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Which Risks Get Managed? Addressing Climate Effects in the Context of Evolving Water-Governance Institutions

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ABSTRACT: Warnings about climate change invariably stress water-related effects. Such effects are typically framed as both unpredictable and disruptive, and are thus said to create large new risks to the water sector demanding adaptive responses. This article examines how such responses are mediated by, and also compromised by, two dominant trends in the evolution of water governance institutions: (1) the rise of an "integrated" paradigm of water resources management, which has encouraged the development of more complex and interconnected water institutions, and (2) the rapidly changing political economy of water financing and investment. Each of these trends carries its own strong presumptions about what constitutes water-related risk and how such risk is properly managed. The article uses the specific example of large dam projects to illustrate how these ongoing trends in water governance shape and complicate the prospect of managing climate-water risks.

KEYWORDS: Integrated Water Resources Management, climate change, climate adaptation, risk, uncertainty

INTRODUCTION: WHICH RISKS GET MANAGED?

Warnings about the dangerous consequences of climate change invariably stress water. Changing patterns of precipitation and evaporation will alter run-off, with consequences for water availability and ecosystem functioning. Effects on soil moisture will alter the availability of 'green water' in the root zone, with consequences for soil moisture, ecosystem functions, and agricultural productivity. Impacts on glacier formation, including changes in the timing and volume of seasonal melting, will have profound effects on economic and social systems that have developed in sync with this natural mechanism of water storage and release. Many climate models project that extreme weather events – including cyclones, flood-inducing heavy rains, and periods of drought – will grow in frequency and/or intensity. As the UN's most recent *World Water Development Report* put it, "Water is a primary medium through which changes in human activity and the climate impact with the earth's surface, its ecosystems, and its people. It is through water and its quality that people will feel the impact of change most strongly" (WWAP, 2012: 10).

Warnings about the water-related consequences of climate change typically contain three premises: that significant effects are likely, that they are unpredictable in their precise spatial and temporal manifestation, and that they will be disruptive of the existing ways societies use and interact with water. Taken together, these three presumptions frame the climate-water problem as one of emergent risks to be managed through adaptation.

Driven in no small measure by climate predictions, emphasis on risk management is emerging as a core theme in the broader water policy literature. This growing focus on risks contrasts strikingly with the dominant tendencies of international water-policy discourses of the 1990s and early 2000s – a period in which several major water summits were held, many new organisations and initiatives were launched, and efforts were made to elevate water on the global policy agenda. Much of the discourse from this earlier period emphasised the need for political will to tackle problems that experts felt were well understood: water poverty, inefficient water pricing and allocation, and harm to critical freshwater ecosystems.

Without doubt, climate change adds important elements of uncertainty to the challenges of water governance, and the most likely changes in the water cycle portend many hazards. Framing the problem as one of risk management, however, begs the question of which risks are in fact being managed or are likely to be managed, by whom, and toward what end. Water futures are highly uncertain, for reasons that encompass far more than just climate change, and risk-managing behaviour already pervades the world of water. Climate-related dangers may be very different from, say, the dangers investors face in global capital markets, or the hazards local communities face when they find themselves in the path of large water-development projects, or the threats to their power that political decision-makers face in trying to reconcile water-related controversies. Each of the preceding can be understood as a risk, in the sense of a danger whose probability of occurrence cannot be known precisely. 'Managing' such risks simultaneously, however, may not be a simple act of convergence on optimal policies, and the power to choose which risks to manage or how to respond to them is not evenly distributed. Thus, even if we are able to agree on how best to manage the water-related risks inherent in climate change, any such actions must fit into the wider context of how water-related risks are currently managed and how water decisions are currently made.

In other words, managing risks at the climate-water interface is emerging as an object of concern in the context of an already built landscape of risk management around water. The main features of that landscape are two important, and sometimes conflicting, trends that have already been changing how water is governed and how water-related risks are managed. On the one hand, the past few decades have seen the spread and increasing institutionalisation of an approach known as Integrated Water Resources Management (IWRM). IWRM encourages more complex and interlocking policy mechanisms to manage water more comprehensively: across different user sectors, across different scales, in a more participatory way, with greater attention to the environment, and in a more knowledge-informed manner. Roughly simultaneously with the spread of IWRM, we have also seen the emergence of a new political economy of water, rooted in the growing marketisation of water resources and some dramatic changes in how water projects are financed. These changes are part of a broader shift in the public-private division of labour in the water sector.

The combination of these trends of administrative integration and financial marketisation have produced dynamic, ongoing, and non-incremental change in the water sector, on scales ranging from local to global. This is the world into which any effort to manage climate/water risks must fit. Yet, in this world, risks are framed and conceived in terms that are often quite different from those in the emergent discourse on the links between climate change and water consequences. The IWRM approach presumes that the biggest 'risk' is sub-optimal water use, rooted in poor coordination, a lack of information, and weak stakeholder participation. Most of the institutional adaptations to manage this risk have involved creating greater administrative complexity. More broadly, IWRM is rooted in a paradigm of optimising water use under relatively predictable circumstances, rather than flexibly adapting to change in a dramatically uncertain environment. In the brave new world of water economics, on the other hand, the core hazard is often constructed as the threat to the financial or political 'bottom line' of particular agents, with water adequacy merely one consideration among many. Only some of the resulting risk-management strategies involve protecting water supplies or using them with greater care. Others involve virtualising water supply – shifting modes of investment, production, and trade to outsource the need for water. Still others financialise water risks through hedging – redistributing assets in a manner that allows investors to offset losses, or even reap gains, when water-related outcomes harm economic performance.

This article examines these colliding notions of hazard, uncertainty, risk, and response. The next section provides a brief overview of concepts related to risk, sketches the emergence of calls to manage water-related risks stemming from climate change, and assesses the wider rise of a risk-management frame in water governance. This approach is then contrasted with a very different concept of risk management embedded in the IWRM paradigm, which flourished in the 1990s and which has driven many legal and policy reforms around the world. Risk-management concepts embedded in the new political economy of water are then considered, followed by an examination of how these various approaches to risk interact in the specific context of large water-infrastructural projects.

CLIMATE CHANGE AS WATER RISK

Risk is a threat, laced with uncertainty, to something of value (Fischhoff and Kadvany, 2011). In a technical sense, risk may be conceived as the extent of damage or harm that a hazard entails, multiplied by the probability of that hazard's occurrence. In this formulation, some degree of uncertainty surrounds both the extent of harm and the probability of occurrence. To manage risk is to follow a strategy that copes with the fact that the likelihood and consequences of hazards cannot be known with full precision.

More fundamentally, risk is difficult to specify with precision because, as Lidskog and Sundqvist (2011) point out, "risks are always situated in a social context and are necessarily connected to actors' activities". They caution against "the reification of risks, where risks are lifted out of their social context and are dealt with as something uninfluenced by activities, technologies, and instruments that serve to map them". In this view, risks have a real, material component of hazard that threatens harm, but that materiality of risk is perceived and interpreted in the context of interests, beliefs, cultural norms, worldviews, and causal assumptions that are worked into shared understandings through discourse and practice. 'Risk management' is thus a socially constructed way of countering danger (Zinn, 2006).

As Beck et al. (1997) have pointed out, citizens rely increasingly upon experts to assess risk and identify risk-management options (see also Lupton, 2006). In the context of climate change and its potential impacts on water resources, however, multiple 'expert' communities, ranging from climate modellers to water system managers to water financiers to large corporate users of water, become relevant. These expert communities have views that differ, often sharply, on both the nature and significance of water-related risks in a greenhouse world, as well as on appropriate strategies of risk management at the water-climate nexus. This may be because their interests differ; or, following the work of Mary Douglas, it may be because "Ideas about risks are part of shared cultural understandings and practices that are founded on social expectations and responsibilities. Preestablished cultural beliefs help people to make sense of risk, and notions of risk are therefore not individualistic but rather shared within a community" (Lupton 2006: 12-13).

An important reference point on how climate change may affect water, and thus an important influence on how actors construct an understanding of water-related risks, is the Intergovernmental Panel on Climate Change (IPCC). IPCC has identified seven broad categories of water-related effects of climate change, including changes in precipitation, snow and land ice, sea level, evapotranspiration, soil moisture, run-off and river discharge, and patterns of large-scale variability (Bates et al., 2008). According to IPCC's most recent assessment report (AR5), "Freshwater-related risks of climate change increase significantly with increasing greenhouse gas emissions (*high agreement, robust evidence*)" (IPCC, 2014: 2). Table 1 summarises IPCC's principal statements about the water effects of climate change in AR5. Taken as a set, these statements express a relatively high confidence in understanding generalised hydrologic effects, at least at macro scales. With regard to the consequences of these effects, however, IPCC stresses greater physical uncertainties around water as one important outcome, with net harmful consequences for the functioning of water systems. As AR4 put it in 2007:

Table 1. Highlighted statements on the water consequences of climate change, from IPCC's Fifth Assessment Report (AR5).

Statement	Confidence interval	
	Level of agreement	Level of evidence
Key risks at the global scale		
Freshwater-related risks of climate change increase significantly with increasing greenhouse gas emissions.	High	Robust
Climate change is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions. This will exacerbate competition for water among agriculture, ecosystems, settlements, industry and energy production, affecting regional water, energy and food security.	High	Robust
So far there are no widespread observations of changes in flood magnitude and frequency due to anthropogenic climate change, but projections imply variations in the frequency of floods.	Medium	Limited
Climate change is likely to increase the frequency of meteorological droughts (less rainfall) and agricultural droughts (less soil moisture) in presently dry regions by the end of this century under the RCP8.5 scenario (medium confidence). This is likely to increase the frequency of short hydrological droughts (less surface water and groundwater) in these regions.	Medium	Medium
Climate change negatively impacts freshwater ecosystems by changing streamflow and water quality.	High	Medium
Climate change is projected to reduce raw water quality, posing risks to drinking water quality even with conventional treatment.	High	Medium
In regions with snowfall, climate change has altered observed streamflow seasonality, and increasing alterations due to climate change are projected.	High	Robust
Because nearly all glaciers are too large for equilibrium with the present climate, there is a committed water resources change during much of the 21st century, and changes beyond the committed change are expected due to continued warming; in glacier-fed rivers, total meltwater yields from stored glacier ice will increase in many regions during the next decades but decrease thereafter.	High	Robust
There is little or no observational evidence yet that soil erosion and sediment loads have been altered significantly due to changing climate.	Medium	Limited
Adaptation, mitigation, and sustainable development		
Of the global cost of water-sector adaptation, most is necessary in developing countries where there are many opportunities for anticipatory adaptation.	High	Medium
An adaptive approach to water management can address uncertainty due to climate change.	High	Limited
Reliability of water supply, which is expected to suffer from increased variability of surface water availability, may be enhanced by increased groundwater abstractions.	High	Limited
Some measures to reduce greenhouse gas emissions imply risks for freshwater systems.	High	Medium

Source: IPCC, 2014, Executive Summary.

> Climate change poses a major conceptual challenge to water managers, in addition to the challenges caused by population and land-use change. *It is no longer appropriate to assume that past hydrological conditions will continue into the future* (the traditional assumption) and, due to climate change uncertainty, managers can no longer have confidence in single projections of the future (Kundzewicz et al., 2007: 199; emphasis added).

Similarly, AR5 warns of so-called 'deep' uncertainty at the climate/water modelling interface, "which arises because analysts do not know, or cannot agree upon, how the climate system and water management systems may change, how models represent possible changes, or how to value the desirability of different outcomes" (IPCC, 2014: 24).

IPCC assessments have been much less specific on how to manage water-climate risks, beyond generic recommendations such as the need for joint international responses, better design, and disaster planning. Again, however, the message blends relative confidence in the broad implications of climate models, relative confidence in predicting increased physical uncertainties around water, and relative confidence that there will be resulting threats to the smooth functioning of human water systems. Among the threatening uncertainties are reduced reliability of water supply, increased variability in the availability of surface water, and variable increases in the frequency of flooding. Social responses, including increased competition for water resources and some mitigation measures, are also noted to have unpredictable consequences.

Such warnings resonate with a few longstanding themes in mainstream water policy discourse. One such theme is that many important influences on managing water come from sources external to the water policy domain – or, as it is often phrased, from outside the 'water box' (de Gooijer, 2010; Galloway, 2011). A second theme that resonates with longstanding elements of mainstream water discourse is that the water problem is, at heart, a managerial one. As the World Water Assessment Programme (2012: 6) has put it, "Water is characterised by the fact that all benefit from it but few understand why and fewer actually manage it".

Calls to manage the risks that climate change creates for water tap these longstanding views; they also resonate with and drive important new elements of mainstream water policy discourse. In particular, there is underway a notable tendency to suggest that uncertainties, rather than being a longstanding and well-understood fact of life in the water world, demand new approaches to managing water. The 2012 edition of the UN's signature document on water, the World Water Assessment Programme's *World Water Development Report* (WWDR4), provides a clear example of this reframing:

> Projected pressures on water resources lie outside the control of water managers. These can significantly affect the balance between water demand and supply – sometimes in uncertain ways – and thus create new risks for water managers and users. Such increasing uncertainties and risks necessitate a different approach to water management strategies (WWAP, 2012: 12).

WWDR4, which is subtitled "Managing water under uncertainty and risk", carries this theme throughout, stressing how various uncertainties – in the demand for water, in climate-induced consequences for water-supply, and in availability of financing for water projects – are pushing risk management to the forefront of water policy. This emphasis contrasts sharply with the much more confident analysis of the problem a decade earlier, in the first *World Water Development Report*:

> We know most (but not all) of what the problems are and a good deal about where they are. We have knowledge and expertise to begin to tackle them. We have developed excellent concepts, such as equity and sustainability. Yet inertia at leadership level, and a world population not fully aware of the scale of the problem (and in many cases not sufficiently empowered to do much about it) means we fail to take the needed timely corrective actions and put the concepts to work (WWAP, 2003: 4).

The World Bank struck a similarly assured tone around the same time, when it released its draft Water Sector Strategy for review and discussion in 2002: "There is broad consensus on what constitutes good water resources management, but all countries are far from managing water resources according to these principles" (World Bank, 2002: 28).

The new emphasis on managing water risks under conditions of uncertainty leads to policy recommendations that typically include some mix of risk analysis, adaptive management, and improved knowledge and information systems. WWDR4, for example, suggests three core principles:

- Seek robust projects or strategies, and substantially revise the current economic and optimisation decision rules routinely used in water resources management.
- Employ adaptive strategies to achieve robustness; near-term strategies should be explicitly designed to be revised as better information becomes available.
- Use computer-aided processes to engage in interactive exploration of hypotheses, options and possibilities (WWAP, 2012: 293, citing Lempert and Groves, 2010).

In this context, *robust* strategies are those that 'will work reasonably well' across the full projected range of future circumstances, while *adaptive* strategies are "strategies that can be modified to achieve better performance as one learns more about the issues at hand" (WWAP 2012: 242). IPCC's AR5 takes a broadly similar tone, with its emphasis on "flexible and low-regret solutions that are resilient to uncertainty" (IPCC, 2014: 4).

RISK MANAGEMENT IN CONTEXT, PART ONE: INSTITUTIONALISATION OF IWRM

Calls to manage the water-related risks of climate change do not ring out across an empty landscape; they must find their place within currently institutionalised practices of governing water. One important hallmark of water governance in recent decades has been the emergence, growth, diffusion, and legitimisation of a paradigm of water management widely known as Integrated Water Resources Management (IWRM). The aspirations of IWRM are to integrate water management across sectors (agricultural, industrial, municipal, ecological) and across scales (local, regional, national, transnational), while also making it more participatory, knowledge-driven, and rational in economic, ecological and hydrological terms. Conca (2005) has described the growth and spread of IWRM as follows:

> IWRM is significant not only as a conceptual approach but also as a political force. More than two decades of transnational networking among water policy elites has rewritten the conceptual rationale for global water governance. A set of transnationally disseminated water management norms that began with the specific goal of supplying clean water for human needs would expand and evolve to the point that, by the late 1990s, they bore the unmistakable stamp of IWRM. In the process, IWRM evolved from being merely an expression of frustration on the part of water planners and managers to become *the* language in which the challenge of global water governance is framed (Conca, 2005: 433).

The drivers of this process of diffusion and uptake have included transnational expert networks; the rise of new organisations such as the Global Water Partnership; processes of learning, emulation, and policy diffusion; codification via national legal reforms, which a large number of countries undertook in the 1990s and early 2000s; and reform conditions or incentives within development lending- and foreign-assistance programmes. This is not to say that policy equals practice, or that the shift from prior ways of managing water has been complete: implementation has often lagged behind conceptualisation (Lankford et al., 2007), and even where new institutions are created they interact in complex ways with traditional practices, particularly at local scales (Sokile et al., 2005). Still, there is no doubt that IWRM has transformed the water-governance landscape, leaving in its wake new laws; new bodies such as national water councils, basin commissions, and stakeholder dialogues; new tools for pricing and allocating water; and new frameworks for understanding what constitutes optimal water use.

Turton et al. (2007) describe these shifts as moving simultaneously from the supply-side to the demand-side and from centralised management to decentralised management. However, the shift is not merely one of objectives or scales: IWRM also changes important elements of the authority relations around water, "from a political and territorial basis to a knowledge-based and stakeholder basis" (Conca, 2005: 433).

One tension between IWRM and the emergent discursive emphasis on risk management under uncertainty is that IWRM is a paradigm of optimisation that assumes relative predictability in the wider environment (Pahl-Wostl et al., 2007; Giordano and Shah, 2014). Although some variants of IWRM stress other values, notably equity, the common denominator of all that integrating, multilevelling, participatory dialoguing, etc. is the goal of improving efficiency, by having water flow to its 'highest-value' uses. Thus, pricing reforms such as cost-recovery and marginal-cost pricing are staple elements of IWRM. Sometimes 'highest value' is understood in market terms, and at other times more broadly in terms of social utility. Yet, in both instances, the central image of 'bad' water governance against which IWRM is most often pitted involves isolated decision-making on sector-specific or place-specific water uses, which often prove less than optimal in the wider context of multiple water uses and users.

As uncertainty increases, however, the ability to say what constitutes optimal use of water decreases – or, more accurately, there is a decrease in the time horizon over which statements about optimality can be made with a given level of confidence. As Pahl-Wostl et al. (2007: 3) point out, uncertainty in water management comes from several directions and takes several forms: lack of data; unpredictability of future circumstances; inadequate hydrologic models that cannot capture nonlinearities, feedbacks, and delays; and "diversity of the rules and underlying mental models" that shape the actions of different actors. Under such circumstances, sustained optimisation requires a great deal of flexibility in adjusting to change and surprise, to say the least.

This raises a second tension between IWRM and the risk-management approach: the institutional complexity that results when IWRM thinking is put into practice. In its quest for multilevel, multisectoral, knowledge-intensive, participatory, basin-scale water governance, the IWRM paradigm promotes complex administrative mechanisms that stress coordination, information exchange, and policy dialogue among a large and disparate cast of water users and affected parties. Such arrangements may prove quite inflexible when faced with the uncertainties, surprises, and extremes promised by climate change. Not surprisingly, as Arnell and Charleton (2009: 44) point out in their study of adaptation options to improve water supply reliability in southern England, "Different stakeholder groups rate different adaptation options, and barriers to their implementation, differently, reflecting their organisational objectives".

The difficulties inherent in greater institutional complexity have led, in turn, to a growing emphasis in recent years on 'adaptive' water management (Pahl-Wostl et al., 2007; Medema et al., 2008; Engle et al., 2011). In an early critique along these lines, Lankford et al. (2007) contrasted the 'partial ideal' of IWRM in practice with a more expedient, recursive approach they termed Adaptive Water Resources Management. Similarly, Pahl-Wostl and colleagues argue that "adaptive management supports reflexive governance, and the actors within the system adopt the strategy of rethinking and renegotiating their assumptions" (Pahl Wostl et al., 2007: 5.)

To be sure, there are ways in which the integrated approach to management may enhance adaptation – for example, by mobilising better information, which may make it easier to spot adaptive challenges earlier. Integration may also stimulate social learning processes, and robust participatory mechanisms may help to prevent disastrously risky actions. Desire to tap such synergies – to have our water and drink it, too, so to speak – can be seen in WWDR4's embrace of the cumbersome phrase "adaptive integrative water resources management".

However, a growing chorus in the water-policy literature points to the tensions between integration and adaptation. Engle et al. (2011), for example, identify several tensions and trade-offs between integration and adaptation in their research on IWRM-inspired water reforms in Brazil. For example, smaller teams of technocrats may have greater capacity for flexible action, and may employ longer time horizons that capture sustainability criteria more effectively. Engle et al. (2011: 1) found that "although integrated systems may be more legitimate and accountable than top-down command and control ones, the mechanisms of IWRM may be at odds with the flexible, experimental, and self-organising nature of [adaptive management]". More provocatively, they conclude that "In many ways, systems that exhibit stronger remnants of centralisation, e.g. technical bodies, sectoral dominance, etc. seem to be more equipped to make rapid and conjectural decisions in response to surprises than those that have successfully transformed into deliberative, participatory, and pluralistic forums" (Engle et al., 2011: 7).

Worse, there are documented cases of IWRM-inspired 'reforms' that create institutional rigidity without the benefit of better participatory decision-making. The aforementioned decentralisation trend – which should not be confused with simplification – is often paired, in practice, with underdeveloped or poorly functioning participatory mechanisms, resulting in capture by vested local interests. In Burkina Faso, Sally et al. (2011) document cases in which reform-driven sub-basin management councils intended to have a broadly deliberative, participatory character have instead become *de facto* reservoir management institutions, dominated by large users. Participatory models often struggle to transcend broader social inequalities, leaving local elites firmly in charge or creating new elites with equally rigid preferences (Aubriot and Prabhakar, 2011). More generally, Engle and Lemos (2010) found recurring trade-offs in the ability of basin-level management schemes in Brazil to implement the full range of institutional mechanisms implied by the IWRM approach (see also Engle et al., 2011).

RISK MANAGEMENT IN CONTEXT, PART TWO: THE NEW POLITICAL ECONOMY OF WATER

As suggested previously, the water-related warnings from climate experts and advocates typically stress altered flows of water in a directly physical sense. Yet, for many influential water decision-makers, those physical changes are only one part of the water-risk equation. For actors as diverse as local municipalities and multinational corporations, water-related risks stem not only from impacts on supply and quality but also from sources as diverse as price volatility, regulatory uncertainty, and reputational or political damage created by water-related controversies (Larson et al., 2012). For governments and communities, the risks resulting from such hazards may be viewed in terms of net social welfare or political legitimacy. For investors and firms, the same hazards are likely to translate into risks to profitability, market share, and corporate reputation.

As awareness of such hazards and interpretation of such risks has risen, we are also seeing the institutionalisation of a range of responses. These responses are another important part of the landscape with which any effort to manage climate impacts on water must contend. For example, instrumentalities are emerging for addressing political risks around water. Examples include international stakeholder dialogues such as the World Commission on Dams and the Water Dialogues, dispute-resolution mechanisms built into international agreements over shared rivers, basin-level mechanisms for participation and dialogue, and dispute resolution platforms such as the Udall Foundation’s Institute for Environmental Conflict Resolution. UNESCO-IHE now offers a specialisation area in water-conflict management.

Perhaps the most important development in this part of the landscape, however, is the growing engagement of powerful corporate and financial actors with questions of risk management around water. Hepworth (2012: 543-4) reports

> Over the past decade the level of activity on water and interest in water policy by corporate actors has grown at a formidable pace. Distinct from established debates about private sector involvement in water service provision, this new agenda concerns multinational commercial entities that use significant volumes of water to produce goods and services, and their adoption of new tools, partnerships, initiatives and roles to drive changes in the way they, and wider society use and manage water.

A March, 2013 forum on water investment, technology, and policy, convened by Goldman Sachs, General Electric, and the World Resources Institute, drew more than 250 public- and private-sector water leaders to what Goldman Sachs billed as a "summit meeting" on emerging water-related "risks and opportunities" (Goldman Sachs, 2013). The World Economic Forum, which hosts the annual Davos meeting of global political and economic elites, named water crises in its 2015 Global Risks report as the top global risk in terms of impact (WEF, 2015).

Along with this growing engagement has come an array of new tools, financial as well as conceptual, for businesses to manage water-related risks. Larson et al. (2012) identify some two dozen such instruments, which they group into four clusters: water-use accounting tools, business risk-assessment frameworks, reporting and disclosure protocols, and standards and certification frameworks. The World Resources Institute's Aqueduct project provides an example that integrates many of the aforementioned aspects: the multidimensionality of risks, with combined political and financial components; the growing engagement of powerful corporate and financial actors on the question of managing water-related risks; and the emphasis on risks to profitability and reputation, as opposed to water supply or quality. Aqueduct is a partnership with Goldman Sachs, General Electric, and others that seek to "help companies, investors, governments, and communities better understand where and how water risks are emerging around the world" (WRI, n.d.). At the centre of the project is a risk-mapping tool that integrates the management of the multidimensional risks around water use in specific locales around the world. Along with risk indicators related to water quality and availability, the tool is developing indicators of 'regulatory and reputational risks', defined as "the risks to businesses driven by unstable regulatory environments and social tensions and conflicts around water" (WRI, n.d.).

An example of the shifting landscape around water risks is seen in the financial instruments known as weather derivatives, which allow investors to hedge against extreme, unanticipated, or undesirable weather such as an early frost or an extended drought. CME Group, one of the world's largest operators of options and futures exchanges, offers an extensive line of weather-derivative financial instruments across North America, Australia, Europe and the Pacific Rim, including Snowfall Futures and Hurricane Contracts (CME Group, n.d.). Although such products are an extension of longstanding approaches to managing agricultural risk through hedging, utilities are reportedly now the single biggest class of weather-derivative users (Larson et al., 2012: 586).

An important feature of this approach is that it involves the financialisation of risk rather than a tangible water-use adaptation. Larson and colleagues conceptualise a set of response strategies to physical, regulatory, and reputational risks (Figure 1). While the adjustments to the right side of Figure 1 act to correct an imbalance of supply and demand, those to the left act instead to financialise the risk. Importantly, financialisation may add elements of risk to the overall system even as it may help individual actors manage their specific risk concerns. Continuing with the example of weather derivatives, the underlying asset is a good – the weather – for which no direct market exists. This greatly complicates its pricing and adds a strongly speculative element to transactions whose profitability hinges on weather-related outcomes. The market for snowfall derivatives, for example, struggled with volatility, sputtering to a halt in 2013 after a noteworthy launch in 2011 (Gandel, 2014).

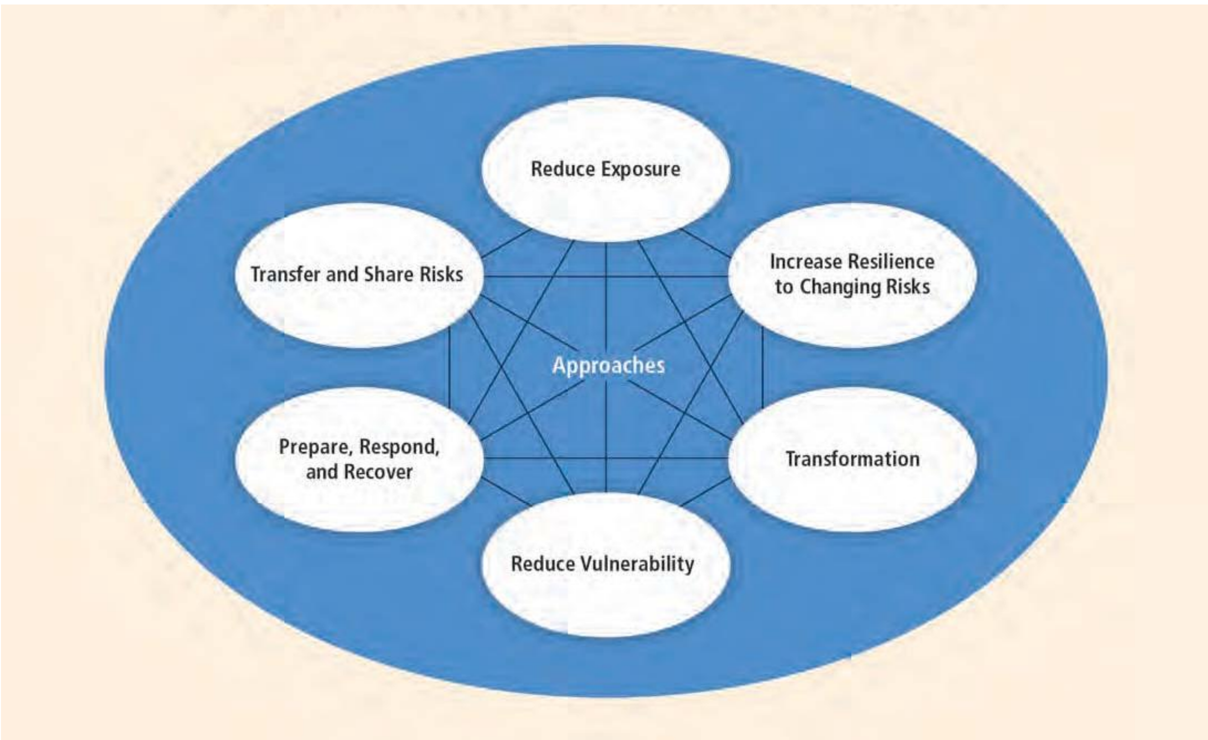
The tensions between the climate-adaptation and political-economy discourses of managing climate-driven water risk can be seen by comparing Figure 2 and Figure 3. Figure 2, taken from IPCC's 2012 SREX report on climate change and extreme weather events, presents a typical climate-adaptation policy framework; Figure 3, in contrast, presents a business model formulated by Larson et al., for assessing and responding to water-related risks. Figure 2, which stresses hazard exposure, system resilience, social vulnerability, and adaptive as well as reactive responses, epitomises an attempt to manage risk in the context of the new institutional terrain for water, the world of integration-plus-adaptation. Figure 3 stresses financial optimisation in the face of a range of uncertainties, many of which are tied only indirectly to the physical flow of water, and is thus characteristic of the new political economy of water.

Figure 1. Spectrum of corporate responses to water risk.

Response	**Hedge** using commodity derivatives for water
	Insure against adverse weather events that cause water scarcity
	Buy or trade water rights and physical quantities of water
	Reduce water use in the value chain and **Reuse** wastewater
	Enhance supply in the value chain

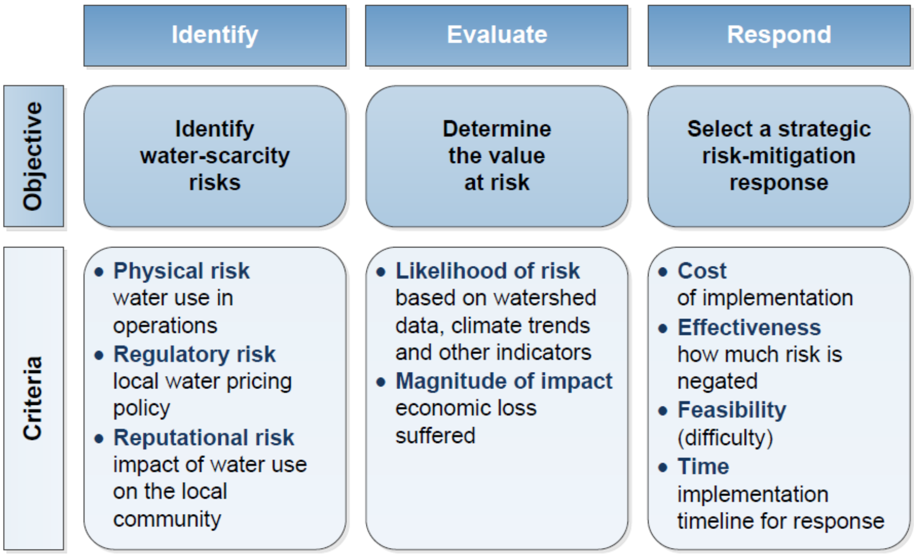
Source: Larson et al., 2012.

Figure 2. IPCC Framework for managing extreme-event risks.



Source: IPCC 2012, p. 4.

Figure 3. A model of managing water-related business risks.



Source: Larson et al., 2012.

The following section, which turns to a discussion of the specific question of financing large dams and other water infrastructure projects, illustrates some of the tensions between the two discourses, and how the decision models they favour may yield dramatically different response to the same scenario of uncertainty and risk.

LARGE WATER-INFRASTRUCTURE PROJECTS

Large-scale water projects – including dams, irrigation schemes, and wastewater and water-treatment systems – come with an array of climatological, financial, regulatory, political, and reputational hazards and uncertainties. Key economic uncertainties include the eventual financial cost of these complex undertakings; the stream of revenues they will generate; the impact of potential human-rights or environmental controversies on ultimate costs, social benefits, and profits; and the economic conditions that will obtain through the several decades of the project's lifetime. Some of these uncertainties receive extensive scrutiny: How much will the project cost? What revenues will it generate? Others get less attention, but may be no less central to the 'bottom line' of net social benefits: What will be the alternate uses of the land and water 30 years from now, and how do they compare economically to the uses in the proposed project? How much certainty is there around the main parameters that will dictate the project's ultimate usefulness, for decades to come? Is there a "real options value" (Anda et al., 2009) in choosing smaller and more flexible systems that allow for learning, new information, and possible mid-course corrections at some future date? If so, how does the value of flexibility compare to the economies of scale typically enjoyed by large projects?

The controversies surrounding water projects create an additional set of dangers, felt not only in the project's finances but also in political, regulatory, and reputational spheres. When the World Bank released its revised water sector strategy in 2003, in the wake of a decade wracked with contention around large dam projects, it identified risk assessment as a central consideration in decisions on financing water infrastructure. Tellingly, the report stated that the risks to be assessed included risks to the Bank itself, rooted in negative public and activist perceptions about such projects in donor countries, as well as equally negative views among borrowers about the Bank's reliability as a development partner (World Bank, 2003: 53). An earlier draft made a blunt statement, ultimately scrubbed from the final report, about what it saw as the Bank's increasingly skewed risk calculus: "Discussion of risk in the World Bank has been too narrowly focused on the reputational risks to the World Bank as articulated directly and indirectly by activist NGOs" (World Bank, 2002: 40).

The problem of assessing and managing risk is further complicated by changing patterns of water-infrastructural financing, in which private and public capital play quite different roles today than just a few decades ago. Consider Nam Theun 2, a 1070 MW hydropower project built on a tributary of the Mekong River in Lao PDR and commissioned in 2010. The traditional vision of how to finance such a scheme, with a World Bank loan to the borrowing government's finance ministry as the centrepiece, bears little resemblance to this dam's complex financing package. The project involves 27 public and private investors, including the governments of Lao PDR, Thailand, and France. Their revenue stream derives primarily from a long-term power-purchasing agreement with neighbouring Thailand. Together, the World Bank and Asian Development Bank provided about US$240 million in funds for the billion-dollar project, with the bulk of funding going not to build the dam directly, but rather into various forms of risk management. The development banks provided risk underwriting for the investment consortium and funded a series of environmental and social projects intended to reduce controversial impacts (and, presumably, the anticipated political opposition to projects of this size and impact).

In other words, the primary role of the multilateral development banks here was to manage perceived financial and political risks sufficiently so that the investor consortium would find the project attractive. They succeeded in doing so, despite what would otherwise seem to be a questionable payback ratio for the investors (US$ 1.93 billion in projected revenue over 25 years, on a US$ 1.45 billion investment). Clearly, the financial viability of the project rests not simply on construction costs, operating expenses, and electricity revenues, but also on the regional governments' perceptions of multiplier effects from expanding the regional power grid, and the capacity to manage the controversial project's financial and political dangers to investors with the help of the multilateral development banks.

How do climate-related water uncertainties complicate risk management for a long-lived, controversial, and expensive project such as a large dam? Consider the Belo Monte Dam in the Brazilian Amazon. The ongoing project, with a planned hydro capacity of more than 11,000 MW (which would make it the world's third largest hydro generator), is being built by a consortium of 18 financial partners. These include the Brazilian state-owned electric company Eletrobras, several investment funds, and several large Brazilian construction firms. Multilateral development banks have shied away, presumably due to the project's ecological, social, and human-rights controversies and perhaps its questionable economic prospects (discussed below).

An analysis of the project's economics under prevailing uncertainties (Sousa Junior and Reid, 2010) illustrates what is required to 'manage risk' in a case such as this. The authors identified the principal variables that would affect the project's net economic benefits to society, and estimated the range and distribution of uncertainty around each variable. Variables assessed included costs related to construction, financing, and operation; the opportunity costs from foregone uses of the land and water; environmental impacts; and project benefits such as generated electricity and avoided carbon emissions. The authors then conducted a Monte Carlo-style analysis of the dam's expected economic utility to society – essentially, running the cost-benefit model a very large number of times and allowing the individual parameters to vary around an assumed range and distribution function, to account for uncertainty as to the 'correct' value for each variable. Doing so yielded a probability distribution function in which, over a 50-year time span, the dam proved to be economically beneficial to society in only 29% of the 10,000 simulation runs.

If we construct society's 'risk' in this case as the misallocation of resources for a secure water future, then both of the approaches to managing risk discussed in the preceding sections – administrative integration and financial marketisation – have failed in this case. Brazil has been a leading example of IWRM-style water reforms, dramatically reworking its legal, managerial, and participatory institutions of water governance over the past 20 years (Conca, 2006; Abers and Keck, 2013). Those reforms have not been able to produce, in this case at least, the sort of measured, interconnected, deliberative, and participatory decision-making for which 'integrated' stands. Nor have they been able to hold the project accountable to legal requirements for impact assessment and participatory engagement with affected communities.

Meanwhile, financialised approaches to risk management have made viable a project that the multilateral development banks would not touch. According to Banktrack.org (2013), the principal underwriters of the financial risks in this case are the Spanish insurer MAPFRE, Munich Reinsurance AG, and IRB Brazil, a reinsurance joint venture under state control. If the analysis of Sousa Junior and Reid is in any way instructive, then the successful underwriting of project funding is hardly a cause for celebration: some combination of local communities, other resource users in the region, Brazilian citizens, and future generations seem likely to pay a net public cost, potentially quite large, for the project's viability with investors.

This example poses three hard sets of questions for climate adaptation initiatives on the current water landscape. First, could the IWRM administrative approach have 'optimised' under these conditions of cascading uncertainty, even if it had been allowed to function properly? If the project turned out to make sense, would it have been possible to negotiate it through the terrain without ignoring the rules? If it did not make sense, would it be possible to see and act on that fact under current 'integrated' practices?

Second, can the financialised system effectively underwrite risk under those conditions? If an important element of such a system is that poorly conceived projects fail to thrive in underwriting and investment markets, how well did that system perform in this case?

Third, and perhaps most importantly, could climate considerations even get to the table? One implication of Sousa Junior and Reid's analysis is that, despite dire warnings about climate-induced uncertainties, the financial uncertainty around Belo Monte over its lifetime appears to exceed the climatological. Climate matters, to be sure: the project has essentially a run-of-the-river design with limited water storage, making stream flow the key indicator of the proportion of generating capacity that will be usable under normal operating conditions. Recently, parts of Brazil further south have been experiencing droughts of epic proportions, with severe social impacts and economic dislocations. Yet, over the past 35 years, the variability in stream flow on the Xingu River between particularly wet and particularly dry years has been roughly a factor of two. The ranges of plausible values for several of the most important economic parameters surrounding the project, including opportunity costs of land and water use over the dam's lifetime, environmental impacts, the value of the generated electricity, and the value of avoided carbon emissions, are at least as large, and in several instances substantially greater (Sousa Junior and Reid, 2010; see also Jeuland, 2010). If this is correct, and if financial markets read it as an indicator of relative importance, then calls for climate adaptation as a way to manage risks may be forced to get in line for attention, behind the risk considerations seen to outweigh them.

CONCLUSION

According to the IPCC, climate change is likely to impact the water cycle in several consequential ways, including significant changes in the quantity and timing of water availability, increased extremes of flooding and drought, impacts on critical ecosystems and water quality. These effects create at least three broad categories of risk to society. The first and most obvious of these is the risk of water insufficiency, the result of undesirable changes in the availability, reliability, and quality of water supplies relative to existing patterns of water use, demand, and administration. A second broad class of risks involves the effects of climate uncertainty on economic resource allocation. Climate change makes it harder to say with a given level of confidence that investments in water infrastructure will in fact pay off in the form of net social benefits over a project's lifetime. And the uncertainty surrounding the precise 'when, where, and how much' of climate change also makes it difficult to allocate resources efficiently in response to the anticipated problems. Finally, there are what might be termed the administrative risks of climate change. Investing in a given set of institutional arrangements also has a set of life-cycle costs and benefit, and many institutional arrangements endure on a time scale of decades or more.

However, risks are not managed by society, but rather by particular agents who bear specific interests and operate from within particular social constructions of risk. And their actions do not occur on a blank institutional slate, but rather against an already extensively built institutional landscape. In both the institutions of administrative water governance and the institutionalised political economy of financing water infrastructure, a pre-greenhouse logic prevails. In the former instance, the governance system has been moving toward integrated mechanisms of increasing complexity and interconnectedness; in the latter, the financing system has been moving toward volatile private capital markets. One approach strives for the unattainable goal of identifying and pursuing optimal outcomes, even as an increasingly unpredictable context demands flexible, adaptive, learning-oriented risk management. The other approach is, in contrast, quite flexible in its ability to manage risk in the form of financial exposure, but it does so without, for the most part, addressing the underlying changes to the water cycle that are its ultimate source.

Across this fragmented and sometimes contradictory landscape, efforts to 'manage' water-related risks from climate change face an unappealing choice. They can muddle through an institutional framework for water policy built for other purposes, or they can gamble that the tremulous invisible hand of capital markets will yield the sort of resilient, robust choices that can endure and adapt through the uncertain decades ahead.

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