guide agency adaptation and resilience activities, 2) a six-step approach to climate change adaptation and resilience, and 3) a proposed set of government-wide enabling investments to support the effective implementation of the framework. USACE is among four agencies currently testing the framework.

on a key knowledge gap that, it is hoped, will be applicable to other projects. These pilot studies are led by district staff and may include interagency, academic, and other expert participation.

Future pilot studies will focus on evaluating and testing approaches, frameworks, and guidance for incorporating climate change into USACE district life-cycle decision making. For example, one pilot study will focus on assessing the impact of climate change on the Coralville Reservoir. This is a multipurpose USACE reservoir on the Iowa River with authorized purposes of flood risk reduction, fish and wildlife management, water quality, low flow augmentation, and recreation. This study will identify potential strategies to assess and improve the robustness of reservoir operations in the context of climate change.

The pilot study approach exemplifies the ideas of experimentation, learning, and innovation. These studies will be invaluable for understanding how the Corps can continue to adapt to climate change, and will be incorporated into Corps guidance (including Engineering Regulations and Engineering Technical Letters) and also inform future updates to Water Control Manuals. Current pilot studies have already been useful in identifying issues that should be covered in future guidance.

Collaboration and Partnerships

As mentioned earlier, the Corps does much of its climate change work in partnership with other organizations. For instance, the foundational report that kicked off the four U.S. federal water management agencies' approach to climate change was an interagency report. "Climate Change and Water Resources Management: A Federal Perspective" was published as USGS Circular 1331 in 2009. The purpose of this report (prepared by the Corps, the U.S. Geological Survey, the Bureau of Reclamation, and the National Oceanic and Atmospheric Administration) was to explore collaborative strategies to improve water management by tracking, anticipating, and responding to climate change.

Partnerships with other agencies are critical because they allow the Corps to capitalize on interdisciplinary expertise, avoid duplication, and produce cutting-edge products that they do not have the resources to create on their own. Combining resources and leveraging expertise will enable the Corps to more effectively adapt to climate change.

Many stakeholders are interested in Corps reservoirs because of their specific preferences related to downstream flow, stages, and water quality. Reservoirs are usually constructed for multiple purposes, such as recreation, hydropower, and flood control. Therefore, if the Corps desires to change the operations of a reservoir (via an update to the Water Control Manual) for climate-related reasons, they must address various tradeoffs between these varied interests.

Attempting to update a Water Control Manual can result in a long process fraught with conflict among the interest groups impacted by the reservoir's operations. There are usually competing desires associated with these purposes, and each interest group would prefer a different pattern of storage and stream flow regulation. The recent effort to update the Missouri River's Water Control Manual took 15 years and cost millions of dollars, in part due to an inability to reach agreement among the various stakeholders. This kind of conflict could keep the Corps from rapidly adapting to climate change.

A more successful “re-operation” (regulation schedule change) was undertaken with a significant Corps stakeholder, The Nature Conservancy (TNC), for Green River Lake and Dam in Kentucky. TNC worked closely with the Corps to alter the regulation schedule for the dam to better accommodate downstream ecological functioning. While the re-operation was for environmental reasons, it is an example of how such a collaborative process could work for climate change reasons. More details are in the following section.

External Regime

The ability of the Corps to alter its reservoir operations and adapt to changing and unexpected conditions is governed by the congressionally authorized purposes of the reservoir, the Water Supply Act, the Rivers and Harbors Act, the National Environmental Policy Act (NEPA), and the Flood Control Act. Changes or deviations from published regulation schedules—whether emergency, short-term, or long-term—are possible with appropriate studies and approvals. Some examples of reservoir operation modifications that could occur to adapt to climate change are modification of storage allocation within the reservoir (seasonal or permanent), modification of the reservoir release schedule, and expanded use of forecast tools in reservoir operation.[54] The significance of the change to be made and the context in which it is made dictate the regulatory process the Corps must follow.

For significant changes in allocation of water storage, the Water Supply Act of 1958 provides the basic authority for USACE to reallocate storage for water supply, allowing each Corps reservoir to meet present or anticipated future demand for municipal and industrial water supply. The Corps must receive congressional approval in the form of legislation to undertake such reallocation. The Corps may also seek major changes via a project modification study, as provided for by the Rivers and Harbors and Flood Control Act of 1970. This authority allows a new feasibility study of an existing project based on observed changed watershed hydrologic conditions; new needs; or the need to add, drop, or revise existing authorized purposes. This type of study requires public consultation and an environmental impact statement, but can result in a revised water control plan. Additional guidance for changing water control plans during times of water shortage is contained in Corps guidance regarding drought contingency plans. Drought contingency plans are easier to update than Water Control Manuals and can address future droughts, but they may also require NEPA documentation.

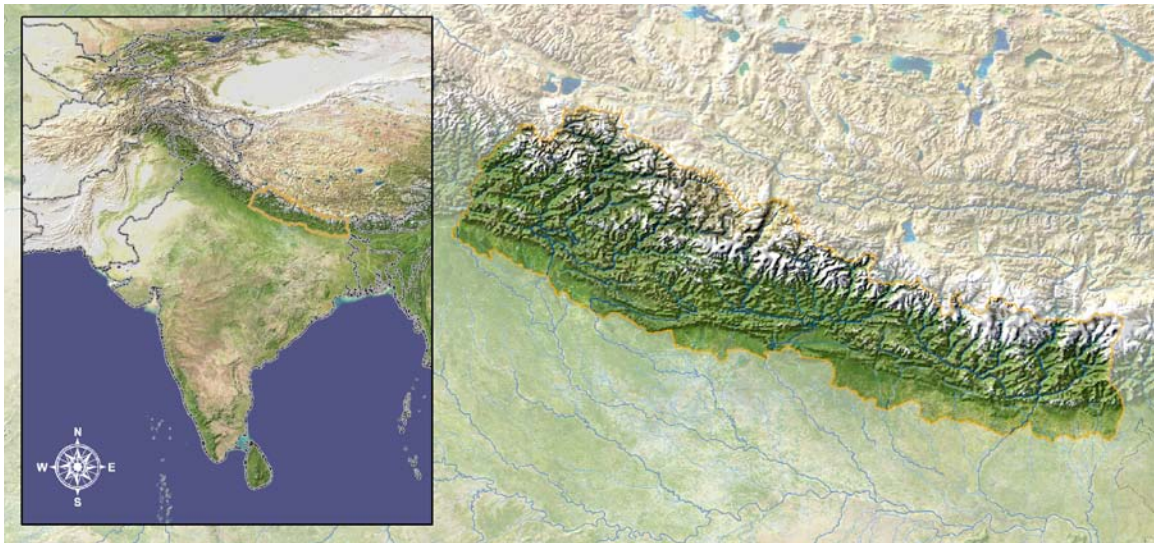
Minor changes to reservoir operations can be implemented in the context of existing authorities. Obtaining a temporary deviation is possible if NEPA documentation is completed, there are no significant adverse impacts, and there are no state and federal disagreements. One example, mentioned above, was the TNC-Corps 2002-2006 partnership to alter the regulation schedule for the Green River Lake and Dam to better accommodate downstream ecological functioning. The regulation change, which was implemented via an interim arrangement mechanism called a “deviation,” included altering the storage and release schedules to partially mimic the historic natural flow pattern. After three years of testing and vetting with the public and stakeholders, the interim regulation schedule was made permanent. After implementing some innovative solutions,

54 Expanded use of forecast tools could be problematic because current regulation plans were not designed to employ modern forecast products. Reservoirs are usually regulated for “water on the ground or in the system,” a principle that is followed to control operations that might otherwise be based on speculation or uncertain forecasts.

the regulation changes adopted had no negative impact—and even had some positive impact—on the authorized purposes of flood damage reduction, recreation, and water supply.[55]

The external regime negatively affects the Corps' ability to quickly alter its reservoir operations in response to climate change. The quickest way to change a reservoir's operations would be a series of adaptive measures requiring minor regulation changes that have no negative impact on the authorized purposes of the reservoir and no significant adverse impacts per NEPA. Thus the changes would not entail a contentious process and would require little involvement of external institutional factors. In such a case, the required documentation and approvals would be straightforward and achievable in less than five years, as was the case of the Green River Lake and Dam. Drought contingency plan updates could also be a quicker, cheaper process. If, on the other hand, the required adaptive measures that would necessitate a change in reservoir operations are significant, would have a negative impact on the authorized purposes, and have detrimental environmental impacts, the process would be highly controversial and involve various external institutional factors. In this case it could take many years and a considerable amount of money to produce the required documentation and internal and external approvals. Such funding may be hard to come by in times of limited budgets and competing priorities.

55 A Call to Enhance the Resiliency of the Nation's Water Management http://ascelibrary.org/wro/resource/1/jwrmd5/v137/i4/p305_s1?view=fulltext&bypassSSO=1



Water and Energy Commission Secretariat, Nepal

Ryan Bartlett, The Nicholas Institute, Duke University

Context

Lying between the two most populous countries of India and China, Nepal covers a thin expanse of the eastern half of the Hindu-Kush Himalayas along India's northeastern border near Bhutan. It is a nation of rich biodiversity and vast natural resource wealth—especially water—with more than 6,000 rivers cutting across numerous microclimates, from the high peaks, glaciers, and incised valleys of the High Himalayas (including Mt. Everest) to the tropical broadleaf and coniferous forests of the Middle Mountains and the savanna and grasslands of the Terai.

This resource wealth has not translated, however, into socioeconomic wealth. The vast majority of Nepal's population still relies on subsistence-based agriculture, and Nepal is the poorest country in South Asia. More than 30% of the population lives under the international poverty line (US$1.25/day), there is high unemployment (as much as 46%), and the annual GNI per capita (PPP) is only US$1,180 (World Bank 2011). Health statistics are similarly poor. There are high malnutrition rates (malnutrition causes 60% of annual child deaths due to curable diseases), and only 31% of the population has access to basic sanitation (World Health Organization 2011).

As a nation, Nepal is therefore extremely vulnerable to the impacts of climate change—especially those related to water resources. Many of these changes are already being felt (NCVST 2009; Eriksson et al. 2009; ICIMOD 2009; Bartlett et al. 2010).

Climate Change

Long-term trend data is extremely limited in the Himalayas, and building global and local circulation models is a challenge due to extreme topography changes over short distances. Nevertheless, there are emerging climate change trends in variability and seasonality, especially in the country's more mountainous regions. Annual average temperatures are increasing with altitude. The highest temperature increases in the colder regions of the High Mountains and High Himalayas ecoregions have led to drought, forest fires, higher prevalence of crop disease, higher biodiversity loss, ecosystem boundary shifts, and the drying up of spring sources. More rapid glacial melt and retreat is causing glacial lake outburst floods (GLOFs) that threaten infrastructure and population centers (Eriksson et al. 2009; NCVST 2009; Agrawala et al. 2003; Xu et al. 2009).

In terms of precipitation, local observations indicate that the South Asian monsoon is becoming increasingly variable. Fluctuations in seasonality (onset and termination dates) and short-term changes in river flows are contributing to erosion, landslides, and flooding from intense rainfall events occurring after long periods of drought (Eriksson et al. 2009; NCVST 2009; Cruz et al. 2007; Bartlett et al. 2010). These have already begun to have socioeconomic impacts—especially for food security and hydropower—because the vast majority of the country is dependent on rain-fed crops and Nepal's energy comes almost entirely from hydropower sources (NCVST 2009; Eriksson et al. 2009; Agrawala et al. 2003; WECS 2011b). Farmers, in recent years, have lost entire rice crops due to delays in rainfall that have made transplantation timing increasingly difficult. The result, especially in the rural mountainous regions, has been increased malnutrition and an enormous demand for food aid ("Nepal: Another blow to food security" 2010).

The country's national energy supply is extremely vulnerable to changes in climate, especially greater variability of river flows. This can mainly be attributed to their reliance on insufficient and degraded run-of-river hydroelectric schemes that already struggle to meet energy demand. This issue is already acute during the dry season when flows are lower, resulting in 16-20 hour power cuts per day. Increased uncertainty in low flow conditions may have even further detrimental impacts to energy supply for the country.

Certain ecosystems are also becoming more vulnerable as prolonged drought and temperature increases dry-out of wetlands and spring sources. This is leading to key species losses, which is likely have cascading effects and trigger secondary extinctions in certain regions (Xu et al. 2009).

Institutional Description and Response to Climate Change

In 1975 Nepal's (then) royal government created the country's Water and Energy Commission (WEC) as an apex body for water management. WEC had the objective of "developing water and energy resources in an accelerated and integrated manner" (Nepal: Water and Energy Commission Secretariat 2004, p. 4). To support this objective, a permanent secretariat was established in 1981 to better coordinate the commission's activities, creating WECS (Water and Energy Commission Secretariat).

WECS' responsibilities cover a wide spectrum, from formulating "policies and strategies for conducting . . . analysis on various aspects of water resources and energy development" to enacting "the necessary laws pertaining to the development of water resources and energy." Its

goals include coordinating Nepal's existing national water and energy policies according to a host of new directives laid out in the 2005 National Water Plan (NWP)—the country's most relevant (and recent) national-level water resource planning document. The 2005 Plan organizes all of the various roles of WECS over the years into one basic, core function: "to act as an apex institution to coordinate national-level planning to the entire water resources sector" (WECS 2011a). With more than thirteen ministries and numerous other departments involved in the water sector, national coordination was and continues to be a critical need.

The WEC, which still exists apart from WECS, is currently comprised of each of the secretaries of the relevant national ministries (along with outside water and energy experts from NGOs and national universities). It is chaired by the Minster of Energy and acts as the board of advisors to WECS. WECS is broken down into four major divisions, each with its own subdivisions: Water Resources (includes Hydropower, Irrigation, and Basin Study); Energy Planning (includes Traditional Energy, Alternative Energy, and Commercial Energy); Environment; and Legal and Institutional Arrangement.

Externally, WECS is positioned at the ministerial level, liaising with the various other national ministries (Irrigation, Agriculture and Cooperatives, Local Development, etc.), and works in conjunction with, or is partially funded by, NGOs and various foreign development institutions (WWF, the World Bank, Asian Development Bank, the Canadian International Development Agency, GTZ, etc.). Ultimately, however, due to a number of constraints, it occupies a diminished role at the national level among the ministries and is struggling to meet its enormous mandate.

Like the rest of Nepal's bureaucracy, WECS generally faces many institutional pressures—from extremely limited financial resources and low capacity to diminished legal power. This is due in part to a fragmented national legislature that has been solely focused, since the end of the civil war in 2006, on a protracted political battle around writing the country's new constitution. WECS has been unable to get the necessary statutory changes passed that would empower the organization to act as a strong national coordinating agency. It has thus remained more a research institute than the national-level, central water resource/energy planning division it is intended to be.

Climate change impacts are likely to have both positive and negative effects on WECS. WECS may actually benefit from a crisis situation; obvious climate changes may provide a powerful incentive (beyond the more obvious current critical need for improvements in water resource management) for it to receive better funding and more authority—especially given the country's dependence on water. Better coordination and integration is already seen as important (especially in water resources), and there is a perception that such responses should ideally be implemented in Nepal by an apex body with exactly the mandate of WECS (Bartlett et al. 2010).

However, even if its importance is realized in-country, WECS has an upward climb. Much of Nepal's water infrastructure is in a state of disrepair, and a high percentage of the population is directly dependent on subsistence agriculture. Underdeveloped national water infrastructure will make it extremely challenging to manage increasingly uncertain flows. No matter how powerful the organization becomes, without infrastructure in place WECS will have no (or extremely minimal) control over the system.

WECS is only in the beginning stages of analyzing potential climate related impacts to water and energy in Nepal. These efforts include initial assessments of the climate change vulnerability of selected watersheds and the hydropower and agriculture sectors (WECS 2011b; Bartlett et al. 2011). While efforts to date have been minimal, there are opportunities for WECS to further incorporate climate consideration into future development, particularly in the underdeveloped hydropower sector.

Discussion of Most Important Climate-Adaptive Principles

External Regime

The most significant obstacles to WECS meeting its mandates is lack of authority. As mentioned previously, WECS lacks the basic statutory authority either to oversee or coordinate the multiple different national ministries and departments involved in water resource management. For example, the 2005 Plan gives WECS the authority to provide clearance for various major large-scale water projects (such as hydroelectric facilities and interbasin transfers) that have transboundary implications. However, because WECS does not have the legal power to enforce the relevant laws, those portions of the 2005 Plan have gone unaddressed.

A recent article succinctly states: "WECS, at the moment . . . looks like a toothless agency, having no mandatory authority in the process of implementation of water-related issues" ("Water and Energy Commission Seeking Legal Mandate" 2011). As one of its divisional engineers noted:

> "As long as WECS is not made [a] mandatory institution [and given] certain legal authority, I don't think we can make any differences. In the coming days, when Nepal has to face many challenges in the context of utilization of water in [an] integrated manner, a stronger and more powerful organization like WECS will be needed" ("Water and Energy Commission Seeking Legal Mandate" 2011).

Leadership

Larger-scale institutional instability at the national level further constrains WECS ability to begin addressing the impacts of climate change. With a different prime minister every year for at least the last ten years, the national government (including all of the subsequent ministry appointees) is constantly in a state of flux. In 2009, for example, the Ministry of Water Resources was divided into the Ministry of Energy and the Ministry of Irrigation. This caused a shake-up within WECS because the WEC had historically been chaired by the Minister of Water Resources.

The short-term nature of the Nepalese executive branch means it is extremely difficult to focus on medium- and long-term goals—especially the necessary strategic planning critical to the adaptation process.

Resources

The availability of resources to WECS is mixed. There is a general lack of financial resources which most notably results in insufficient technology and data. There are, however, also some reasons for hope.

WECS has always been characterized by genuine technical capacity and expertise in the water sector. It has an extensive knowledge base and a deep understanding of core water resource management issues. As its secretary recently stated:

> "WECS's expertise on river basin planning and management, modeling of water use and allocation, development of multi-purpose projects, and trans-boundary water issues will be very useful for the government agencies as well as private developers. … No other institution in the country can provide a holistic overview of the water sector of Nepal" (Prasad 2011).

A number of recent projects and reports focused on these very aspects prove that WECS is indeed meeting its goals related to research and reporting (Prasad 2011).

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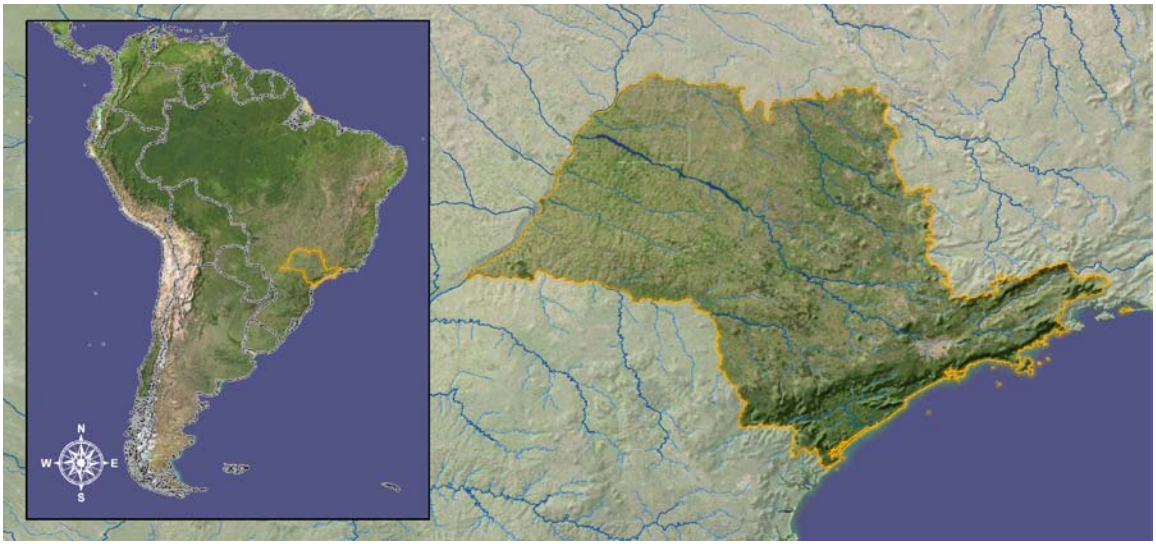

São Paulo Secretariat of Environment, Brazil

Glauco Kimura de Freitas, WWF-Brazil

Context

São Paulo is the world's seventh-largest city by population. The city anchors the São Paulo metropolitan area (SPMA). It is the second most populous metropolitan area in the Americas and among the five largest metropolitan areas on the planet, with almost 20 million inhabitants.

The Tietê River, and its tributary, the Pinheiros River, were once important sources of freshwater and leisure for São Paulo. However, industrial effluents and wastewater discharges in the last half of the 20th century caused the rivers to become heavily polluted. There are no large natural lakes in the region, so the Billings and Guarapiranga reservoirs on the southern outskirts of the city are used for power generation, water storage, and leisure activities. Most of the reservoirs serving the SPMA are completely polluted because of the development of slums around the streams and rivers that feed them. Thus far the lack of affordable housing in the urban areas of Sao Paulo means it has been impossible to reverse this informal land occupation, and it is anticipated that this encroachment pattern will continue.

For clean water, the SPMA depends on a neighboring watershed, the Piracicaba-Capivari-Jundiai, which provides water to the city via a diversion system (the Cantareira system). Today, the Cantareira supplies water to approximately 50% of the SPMA population. To meet rising water needs, a new water diversion project (expected to begin in the next two years) will withdraw water from the rio Ribeira de Iguape microbasin in the Vale do Ribeira (approximately 80 km south of the city). This project is expected to cost US$630 million, and will ensure a water supply for SPMA until only 2020—it is not a permanent solution to the problem of clean water scarcity.

The state of São Paulo has the highest GDP in Brazil and is the most populous state nationally, with 41 million people. The state contributes a third of the national agricultural GDP (including crops such as corn, sugarcane, and coffee), and is characterized by intensive land use. Only 14% of the natural vegetation still remains, mostly within parks and natural reserves (São Paulo (Estado) 2010).

Climate Change

The climate in São Paulo state varies by region. The north and northeast are seasonal, with a wet and warm summer and a dry and cold winter, but average temperatures are above 20°C and rainfall is over 1,200 mm. The south and coastal zones have rainfall distributed more regularly throughout the year, with a mean temperature above 20°C and rainfall reaching 2,000 mm per year.

The state of São Paulo is vulnerable to the risks associated with extreme climate events. Flooding and landslides are already frequent consequences. The state also faces a series of non-climate pressures because of high rates of urbanization and land conversion, including poor sanitation (of the existing water supply and due to lack of sewage service and treatment) and degradation of water sources.

Climate change is expected to intensify these risks. According to recent climate modeling, extreme rainfall events are expected to become more frequent in the state and in the SPMA, leading to increased flooding and landslides (Nobre et al. 2010). Additionally, mean temperatures will rise, escalating the risk of health problems and diseases.

The agriculture of the region is also expected to change; according to the Brazilian Agricultural Research Agency, which considered three potential scenarios of temperature and rainfall increase (+1°C, +3°C, and +5°-8°C, all with 15% higher rainfall), the main crops in São Paulo state could be severely affected. Corn, which grows in sandy soils, would be reduced by 75%. In the warmest scenario, coffee would lose 90% of its current viable soil. Sugar cane, on the other hand, is tolerant of warmer temperatures and would benefit from the intermediate scenario (+3°C), nearly doubling its viable area. However, the warmest scenario (+5°-8°C) would limit sugar cane's growth to 50% because of the water scarcity inherent in a temperature increase of 5°-8°C.
In short, the SPMA is extremely vulnerable under these projected future conditions. The Sao Paulo urban area is expected to double in size by 2030. Under that scenario up to 12% of the total area would become highly vulnerable to landslides (Nobre et al. 2010).

Institutional Description and Response to Climate Change

Many Brazilian states have developed or begun to work on climate change policies and plans (addressing mitigation and/or adaptation). In 1995 the state of São Paulo established the State Program for the Prevention of Climate Change (PROCLIMA), which is responsible for coordinating the state's mitigation efforts. At the present time, among the twenty-seven Brazilian states, nine already have climate change policies. The state of São Paulo launched its most recent climate change policy in 2009. It prioritizes a shift to a low-carbon development pathway but also tackles some key aspects of adaptation, mainly urban development planning and its integration with other instruments and policies.

The Secretariat of Environment (SEA) of São Paulo is still being restructured after the 2010 change in the state government, as well as its new responsibilities as defined by the 2009 climate change policy, which the SEA became responsible for implementing. SEA's Water Resources Technical Advisory Team coordinates the adaptation components.

In 2009 the SEA launched the Pacto das Águas (which translates to "Water Deal"). This ambitious program is designed to engage all of the 645 municipalities in the state of São Paulo, encouraging them to make commitments and set goals for improving water management conditions. The Pacto das Águas is a group of 21 goals, divided into three topics including sanitation and headwaters and springs protection. The third topic is defined by the individual municipalities according their specific priorities.

Even though the state of São Paulo has only just begun a systematic vulnerability assessment, investing in sanitation and headwater protection are already "no-regret" adaptation actions. The major vulnerabilities predicted across the state are related to water security. Ensuring a water supply for people and the environment will require a shift in "business as usual" ways of managing water. Reservoir construction has been proven to be an inefficient and perhaps inadequate way of providing drinking water for São Paulo; it is clear that water security will require the protection and/or restoration of springs and headwaters.

Sao Paulo's water security problem involves not only water availability but also water quality. Less than 50% of the residents have access to treated water. In the future, extreme rainfall events are expect to become more frequent and intense. If the water quality problems are not addressed now, public health problems in the metropolitan region will likely increase.

Since the launch of the Pacto das Águas, 93% of the municipalities (598) have adhered to the new rules and 26% (153) of the municipalities involved have already achieved their goals (see Figure 1). These impressive results are due to a huge effort from the state to mobilize and engage its municipalities through the media, educational campaigns, and capacity-building workshops. The SEA also benefited from existing state programs that were already active in some municipalities, such as the Green Blue Village (Municipio Verde Azul) state program.

Discussion of Most Important Climate-Adaptive Principles

External Regime

The 2009 São Paulo Climate Change Policy is what led to the restructuring of the SEA, since the state government has a mandate to coordinate and implement the policy. This kind of legal framework was important for the development of an appropriate institutional framework and for the establishment of infrastructure (such as financing).

The SEA is already working on a national inventory of adaptation measures and has started to consider a state water and climate change adaptation plan. However, this component needs a formal "owner" (since the restructuring is still in process) in order to ensure the institutional capacity needed to deal with mitigation and adaptation.

The São Paulo state administration has utilized the Pacto das Águas in order to begin preparing the state for the impacts of climate change. The Pacto das Águas was considered a powerful platform by the prior administration, and the new state administration has just established a permanent structure to advance this effort. However, due to its relevance and its connection to climate change initiatives, the Pacto das Águas should become an institutional priority and be fully incorporated into water resources state legislation.

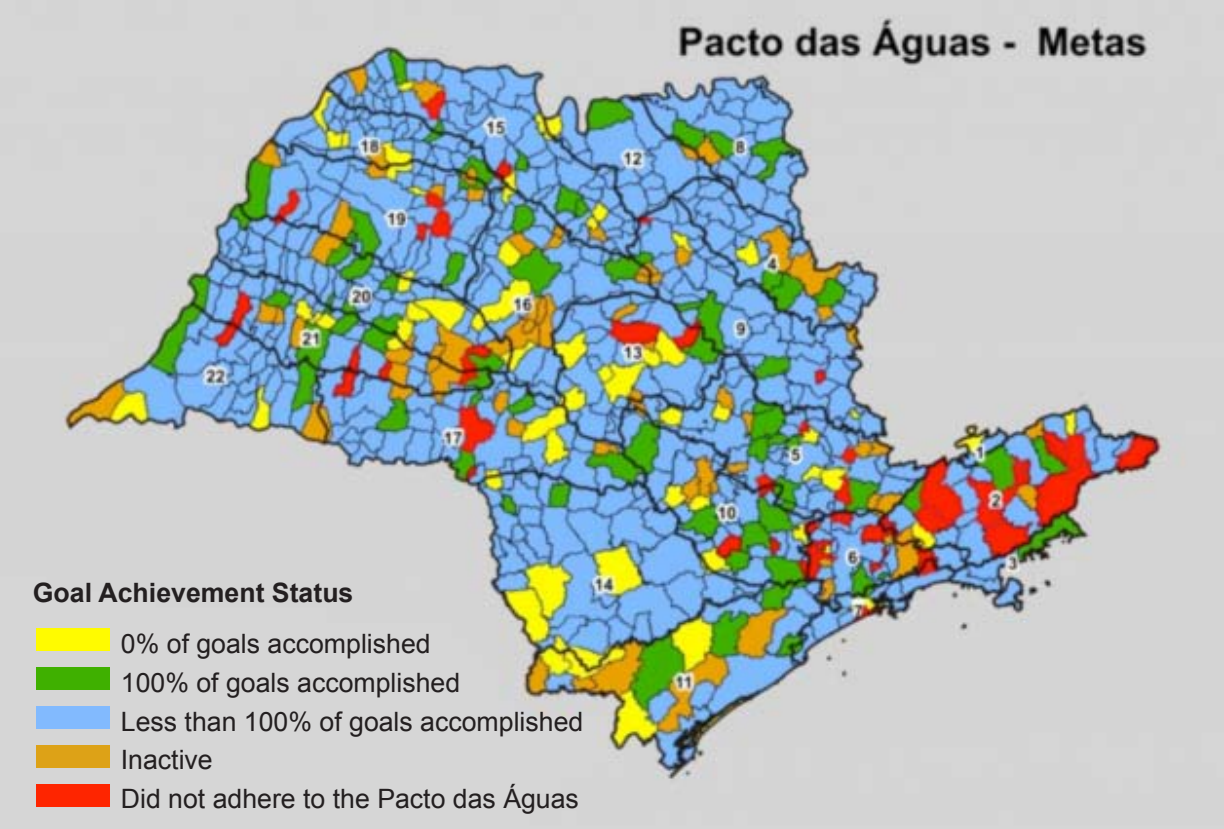

Figure 1. The 645 municipalities of the state of São Paulo and their engagement in the Pacto das Águas.

Resources

The state of São Paulo has so far demonstrated leadership by launching its first climate change state policy. Also encouraging was the vulnerability assessment for the SPMA launched in 2010, which was to be the first in a series that quantifies the impact of climate change on Brazilian mega-cities. However, the state government changed in 2010, and the new state administration has the huge duty of addressing these issues for the region. It is no longer enough to set goals for emissions reductions. The state has a responsibility to advance the adaptation agenda by investing in human resources, training, and capacity building within the SEA; making state funds available; going forward with vulnerability assessments; implementing sustainable planning for its urban areas; and managing risks at vulnerable sites.

Even though the Water Resources Technical Advisory Team has been taking the lead on this agenda successfully so far, the internal capacity (both human and financial resources) within the SEA needs to be increased to meet the considerable challenge of promoting changes at the state level. This must be a priority. Extreme rainfall episodes, flooding, and landslides are becoming frequent and are increasing in magnitude every year. Financial losses, diseases, and deaths could be avoided by investing in greater capacity within the SEA.

Collaboration and Partnerships

While the SEA currently lacks the resources required to promote sound adaptation at the state level, it has been very effective at reaching out to a strategic set of other institutions and organizations for assistance. WWF-Brazil, in particular, has been engaged on a number of fronts, including a collaborative effort to submit a proposal for the National Climate Change Fund that would take advantage of the Pacto das Águas structure and mobilization. Even if that proposal is not approved, WWF-Brazil will support SEA as it develops an adaptation framework, integrated with a plan for water resources protection, with the goal of ensuring water security at the state level. Through this partnership with WWF-Brazil, the SEA has the ability to mobilize all 645 municipalities to develop local adaptation programs within the Pacto das Águas structure. Partnerships like this can enable, on an unprecedented scale, the dissemination of adaptation concepts and principles as well as the demonstration of local adaptation initiatives.

While such adaptation-related collaborations with WWF-Brazil and other institutions are still relatively new, the SEA has a history of collaboration. The Pacto das Águas is a good example of sharing responsibility among municipalities and of consolidating strategic partnerships and efforts. A decentralized framework empowers local authorities to take the lead on key aspects of environment and health, and it represents an effective method for achieving ambitious goals that the state alone could not effectively meet.

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1250 24th Street, NW
Washington, DC 20037-1193 USA
Phone +1 202.293.4800
Fax +1 202.293.9211

www.adaptiveinstitutions.org

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