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(Eds.)

Adaptive and Integrated Water Management

Coping with Complexity and Uncertainty

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With 72 Figures

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Preface

Ladies and Gentlemen,

This year's International Conference on Adaptive and Integrative Water Management in Basel, Switzerland, will bring together more than 250 leading scientists, policy and decision makers from all over the world to discuss new scientific findings and analyse possible implications for water policy. I am pleased that this event takes place with the patronage of the European Parliament, as the initiative is of utmost European interest.

The conference comes at a very special time. Rising temperatures, changing weather conditions, floods in some parts of the world and rapidly spreading drought zones in other regions may permanently alter - and damage - our planet. Scientific reports have established that climate change is a fact and an acute challenge for policy makers worldwide. Climate change is happening and even accelerating. Doing nothing is not an option. The European Parliament has called for Europe to prepare urgently to face up to and tackle these developments. At the beginning of this year, at their Spring Summit, European heads of state and government committed themselves to binding, rapid and responsible measures to combat climate change.

In this context, many voices argue for a profound shift in water management practices. Today’s problems of water supply and quality are expected to grow and intensify due to the effects of climate change over the next decades. The sustainable management of water resources is one of the major challenges for environmental policy in the 21st century. And at the heart of the problem is that the world’s freshwater resources are very unequally distributed. In addition, even in countries which do not have problems of scarcity, a major cause of water shortage and sanitation problems is poor water governance. Even in Europe, almost 18 % of the population suffers from “water stress”.

The European Union strives for a sustainable concept of water quantity and quality management within its borders. Since the early days of European water policy in the 1970s a complex set of directives and regulations has been put in place. In October 2000 the European Parliament approved the Water Framework Directive, which represents a milestone in EU water policy. The Framework Directive covers all inland and coastal waters and represents a powerful tool to address the various pressures on water supply. The Directive not only commits the EU to achieve a "good condition" for all European waters, but also obliges all EU Member States to use water fees policy as an efficient tool for the protection of water resources. In order to support Member States in the implementation process and to involve a broad range of stakeholders, a Common Implementation Process was set up. Furthermore, a platform for sharing information and experience has been established, and the streamlining of reporting has started. The implementation of the legislation is well under way. WISE, a common reporting platform, aims to harmonise and simplify the required reporting.

Parallel to the implementation of the Directive, EU water policy is undergoing a reshaping process: Within the EU, we have undertaken new water actions. The Groundwater Directive entered into force on 16 January 2007. The Floods Directive and the Marine Strategy Directive have been proposed and are under way.

We need to start thinking about how to better integrate the impacts of climate change on water resources, in particular the issue of water scarcity and droughts into all relevant areas of EU policy.

"Adaptation" - tackling the present problems of a changing climate, such as increased rainfall, higher temperatures, scarce water or more frequent storms, while also anticipating future change in aiming to cost-effectively reduce risk and damage - has become the magic term in today's politics. On 29 June 2007, the European Commission adopted its first policy document on "adaptation to climate change in Europe - options for EU action". This Green Paper builds on the work and findings of the European Climate Change Programme.

The international Conference on Adaptive and Integrative Water Management 2007 will address a lot of the issues raised in the recent European Commission paper. This book provides a selection among the contributions preparing for the Conference on Adaptive and Integrative Water Management. Chapter topics range from adaptive steps toward groundwater protection, to regional water management regimes, managing flood risks, improvement of water use and conceptual considerations, as well as methodological analyses of case studies on water management from across the world.

The book successfully aims to contribute to developing and disseminating a much needed knowledge base in the field of water policy. We in Europe can only achieve the ambitious goal of future sustainable management of the world's water resources by building on innovative concepts and methodological approaches developed by scientific experts in close cooperation with policy and decision makers. Besides focusing on technical solutions to individual problems, water management needs to take better account of the complexity and uncertainty of this task and therefore requires that we employ more adaptive and flexible strategies.

The European Parliament supports all efforts made by researchers and scientists in addressing these topics of crucial scientific importance, welcoming a cross disciplinary approach.

The Conference on Adaptive and Integrated Water Management provides an important new exchange forum for both, scientists and policy makers. By supporting scientific networks and touching upon sensitive issues relating to water management, the conference will give vital aid to our common project, sustainable future water governance, in Europe and globally.

Hans-Gert Pöttering,
President of the European Parliament

Preface of editors

What to do if the past does not tell us much about what we can expect for the future? Increasingly water resources management has to cope with situations that have not previously been experienced. Australia faces an extreme drought which threatens the existence of many farmers who have always relied on water supply for irrigation. At the same time what used to be once-in-a-century floods have in some areas occurred several times within one decade. Such events have sharpened awareness of the limitations of current water resources management approaches to cope with complexity and uncertainty and highlights the need to develop and implement integrated and adaptive approaches. Climate change will place significantly more pressure on the water sector. Despite human capacity to adapt, current knowledge of water resource management regimes and what determines their performance and their complex dynamics is quite fragmented. Major research efforts integrating the social, natural and engineering sciences and the scientific and the policy communities are needed to improve this situation.

These are the challenges tackled in the first international conference on Adaptive and Integrated Water Management organized under the leadership of the European project NeWater (New Approaches to Adaptive Water Management under Uncertainty). The conference places a strong emphasis on the human dimension, water governance, learning processes and change management – themes that have for a long time been neglected in water resources management but that are crucial for improving current practices. This book includes a number of papers addressing the key themes of the conference. The topics covered range from conceptual and methodological considerations to case study applications and practical guidance for policy and practitioners. Experiences reported are drawn from case studies from all over the world. A major task for the future is the carrying out of systematic comparative studies to identify those water management lessons from which generalisations can be made. Based on available evidence it is already clear that no generic recipes exist, but what is required are diagnostic approaches that allow the development and implementation of processes of change in management practice tailored to the current situation in a given basin. Furthermore, knowledge gaps should not be used as an excuse for delaying action. The current knowledge base is sufficient to support a transition in water resource management to adaptive and integrated approaches. These approaches are urgently needed to guarantee water-related services without compromising environmental, economic or social sustainability and to decrease the vulnerability of societies to water-related hazards. The fact that the conference takes place under the auspices of the European Parliament is a clear signal of the political relevance and timeliness of the conference theme. We expect that the book will provide a valuable source of inspiration and guidance for scientists, policy makers and practitioners in their work on water policy and management.

We want to thank all contributors to this book for their efforts in providing high quality manuscripts and to Patrick Wild, Torsten Hoch and Stefan Riffert from the CAIWA team at the University of Osnabrück who worked day and night to ensure that the book would be available for the conference. The financial support for the NeWater project from the European Commission is gratefully acknowledged.

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Abstract

Numerous arguments have been put forward regarding the need for a major change in water resources management. In particular increasing awareness of the impacts of climate change has lead to the insight that water management must be become more flexible in order to deal with uncertainties and surprise. This paper argues for a paradigm shift through the development and implementation of integrated and adaptive water management approaches. Adaptive management is defined here as a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies.

Development and implementation of adaptive management approaches requires structural changes in water management regimes. Such changes are slow due the inertia inherent in prevailing regimes. Concepts for understanding water regime properties and transition processes are summarized. Emphasis is given to the role of actor platforms and processes of social learning in multi-level governance regimes. The paper concludes a strong recommendation to implement learning cycles as an integral part of water management.

1 Introduction

Currently water management is in a phase of transition. Over the past decade a whole range of insights have started to undermine basic assumptions upon which traditional water management with its emphasis on technical solutions and command and control approaches was based:

- water crises are often crises of governance and not resource or technology problems,
- increasing uncertainties due to climate and global change reduce the predictability of the boundary conditions under which water management has to perform,
- the polluter-pays-principle and source control are more in line with sustainable water management and have gained increasing support over technical end-of-pipe solutions,
- integrated water management has been strongly promoted as being more efficient and effective as a guiding principle for water management.

Correspondingly, more voices have advocated the need for a radical change, for a paradigm shift in water management (e.g. Cortner and Moote, 1994; Ward, 1995; Gleick, 2000; Pahl-Wostl, 2002, 2007). The arguments put forward differ in detail and emphasis but not in the essential elements of the needed paradigm shift which include:

- a shift towards participatory management and collaborative decision making,
- increased integration of issues and sectors,
- management of problem sources not effects,
- decentralized and more flexible management approaches,
- more attention to management of human behaviour through "soft" measures,
- environment explicitly incorporated in management goals,
- open and shared information sources (including linking science and decision making),
- iterative learning cycles incorporated into the overall management approach.

(Pahl-Wostl et al, 2006)

One can conclude that in the water management community there is a clear recognition of the need for change. The key elements of change can be summarized as a plea for more adaptive and integrated management approaches. The main logic of the discourse and the substance of the dominant arguments are summarized in the following assumptions:

- *Sustainable management of water resources and the implementation of Integrated Water Resources Management (IWRM) cannot be realized unless current water management regimes undergo a transition towards more adaptive water management*
- *The systems to be managed are too complex to predict with accuracy the outcome of management interventions and to know and control all relevant processes.*
- *Water management is a political process and the implementation of all policies is to some extent an experiment.*
- *Adaptive management is needed as a* systematic process *for improving management policies and practices by learning from the outcomes of implemented management strategies.*

(Pahl-Wostl et al, in press)

As defined here adaptive management is relatively comprehensive and broader than the established use of the concept in environmental management where adaptive management has been based upon the possibility of conducting well-defined experiments to test different hypotheses about system behavior (Holling, 1976; Walters, 1986). A systematic approach to learning under conditions of high uncertainty must not necessarily include the implementation of small-scale experiments (which are not always possible) but should be perceived as the guiding paradigm for the design of adaptive policy processes. If taken seriously, this has significant implications for policy and management.

Figure 1 shows the various steps in any iterative policy cycle involving assessment, policy development, implementation and monitoring:

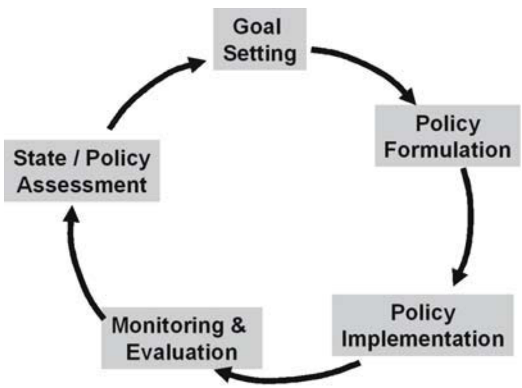

Fig. 1 Steps in iterative policy cycle.

Implementing a systematic approach to learning in order to take into account uncertainties requires different steps in this policy cycle:

- In the problem definition and goal setting phases, various perspectives need to be taken into account.
- The design of policies should include scenario analyses to find strategies that perform well under different possible but initially uncertain future developments.
- Decisions should be evaluated by the costs of reversing them. This might imply monetary costs but also the loss of trust.
- The design of monitoring programmes should include various kinds of knowledge in order to identify undesirable developments at an early stage.
- The policy and management cycle must include institutional settings where actors assess the performance of management strategies and implement change if needed in a transparent and open way.

The implementation of adaptive management also requires open and transparent access to information:

- New information must be available and/or consciously collected (e.g. indicators of performance or change) and monitored over appropriate time scales
- The actors in management system must be able to process information and draw meaningful conclusions. This can be best achieved if the learning process unites actors in all phases of assessment, policy implementation and monitoring.
- Change must be possible and must be implemented in ways that are open and understandable to all actors. It must be clear who decides how and when to change management practices, based on what evidence and why.

These requirements differ considerably from current practices where an expert culture with private access to information prevails (several examples are given in Timmerman and Langaas, 2003). More generally one can note that despite of the presence of the concept of adaptive management for the last several decades and the emphasis of the scientific and political discourse on the need for a paradigm shift in water management, change at the policies and operational management levels is quite slow. Hence one can suspect that barriers prevent change. Therefore this chapter reflects a systematic approach to analysing the requirements for adaptive management and necessary processes of change at various levels in order to establish the foundations that will permit these requirements can be met.

2 Framework of analysis and definitions of key concepts

Adaptive management can be seen as an integral part of water governance. It unfolds at the process level but is clearly shaped by the governance structure. Therefore an appropriate framework of analysis must include the relationship between structure (water management regime) – process (adaptive water management) – outcome (sustainability of water system). A definition of adaptive water management has already been provided. In this section, water management regime and sustainability of the water system are defined in more detail.

Definition of water management regime:

> *A management regime is referred here to as the whole complex of technologies, institutions (= formal and informal rules), environmental factors and paradigm that together form a base for the functioning of the management system targeted to fulfil a societal function.*
> *Due to the high level of interconnectedness and internal logic, individual elements of a regime cannot be exchanged arbitrarily.*

There is a whole range of traditions of regime theories that have found application in environmental resources management. Technology-based approaches assume that regimes unfold around key technologies and correspondingly technological innovation is also a key driver for regime change (e.g. Geels, 2002). The definition above focuses more on the role of the human dimension. It is thus closer to regime approaches in the political sciences where a regime unfolds around a convention and where actors are the focus of attention. According to the generally-accepted definition of international regimes that integrate different discourses in the political sciences, a regime can be characterized as:

> *Regimes are implicit or explicit principles, norms, rules and decision making procedures around which actors' expectations converge in a given arena of international relations. Principles are beliefs of fact, causation, and rectitude. Norms are standards of behaviour defined in terms of rights and obligations. Rules are specific prescriptions or proscriptions for action. Decision-making procedures are prevailing practices for making and implementing collective choice.*
>
> (Krasner, 1983)

In contrast to international regimes that have been assumed to unfold around a single institution (e.g. UN Convention on Biological Diversity, Convention on Long-Range Transboundary Air Pollution, The Kyoto Protocol) a water management regime is assumed to unfold around a societal function (e.g. water supply, flood protection). This gives the definition a constructivist character since societal functions are continuously reinterpreted and enacted by regime actors. Similar to the definition of regime in the political sciences, water management regimes are based on guiding principles that are summarized here in the notion of a paradigm. A paradigm is defined as:

A water management paradigm

- *refers to a set of assumptions about*
  - *the nature of the system to be managed*
  - *the goals of management*
  - *the ways in which these goals can be achieved.*
- *is shared by " an epistemic community" of actors involved in water management.*
- *is manifested in artefacts such as technical infrastructure, planning approaches, regulations, engineering practices, models etc*

The definition of a water management regime and paradigm emphasize the internal logic and the stabilizing nature of a whole array of interdependent elements. This interdependence is important to guarantee the functioning of a regime, and the convergence of expectations of actors. The downside of such interdependence is that it prevents change, that it generates what one may refer to as lock-in-situations. An example is given by waste water treatment characterized by large scale centralized infrastructure and stringent regulations in most industrialized countries. House owners are in most cases obliged to connect to a centralized system. Householders have few choices in this regard. Often they are not even aware of the costs which are in general higher for waste water than for water supply. In recent years, one observes a growing interest in decentralized household technologies. However, the entire legal and regulatory framework prevents the introduction of such technologies. Risk management and accountability need to be newly defined. A shift towards decentralized household technologies would lead to a radical transformation in the whole producer - customer landscape. Change and the overcome of critical thresholds are prevented by the inertia of the established system. Lock-in situations may pose a considerable problem if the prevailing regime does not have the capacity to fulfil the societal function due, for example, changes in boundary conditions (e.g. climate change, economic development) or a shift in priorities in terms of how to evaluate regime performance and how to define a certain societal function (e.g. more importance attributed to environmental side effects or increased importance of economic efficiency). Hence it is of crucial importance to develop a conceptual framework that allows an understanding of what drives and what hinders change, and what determines the nature of change and the characteristics of the regime one observes.

Regarding the sustainability of water systems, obviously one needs to address the question if the three major dimensions of sustainability - environmental, economic and social - are to be respected. The approach chosen here links to a tradition in social-ecological research that argues that these dimensions should not be addressed in isolation. Rather the emphasis should be on system level characteristics such as resilience or adaptive capacity of human-technology-environment systems (good overview articles in Berkes et al., 2002). Unfortunately, one observes a proliferation of terms and use of the same terms with partially differing meanings in this fast-growing research field (addressed for example in a review by Gallopin, 2006). Even when interpreted in a positive sense as an indicator of a dynamic and vibrant research community, this does not necessarily add to the clarity of the communication and thus progress in scientific understanding. A recent special issue in 'Global Environmental Change' addressed the rich and diverse terminology characterizing the use of the concepts of resilience, vulnerability and adaptation (Janssen and Ostrom, 2006). It is beyond the scope of this chapter to enter this rich and somewhat controversial debate. However, the debate highlights the need to give a definition for key terms used in the context of the analysis presented in this chapter.

Adaptation - Transition

Adaptation

refers to change within a given regime structure and management paradigm (e.g. increase of water price)
Structural change in one regime element would still be adaptation if it does not imply any change in other elements.
Adaptation is not a reactive process – it can also happen in a proactive mode (e.g. adaptation to expected climate change)

Transition

refers to structural changes in more than one regime element (e.g. from centralized to decentralized waste water technologies). A transition involves a change in the management paradigm.
In water management transitions are driven by dissatisfaction with the current regime rather than by some randomly emerging innovations.

Adaptive Capacity

refers to the ability of a system to adapt to anticipated or experienced change in its context.

IPCC (2001): Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Regarding the sustainability of water systems one can now make the normative claim:

Sustainable water management should maintain in the long-term the key functions of a water system in order to avoid irreversible developments and catastrophic shifts towards undesirable states. This implies the maintenance of an "appropriate" adaptive capacity of the water system to ensure functional integrity in the context of changing external boundary conditions and to counter undesirable internal non-linear developments. Adaptive management is a key strategy for enhancing the adaptive capacity of water systems. Adaptive management must be both anticipatory and reactive. Anticipation of future developments in scenario planning is needed in order to define what an "appropriate" adaptive capacity should be.

This normative claim is somewhat in contrast to arguments for optimization of the short-term efficiency of water management. The maintenance of adaptive capacity may require maintaining a certain level of redundancy. As outlined above, robust strategies may be those that perform well under different possible but initially uncertain future developments. They are not strategies which are optimal given the most likely future development, but that may fail entirely if certain conditions are not met. This shift in thinking is, for example, reflected in new approaches to flood protection. In the past flood protection aimed at avoiding flooding by the construction of dikes and dams. As a consequence people felt safe and became less aware of the threat of flooding with its concomitant catastrophic consequences if dikes break. The damages from flooding have increased considerably over the past decades because more development takes place in former flood plains. By allowing temporary flooding events and by investing in adaptation and diverse measures for flood protection at the household / community level, society builds resilience and reduces the catastrophic impact of large scale flood events.

3 Characteristics of integrated and adaptive regimes

Our understanding of the complex dynamics of water systems including human, environmental and technical components is still poor. Correspondingly there is no sound basis for deriving the kind of regime properties needed for integrated and adaptive management. This applies in particular to the interdependence between regime elements such as technologies and regulatory frameworks. Table 1 summarizes a number of assumptions about characteristic properties of integrated and adaptive regimes (Pahl-Wostl, 2007a). These assumptions have been derived mainly from concepts and empirical evidence for the individual elements of a water management regime.

Table 1. Expected properties of integrated and adaptive regimes

	Integrated, Adaptive Regime
Management paradigm	Management as learning in complex adaptive systems
Governance style	Polycentric, horizontal, broad stakeholder participation
Sectoral Integration	Cross-sectoral analysis identifies emergent problems and integrates policy implementation
Scale of Analysis and Operation	Transboundary issues addressed by multiple scales of analysis and management
Information Management	Comprehensive understanding achieved by open, shared information sources that fill gaps and facilitate integration
Infrastructure	Appropriate scale, decentralized, diverse sources of design, power delivery
Finances and Risk	Financial resources diversified using a broad set of private and public financial instruments

Explanation and justification of each element in the table:

Management paradigm

The management paradigm takes into account that the systems to be managed are complex adaptive systems. Rather than trying to reduce the degrees of freedom in these systems by attempting hierarchical and centralized control (e.g. large-scale technologies, highly regulated top-down governance), the management paradigm tries to build on the strengths of complex adaptive systems to perform well in uncertain environments. Management facilitates and guides learning processes in complex adaptive systems (Pahl-Wostl, 2007b).

Governance style

Empirical evidence strongly suggests that polycentric governance regimes are more flexible and adaptive than mono-centric regimes (e.g. Ostrom, 2001; 2005; Folke et al, 2005). These findings support the more general understanding that complex adaptive systems are both more effective and efficient than centralized systems in the allocation of scarce resources in dynamic and uncertain environments (Pahl-Wostl, 1995; 2002). Polycentric governance systems tend to outperform monocentric systems governing similar ecological, urban, and social systems. Adaptive governance relies strongly on participatory processes and active stakeholder involvement to build commitment and social capital needed for social learning and to include a wide range of different perspectives.

Governance approaches that embrace the inherent uncertainty and complexity of human-technology-environment systems are required. Rather than advocating the dominance of a single governance approach, adaptive and multi-level governance regimes integrate bureaucratic hierarchies, markets and network governance.

Sectoral Integration

Integrated water resources management requires cross-sectoral analysis to identify emergent problems and integrate policy implementation and adaptive responses to new insights. However, in most countries the institutional landscape is highly fragmented and sectoral policies and planning processes are developed in isolation. This prevents the implementation of integrative solutions. Innovative flood management requires for example a strong coordination with spatial planning and agricultural policy. Biswas (2004) argued that such integration would lead to rigid mega-bureaucracies. This must not be the case – other forms of governance are more promising in achieving the desired combination of sectoral integration and flexibility and learning in management.

Scale of Analysis and Operation

Transboundary cooperation is a key requirement for integrated and adaptive water management. The need to share water resources across national boundaries can be a source for conflict, or even wars, but can also be a trigger for cooperation (e.g. Yoffe and Wolf, 1999; Gleditsch at al, 2006). To cope with impacts of climate change cooperation is mandatory. Increased uncertainty in water supply, an increase in extreme events, a reduction of natural buffering capacity due to the melting of glaciers require that adaptation strategies be developed at the transboundary level.

Information Management

As highlighted before information management is of key importance for integrated and adaptive management. Access to information must be open. Uncertainties must be clearly communicated. A comprehensive understanding of water problems and their solutions is only achieved by open, shared information sources that fill gaps and facilitate integration.

Infrastructure

Large-scale infrastructure with a life-span of decades provides few opportunities for learning and may easily lead to lock-in situations (e.g. Tilman et al, 2005; Pahl-Wostl, 2002). Adaptive management is mainly limited to the operational level. Careful consideration at the appropriate scale, an increased use of decentralized technologies, diverse sources of design adapted to the regional context have been advocated as more promising strategies for achieving sustainable and integrated water management (Gleick, 2000; Pahl-Wostl, 2002).

Finances and Risk

Large infrastructure can produce enormous sunk costs which reduce the flexibility and efficiency of economic instruments. The water price in urban areas may for example be largely independent of water use but reflect mainly the costs of prior investment in water supply and waste water treatment infrastructure. Adaptive and integrated water management will require a diversification of financial resources using a broad set of private and public financial instruments. Risks have often been managed by prescribing technical standards such as regulations for the required size of flood protection systems based on the likelihood of an extreme flooding event. Due to increased uncertainties of climate change the conditions under which such regulations were passed may no longer be fulfilled. Acceptable risks need to be negotiated in participatory processes rather than being prescribed by law.

One cannot expect that design and implementation of integrated and adaptive management regimes will be based on a full understanding of the interaction between regime elements. Some regime properties are emergent and path-dependent, and will unfold during the implementation process. Hence the whole process of change, the transition towards integrated and adaptive management regimes has to be regarded as a kind of adaptive management process as well.

4 The role of multi-level governance and actor platforms

The importance of understanding transitions as multi-level processes has been emphasized by recent work on socio-technical transitions, an active area of research building primarily on complex systems and evolutionary approaches. As represented in Fig. 2 it is useful to distinguish the following three levels (macro-meso-micro) of a system (Pahl-Wostl 1995; Rotmans et al. 2001; Geels 2002):

- The Landscape or macro-level with stabilizing factors which constitutes the context for a water management regime. The landscape encompasses, for example, environmental variability, legal frameworks, deeply rooted societal norms and cultural values. The landscape provides the context and also the selection environment within which a management regime unfolds. The landscape level must not be entirely independent from the micro and meso level since feedback processes can operate bottom-up (e.g. diffusion of innovation) and top-down (e.g. selection of regime).
- The management regime or meso-level with stabilizing interdependencies between the elements as described in the previous section. A regime transition is indicated by changes in the characteristics of regime elements and their linkages.
- The niches or micro-level where innovative approaches can develop in a locally protected environment (e.g. large scale research projects, subsidized pilot studies) and/or in new areas of application such as the restoration of riverine landscapes that has started to become an integral part of water resources management.

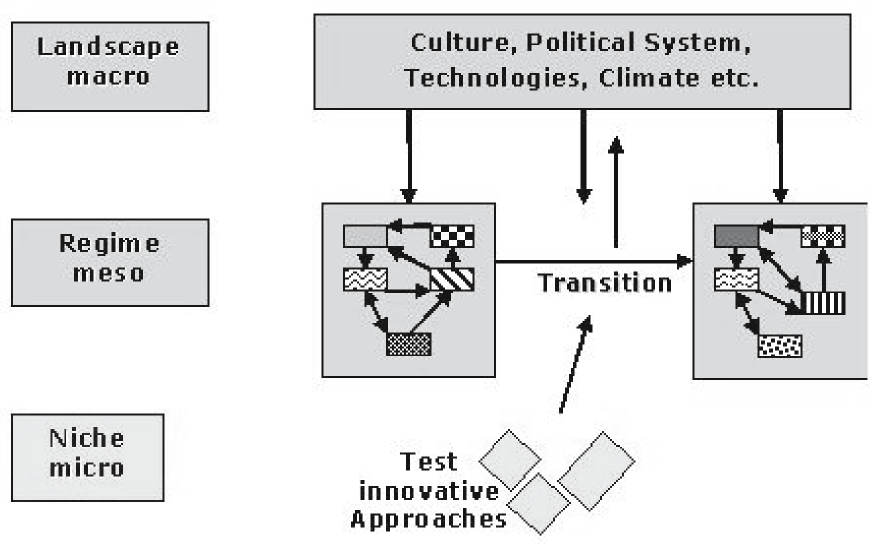

Fig. 2 Multi-level concept of transitions**.**

The distinction between macro-, meso-, and micro level is quite common for complex adaptive systems. As elaborated in more detail in the previous section, the dynamics of transitions are assumed to follow the typical S-shaped curves of changes between alternative states in feedback systems where after an initial critical phase of resistance change becomes autonomous.

The innovative contribution of recent advances in transition research is the attempt to make this approach operational for understanding socio-technical change in strongly interconnected socio-technical systems. The current paper goes one step further and tries to develop a concept for understanding transitions in strongly interconnected human-technology-environment systems.

The understanding of the causes and dynamics of transition processes is still limited. Nevertheless one can identify some clear indications that a transition process has started in water management. The landscape in general provides a stabilizing context for a management regime but it may also impose pressure on it if the landscape changes and existing regimes cannot adapt. The latter is currently the case for water management with respect to global and climate change and the overall increase in the dynamics of socio-economic developments. The increased awareness of the complexity of systems and of management as learning rather than control seems to be an overall trend in various fields (Senge, 1990; Pahl-Wostl, 1995, 2004; Levin, 1998; Hartvigsen at al, 1998; Berkes et al, 2002). On one hand, the systems to be managed and the problems to be tackled have indeed become more complex. The pace of change in socio-economic conditions and technologies is tremendous. Uncertainties arising from global change in general and climate change in particular pose major challenges for the management of environmental resources. On the other hand, awareness of the need to take the complexity of problems fully into account has increased and the frame of analysis has partly changed. In comparison to other areas, environmental resources management, in general, and water resources management, in particular, have been quite slow in adopting such changes. One possible reason for this lack of innovation is the strong interdependence of the factors stabilizing current management regimes.

Figure 3 portrays schematically in a multi-level structure how multi-party processes are embedded from a governance perspective. The network of collective actors characterizing a water management regime (level 2) constitute the direct level of interaction which is itself embedded in the overall governance structure, the societal context (level 3). The perceived inability to tackle challenges of current or future management problems may be a trigger for change in the overall water governance structure. However, a truly fundamental change cannot be limited to water governance only since water management regimes are closely intertwined with the overall societal context. Correspondingly many linkages may be identified between levels 2 and 3. Apart from formal connections (e.g. regulatory structures) informal influence such as the political culture of participation have an effect on water governance (Mostert et al, 2007).

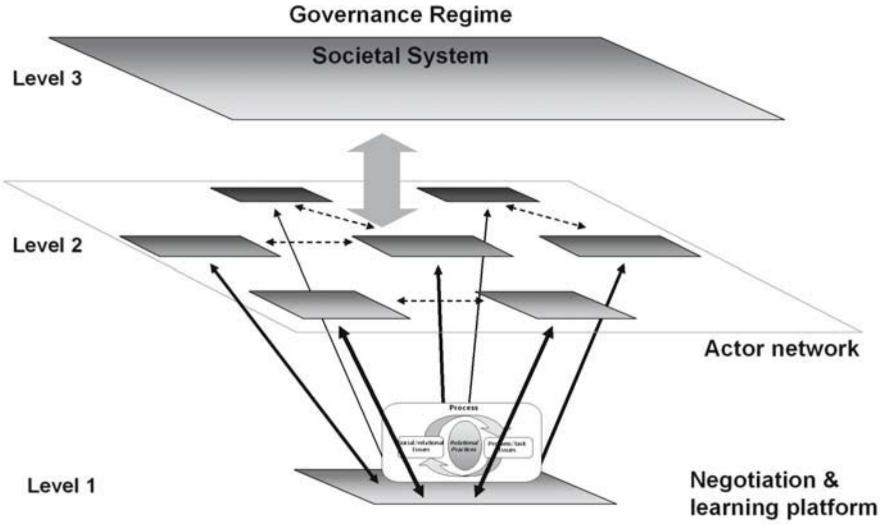

Fig. 3 Multi-level governance structure (Pahl-Wostl et al., 2007).

Pahl-Wostl et al (2007) analysed the role of social learning in informal actor platforms which may operate as a structural element increasing the adaptive capacity of water governance regimes. The structural governance context influences the implementation of such actor platforms and vice versa, the emergence of such informal structures influences the overall governance context.

The informality of actor platforms implies that rules for membership or negotiation strategies are open for negotiation rather than being prescribed by formal institutions. Nevertheless, the lack of accountability and of explicit rules as a result of excessive informality may also create situations of arbitrariness and may make it difficult to change tacit power relationships and regimes.

For social learning to increase both the adaptive capacity and the effectiveness of water management, a fine balance between stabilizing and change-supporting elements of a governance regime is required. Regulatory frameworks and cultural values provide long-term stability whereas flexibility and change are provided by learning and negotiation processes in dynamic actor networks, where the interpretation of rules may be substantially renegotiated or where rules may even be changed. A certain degree of stability is needed for actors to develop their expectations regarding future developments that will influence their own decision making. Processing information, negotiating and changing rules are resource intensive activities that should be limited to what is perceived by stakeholders themselves and by the policy analyst, respectively, to be necessary to cope with the emerging challenges of water resources management in a fast changing socio-economic and environmental context.

Collaborative platforms may become de facto a permanent part of the governance structure and play a key role in cross-scale linkages – both in terms of geographic and organizational scales – and improve horizontal and vertical interplay in water governance regimes. This does not imply that such platforms should be entirely formalized in terms of membership, procedural rules, roles and the distribution of decision making power. Formalization may destroy the characteristics of open platforms embedded in dynamic networks which render them so valuable in adaptive governance. Pahl-Wostl et al. (2007) have developed a conceptual approach to analyzing processes of social learning in actor platforms. The guiding concept indicated by the small feedback loop embedded in level 1 of Fig. 3 is represented in more detail in Fig. 4.

A concept for social learning in river basin management has been developed in the context of the European project HarmoniCOP[1] (Harmonizing COllaborative Planning). The approach adopted by the HarmoniCOP project is characterized by a broad understanding of social learning that is rooted in the more interpretative strands of the social sciences. Fig. 4 represents the framework for social learning developed to account for learning processes in water resources management (Bouwen and Taillieau, 2004, Pahl-Wostl, 2002, Pahl-Wostl et al., 2007). The framework is structured as context, process and outcomes with a feedback loop to account for change in a cyclic and iterative process. The context refers to the governance structure and the natural environment in a river basin. To improve the state of the environment usually implies in practice a change in the governance structure. Social learning is assumed to occur at two levels – on short to medium timescales at the processes level between actors and on medium to long timescales at the change in the governance structure level.

[1] More information on the HarmoniCOP (Harmonizing Collaborative Planning) project is available on the webpage - www.harmonicop.info.

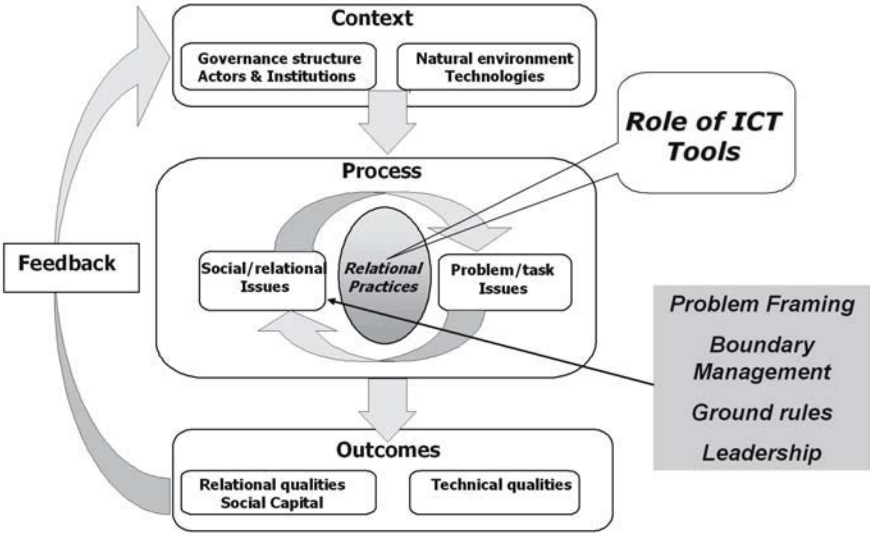

Fig. 4 Concept of social learning (Pahl-Wostl, et al, 2007).

The process concept referring to multi-party interactions in actor networks has two pillars (Figure 4). They relate to the processing of factual information about a problem (content management) and engaging in processes of social exchange (social involvement). Social involvement refers to essential elements of social processes such as the framing of the problem, the management of the boundaries between different stakeholder groups, the type of ground rules and negotiation strategies chosen or the role of leadership in the process. This concept has as its central hypothesis that the management of content and social involvement are strongly interdependent and cannot be separated and that ICT tools play an important role. The overall process leads to both technical qualities such as the improvement of the state of the environment and to relational qualities such as an increase in the capacity of a stakeholder group to manage a problem and/or institutional change. This leads as well to a different interpretation of the role of information and the ability of an actor network to use new information in social learning processes. Such learning environments are perceived to be crucial for the adaptive governance of socio-ecological systems (Folke et al, 2005; Pahl-Wostl, 2005). Hence, an entirely new element of monitoring refers to the quality of the communication process in actor networks, and the appropriateness of a chosen institutional setting. Social learning is assumed to be crucial for the transition towards, and for sustaining adaptive management practices which supports the statement of Bormann et al. (1994) "Adaptive management is learning to manage by managing to learn”. Hence the integration of learning processes in water management is of crucial importance.

5 Integrate learning cycles into water management

Processes of learning and innovation have often occurred outside and independently of formalized management processes. Particularly in early stages of change, the formation of informal networks seems to be essential. The importance of such adaptive networks (Nooteboom 2006) or shadow networks (Olsson et al. 2006) has been documented with empirical evidence. Sometimes windows of opportunity emerge where innovative ideas feed back into policy and management processes. The concept of adaptive management as promoted in this work strongly suggests that learning processes should become an integral part of any management regime and should be included in the design of adaptive policies as an important adaptation strategy rather than emerging by chance. This is indicated in Fig. 5.

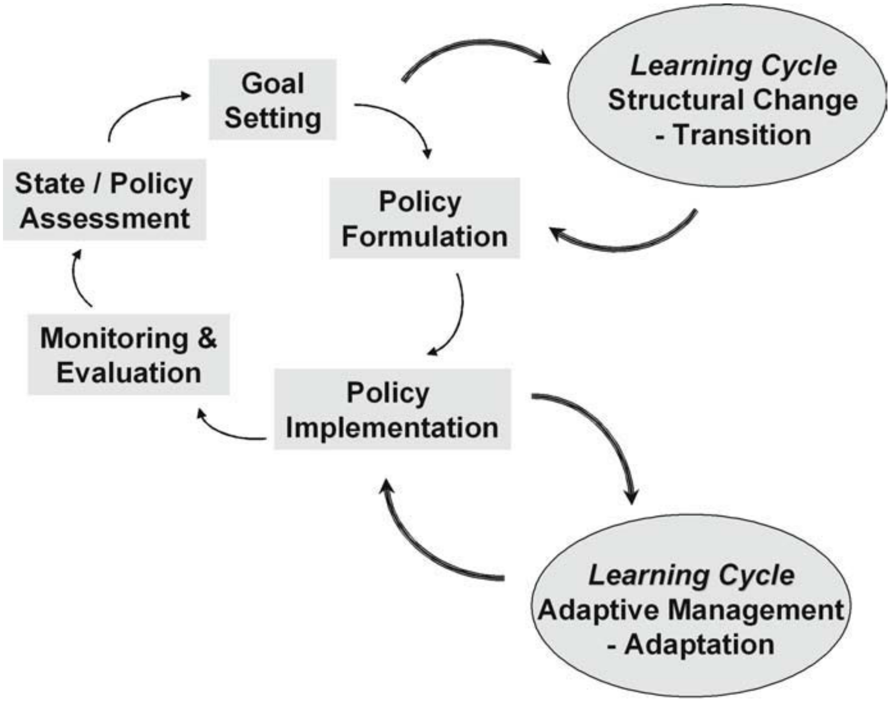

Fig. 5 Learning processes linked to policy cycle.

Learning cycles may be introduced at the level of measures as part of operational adaptive management, to test new approaches where significant uncertainties prevail, for example, the introduction of water trading or decentralized technologies at the household level. Often new approaches may require major transitions. This may be realized during the implementation of innovative measures when structural barriers are encountered (e.g. rigid legislation, prevailing habits of consumers, dominant technologies) or even in an anticipatory fashion at an early planning stage. Structural changes imply learning cycles at the early stage of goal setting and policy development. In most cases such transitions will involve a wider range of stakeholders. They may require changes at a higher level than the planning process. It will be a major challenge to implement learning cycles that, on one hand, have the required degree of freedom and sufficient resources (time, money) to succeed in a reframing of problems and solutions and developing innovative approaches. On the other hand, such learning processes should be linked to formalized policy and management processes to ensure that new approaches developed also lead to a greater change. Pahl-Wostl et al (this volume) describe in more detail the current understanding of such learning processes and the first step in moving from a scientific understanding and analysis to normative claims and practical guidance for design and implementation.

6 Conclusions

Numerous arguments lead to the conclusion that adaptive and integrated water management is essential in order to guarantee a sustainable management of the world's water resources. It has become increasingly clear that knowledge of the past is not a good guide for understanding the future. In particular climate change has exposed water systems to situations never experienced in the past and also revealed major vulnerabilities. Adaptive and integrated management is an important strategy for increasing the adaptive capacity of water systems.

However, water management regimes are still shaped by the tradition of a command and control approach focusing on technical solutions. The implementation of innovative water management approaches thus requires major structural changes in existing water management regimes. Such structural changes are slow since lock-in effects and barriers impede change. Therefore it is important not to focus on developing and analyzing models for an optimal integrated and adaptive water management regime,

but to focus on how to initiate processes of change to get there. Regime properties will unfold during the process of change.
Actor platforms and learning cycles closely linked to established water management regimes have been put forward as important elements to support both learning in operational adaptive management and the process of transition needed to develop the necessary structural requirements. The process of transition itself will require a kind of adaptive management as well. Required are methods and tools that help navigation in a fast changing and uncertain environment. It is evident that no panaceas exist – neither for learning processes nor for adaptive management itself. The alternative that every case is unique would not be a very promising prospect either. In order to identify the kinds of insights that can be generalized from and how lessons learned can be shared and evaluated, a systematic conceptual approach as elaborated in this chapter is urgently needed. Readers are invited to contribute their own experience and to further develop this approach.

Acknowledgements

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Eco-Complexity and Sustainability in China's Water Management*

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Abstract

China's severe water challenges as a result of rapid social and economic development, has led to significant impacts on regional eco-security, ecosystem service and human health. Grounded in ancient Chinese human ecological philosophy, a social-economic-natural complex ecosystem-based approach 'China Water Vision' is briefing to help people understand and simplify the complicated ecological dynamics and cybernetics of water. To transform the complexity vision into a sustainability mission, an integrative and adaptive management approach is being enhanced through capacity building including philosophical rethinking, institutional reform and technological renovation so as to transform reductionism to holism, fragmented to integrated management, and physical to ecological engineering.

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Rapid industrialization and urbanization have taken place in China since its opening up to the world and transition from planned to market economy. In the past 28 years, China's average annual economic growth rate (GDP) was about 9.67%. The pace, depth, and magnitude of this transition, while bringing prosperity to citizens, have exerted severe ecological stresses on local human living conditions and regional water sustainability. Water shortage, contamination, flooding and drought are only the surface symptoms of the water issue. Its indirect and long term impacts on regional and global eco-security are far-reaching. Water sustainability can only be assured with a human-ecological understanding of the complex interaction among environmental, economic, and social/cultural factors.

In dealing with this complexity, the key issue is to allow more people to understand China's comprehensive water vision, its ecological dynamics and cybernetics, and search for effective technological instruments including integrative planning, engineering, management and capacity building to promote water sustainability (Fig. 1).

Key words: ecological, complexity, sustainability, China, integrative water management

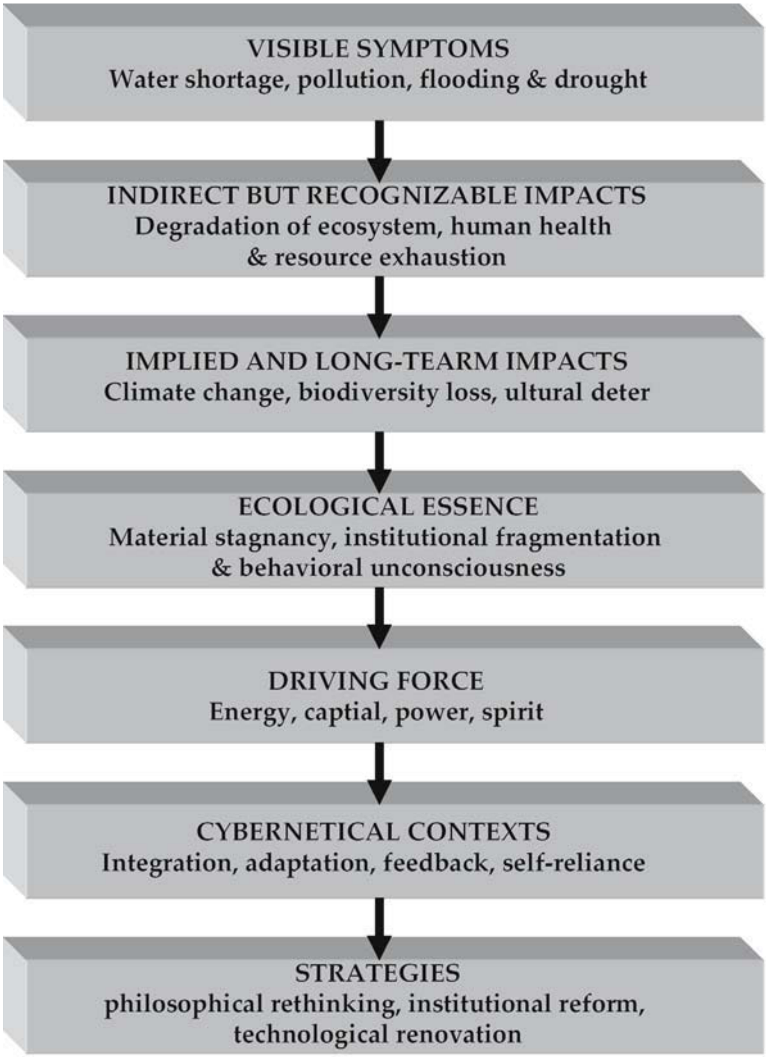

Fig. 1 Comprehensive ecological vision of water in China.

1 Water Crisis in China: Risks and Opportunities of the Fast Development

The word *crisis* (Wei Ji) in Chinese means both *risk* (Wei) and *opportunity* (Ji). With a long tradition of sustainable water management and human ecological philosophy, the water vision in China has both optimistic and pessimistic aspects.

1.1 Risks

Water resource shortage: Though China is ranked 6th in the world in terms of the total water availability, the availability of water resources per capita in China is only 33% and 75% of the world and Asia average level respectively, and the extremely uneven spatial and temporal distribution makes the situation even worse. With 7% of the world's total freshwater resources, China supports more than 21% of the world's population. Over 400 Chinese cities are facing water shortage (with 136 experiencing severe shortages). The average annual duration that the Yellow River runs dry, for example, was 21 days in the 1970s, 36 days in the 1980s, 122 days in 1995, 133 days in 1996, and 226 days in 1997. In North China, per capita water availability reaches only 750 m^3 per year. The groundwater supply in North China in 2004 accounted for 81% of the total groundwater supply in China (State Environmental Protection Administration of China, 2005).

Reduction of water for nature: During the past 50 years, the population of China has doubled, while the amount of water used to fulfill basic human needs multiplied by 5.5 times. Around $450 \times 10^9 m^3$ water originally used by nature has been taken over by human use. As a result, natural ecosystem services have dramatically declined, causing severe ecosystem degradation, depletion of the water table and biodiversity loss. Since 2000, groundwater has accounted for about 30% of China's total urban water supply. However, it is estimated that only 63% of the groundwater provided to urban areas can be regarded as 'potable without treatment'. In the North, there is scarcely enough water to fulfill ecosystem requirements (Lestor 2006).

Water bodies contamination: Over 70 percent of China's rivers and lakes are polluted (Chinese Ministry of Water Resources 2006). Only 20% of lakes and river basins reached Class III or better (Qian and Zhang 2005). In 2005, China's rivers and lakes received about 52 billion tons of wastewater. Industrial pollutants accounted for 46% and untreated urban sewage accounted for 48% of the total discharged wastewater. Furthermore, 32 of 49 lakes (65%) in China in 2004 were found to be eutrophied. In December 2006, the Yangtze Baiji river dolphin was declared "effectively extinct" (The Washington Post 2005). Between 50 and 90 percent of urban underground water is contaminated by agricultural runoff, industrial and municipal waste water, and, in some municipalities, even toxic mine tailings (Turner 2006).

Flooding and related geo-disasters loss: Every year China records around 1,500 casualties to floods (Qiao 2006). One tenth of China's territory, populated by two thirds of the population and producing approximately 70% of all agricultural and industrial output, lies within the floodplains of major rivers (World Bank 2001). The 1998 flooding of the Yangtze River basin claimed more than 3,000 people, devastated 5 million homes, and engulfed 52 million acres of land. The economic losses are estimated at over US$20 billion, and the main causes were deforestation and the destruction of wetlands for unplanned local development along the river (World Bank 2001). The area susceptible to erosion by water account for 37% of the total area of China in 2006 (State Environmental Protection Administration of China 2006).

Drought loss: Lack of water can lead to droughts, crop failures, famine and loss of life. The worst drought in 50 years is hitting China's western, central and northeastern regions, causing drinking water shortages for at least 18 million people and economic loss of 11.74 billion yuan (1.24 billion US dollars). About 10 million people in the southwestern Sichuan Province, 7.65 million in Sichuan's neighbor Chongqing Municipality and 600,000 in northeastern Liaoning Province do not have adequate access to drinking water (http://www.china-embassy.org/eng/gyzg/t268197.htm).

Wetland loss: Dongting Lake originally extended over four hundred kilometers. But the area of Dongting Lake has shrunk by almost two thirds since the Ming Dynasty. The quality of its water has been deteriorating, and the variety and quantity of fish have been decreasing. The diminishing of lake areas might become an element triggering floods. Dongting Lake was the largest lake along the Yangtze River as well as in the whole of China. It is a precious gift endowed by nature (Wang and Ouyang 2001).

Coastal ecosystem deterioration: According to marine water environmental monitoring sources, water quality in 53.4% of offshore areas was worse than class III in 1998, while only 18.7% of offshore areas meet the class I water standard. The concentration of all twelve monitored substances (including activated phosphate, inorganic nitrogen, lead, petroleum, mercury, BOD, and COD) was higher than the lowest standard. Copper, mercury, cadmium, hexachlorocyclohexane, and dichloro-diphenyl-trichloroethane pollution occurred mainly in the sea area near the Pearl River estuary. Between 2001 and 2005, there were 453 reported cases of red tides, contaminating over nine million hectares of sea area, making the water uninhabitable for coastal species and organisms (http://news.xinhuanet.com). 93 cases of red tides took place in the sea of China in 2006, and accounted for an area of 19840 km^2, among which 31 cases were larger than 100 km^2 accounting for 18540 km^2 (State Environmental Protection Administration of China 2006).

Water-bone diseases threaten: Nearly a quarter of China's total population, including more than 300 million rural residents, lacks access to clean drinking water (Liu 2006). They are susceptible to over 50 kinds of disease generated or spread through drinking water in China (Zhai 2004), including diarrhea, which alone is responsible for 11.8 percent of under-five child mortality. As reported in a 2004 national conference on rural water issues, the rural prevalence rate for diarrhea-related diseases could be reduced by half if residents had access to clean water (http://news.sohu.com). Agricultural production has been severely affected as polluted waters poison crop output. Each year, about 12 million tons of crops have to be destroyed because of heavy metal contamination, costing farmers 20 billion RMB Yuan a year (Chow 2006).

1.2 Opportunities

Fortunately, there are also positive developments in China which could alleviate ecosystem risks and provide opportunities for integrated water management

3000 year tradition of human ecology philosophy China has a well established human ecology philosophy of “man and nature be in one”, such as Yin and Yang theory (negative and positive forces play upon each other and formulate all ecological relationships), Wuxing theory (five fundamental eco-elements and movements promoted and restrained by each other), and Feng-Shui (Wind-Water theory expressing the geographical and ecological relationship between human settlements and the natural environment). One example is Chinese 7000 years of eco-agriculture, which has nourished 21% of the world population with only seven percent of the world's arable land and fresh water, while maintaining sustainable production and soil fertility. Its secret is to design and maintain a sustainable agricultural ecosystem by enhancing the mechanisms of material regeneration and recycling, while maintaining ecological integrity and self-reliance. Another example of the holistic ecological view can be found in traditional Chinese medicine, where the human body is considered a functional system closely connected with its environment (Wang et al. 2001).

Growing environmental awareness among the public Environmental awareness amoong the public is highly significanct in making human activities suitable for natural ecological processes. According to an investigation of environmental awareness among the urban public in China in 2005, an increasing number of people pay attention to environmental protection. They believe the most serious environmental problems in China are the destruction of vegetation, farmland reduction and water pollution, followed by air pollution, greenhouse effect and solid waste pollution (State Environmental Protection Administration of China and Chinese Academy of Social Sciences 2005).

Technological innovation for alternative water resources The desalination of seawater is a basic and scientific way of developing new water sources and solving the global crisis of water supply. China started studying seawater desalination technology in 1960s. China has taken great breakthroughs in key technology of seawater desalination. Seawater desalination project of 3 000 m^3 per day has been completed. The cost of seawater desalination is gradually decreased and it was nearly five RMB Yuan per m^3 water (http://gb.cri.cn/14714/2007/08/07/107@1707143.htm).

Institutional integration The Ministry of Water Resources (MWR) is the leading ministry overseeing general water management issues in China and collaborates with other water-related ministries under the State Council. These relevant ministries are integrated in order to gain consensus on the implementation of water policies. This integration can help avoid incoherent policy-making and implementation, and overlapping of investment in water management.

Legislation enforcement The Chinese government has established a set of laws and regulations including the Water Law (1988 and revised 2002), the Environmental Protection Law (1979 and revised 1989), the Water Pollution Prevention Law (1984 and amended 1996) , the Water and Soil Conservation Law (1991) and the Environmental Impact Assessment Law (2002), which has significantly enhanced water governance in China. In particular, EIA has paved the way for better public access to environmental policy-making and implementation.

Increasing investment Since 1998, China started to experiment and carry out the 'Six Forest Key Engineering', including natural forest resources protection project, reafforestation of cultivated land, controlling the wind and sand fountain around Beijng and Tianjin, shelter forest project in East China, North China, West China, the mid and downstream area of the Yangtse River, wildlife protection and nature reserves construction, and development of a rapid fertile forest base in key zones. The six projects initiatives above involved 97% of the national country and city, the area of planned afforestation is 7.6 million hm^2 with an investment of 700 billion RMB. From 1998 to 2006, the cumulative reforested area of 20 million hm^2 with a cumulative investment of 94.5 billion RMB was accomplished. It is also contributed to China's water management (http://www.forestry.gov.cn/old/SHTGC/).

Participation activation Now an increasing number people take part in environmental protection in China. According to the investigation of environmental awareness among the urban public in 2005 in China, 50% of the urban population have actively participated in various environmental protection activities. Television, newspaper, internet, books and magazines are important medium. In addition, school education, NGOs, broadcasting, family education and influence of friends are also useful in activating people to participate in environmental protection and management (State Environmental Protection Administration of China and Chinese Academy of Social Sciences 2005).

2 From Symptom to System: A SENCE approach-based China water vision

The above mentioned complex environmental problems can be simplified by tracing back their origins to three major causes: ecosystem exhaustion due to resource over-exploitation and unused materials remaining in the environment (mass); fragmentation and agglomeration in landscape management (matter); and short-sighted behavior and lack of feedback in dealing with the relationship between parts and the whole (man). Integrated water management needs to deal appropriately with the relationship between mass/matter and man.

The water eco-sphere is a kind of artificial ecosystem dominated by human behavior, sustained by natural life support systems, and vitalized by ecological processes. We call it a Social-Economic-Natural Complex Ecosystem (SENCE) (Ma and Wang, 1984). Its natural subsystem consists of the Chinese traditional five elements: water, fire (energy), metal (minerals), wood (living organism) and soil (nutrients and land). Its economic subsystem includes the components that play the roles of production, consumption, reduction, transportation and regulation respectively. While its social subsystem includes technological, institutional and cultural networks (Fig.2). Its structure is expressed as an ecological complex between/among human beings and their working and living settlement (including geographical, biological and artificial environs), their regional environment (including sources for material and energy, sinks for products and wastes, pools for buffering and maintaining) and their social networks (including culture, organization, technology and so on) which play a key role in sustaining the complicated human ecological relationships such as that of exploitation and adaptation, of competition, symbiosis and self-reliance. Its function includes production, consumption, supply, assimilation, steering and buffering. These fundamental interactions bring about five fundamental flows of material metabolism, energy transformation, information accumulation, currency exchange and population migration in the eco-scape, and result in its cybernetic behavior and formulate specific urban/rural forms. The goal of science and management is to understand and coordinate the temporal, spatial, quantitative, structural, and functional relationships among and within these three subsystems (Wang and Ouyang 1996).

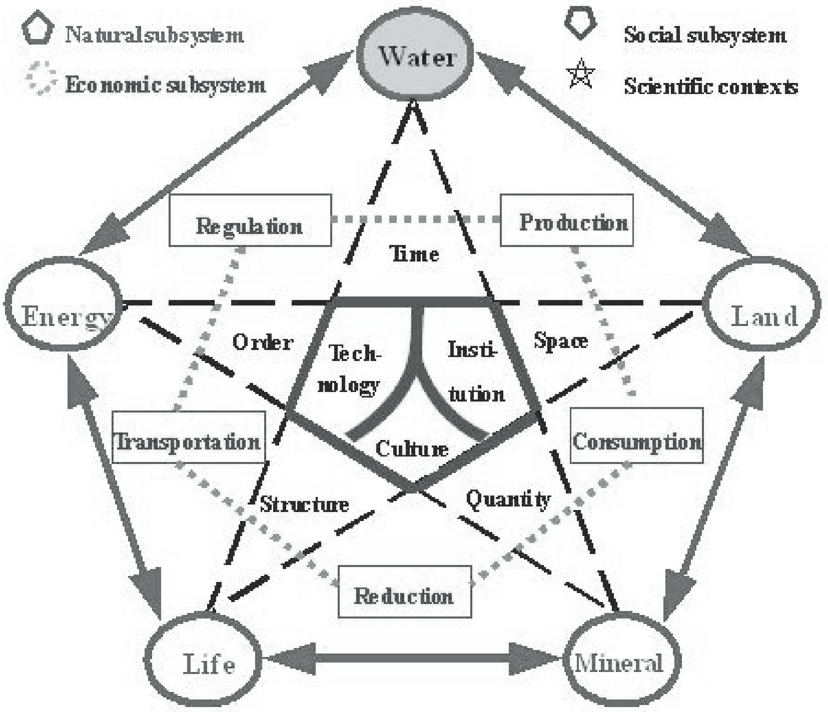

Fig. 2 The eco-sphere of water, environment, life, economy & society.

2.1 Water and Nature: Physical Interconnection

Among all ecological factors, water is the most important for promoting or limiting the survival and development of man and nature. It interacts with other four elements and causes the following changes:

1. Water and Soil (soil and land): soil cultivation and erosion, contamination and degradation, land gain and loss, landscape fragmentation and geo-disaster.
2. Water and Fire (energy, light, atmosphere and climate): hydropower, power generation by fossil fuel, waste heat, climate change, flood and drought.
3. Water and Wood (plant, animal, microbe and biodiversity): rain-fed and irrigation agriculture, biomass production, habitat creation, water-bone disease and pest break-out, and biodiversity conservation.

4. Water and Metal (mineral metabolism and geo-chemical process): eutrophication, contamination and material metabolism.

2.2 Water and economy: the ecology of human activities

The second subsystem in the waterscape is the MATTER-sphere driven by the human activities of production, transportation, consumption, reduction and regulation, which form the economic subsystem contexts including:

1. Water and agricultural production: food, fodder, fiber, fish, and forest productivity.
2. Water and industrial production: material, energy, medium, goods, and capital.
3. Water and human consumption: supply, infrastructure, service, origination, and prosperity/ruin.
4. Water and transportation: waterworks, canals, recreation and trade.
5. Water and regional development: watershed management, regional development, landscape planning, and watershed management.

2.3 Water and economy: the ecology of human activities

The third sub-system of ecosphere is social relationships including:

1. Water and technology: alternative water resources, water saving, purification and exploitation, and hydraulics efficiency.
2. Water and institution: governance, plans, policy, and legislation.
3. Water and culture: attitudes, ethics, morals, and consciousness.

These three physical, economic and social layers promote and restrain each other, playing roles of production, consumption and service, causing the complicated water problems of too much or too little and too dirty or too clean, and supporting the survival and development of life, environment, and human society (Wang et al. 1989; Wang and Qi. 1991).

2.4 Eco-dynamics and cybernetics of water ecosphere

The water-ecosphere is driven by four fundamental forces: energy (physical agent), money (economic agent), power (governance), and spirit (cultural agent). Energy drives material cycling and water flowing. Money promotes or prohibits the improvement of water use efficiency. Power speeds or restricts the development and management of water resource.

Spirit induces or impedes people's behavior. Any of these forces alone cannot work appropriately and leads to unsustainable development. On the other hand, water can in turn generate or stimulate energy, money/wealth, power/governance, and spirit/culture, as well as put on big impacts on their interwoven products of human society (Fig. 2).

The Cybernetic Principles fall into four categories: ***integration*** in recognition, institution and technology; ***adaptation*** to co-evolve with natural, economic and social development, ***feedback*** of material and information; and ***self-reliance*** to sustain structural, functional and procedural stability.

Faced with sharp contradictions between reductionism and the holistic approach, the traditional analytical and statistical approach cannot work well in modeling its dynamics and cybernetics. A methodological revolution is underway with the management target switched from tangible/physical object to intangible/ecological contexts; the measurement rule switched from numerical quantification to functional and multi-scale identification; the regulation strategies switched from mathematical optimization under some simplified conditions and subjective hypotheses to process-oriented social learning and ecological adaptation, while the research goal switched from morphological assessment and hypothesis validation to ecosystem-based sustainability management (Wang et al. 1999).

3 From Complexity to Sustainability：Integrative and Adaptive Management influence China Water Mission (Rethinking, Reform and Renovation)

The ultimate goal of understanding and simplifying of the complexity of water systems is to regulate, conserve and construct a sustainable waterscape and to transform the complex vision into sustainability mission (Fig.3).

Currently, the waterscape mapping in China involves **rethinking** the production mode, consumption behavior, development goal and life meaning; to **reform** the fragmented institution with regard to legislation, organization, governance, decision making, planning and management, and to **renovate** reductionism-based technology (cost-effective resource saving, renewable energy, environmentally friend).

Fig. 3 Transfer complexity to sustainability.

To turn the complexity into sustainability, we need a profound value change in understanding the ecological relationship between man and nature, the influence of the production mode on resource metabolism, and of consumption behavior on environmental impacts. A new ecological philosophy should be encouraged from linear, physical and reductionism thinking to systematic, ecological and holistic thinking, from wealth-only development to a combination of wealth, health and faith development.

To turn complexity into sustainability, we need institutional reform in policy making and inter-sectoral, inter-regional and interdisciplinary coordination. We need a bridge between man and nature, science and society; a scientific tie connecting survival and development, the poor and the rich, the East and West, the traditional culture and the modern technologies; a common language of communication between biology, environmental sciences, engineering and all the branches of natural disciplines and between the natural and social sciences (Wang et al. 1991).

To turn complexity into sustainability, we need technological renovations in ecological research, conservation and design.

The key to fulfill the emerging water mission is to find an appropriate way to help local people to understand, simulate and regulate complex water cybernetics.

A campaign of 'Ecopolis' development has been spread in China since the late 1980s supported by central and local governments. Ecopolis is a kind of administrative unit that has an economically productive and ecologically efficient industry, a systematically responsible and socially harmonious culture, and a biologically adaptive and functionally vivid landscape. Three so called ecopolis legs advocated by Chinese politicians are Circular Economy, Harmonious Society and Safe Ecology. There are currently 13 provinces and 525 cities/counties in China that are engaged in ecopolis development. Yangzhou is one of these demonstration metropolis. It is located in the central part of Jiangsu province, at the confluence of the Grand Canal and Yangtze River, has 4.47 million residents, 6638 km^2 land and 2500 years' history (Wang 2004).

The focus of Yangzhou ecopolis development is on ecological restoration of water resources, water environment, water landscape, aqua-habitat, and water culture. The Yangzhou integrated water management approach includes regional watershed management to ensure the water quality of Eastern water division project from Yangzhou to Beijing-Tianjin; water supply and flooding control of the Lixiahe basin agricultural irrigation, and sustaining a national watershed conservation park; rural non-point water pollution control and eco-sanitation development; and ecological engineering for human settlement sewage/garbage management and traditional water-culture conservation.

A comprehensive ecopolis plan was prepared and 148 ecological engineering projects were implemented for this “water-town of fish and rice”, an integrative ecopolis administrative office has been set up to coordinate the work of the different agencies. After 8 years of development, water quality improved significantly with its comprehensive environmental index ranked second of all prefecture level cities of Jiangsu province compared with seventh in 1998 before the ecopolis campaign was initiated. The city also received several national honors such as national healthy city, national model city for environmental protection, national garden city, and received a human settlement award from UN HABITAT in 2006.

Water is both a positive and negative ecological agent. Only when the roles of government leadership, citizen participation, enterprise support, and scientific and technological guidance are carried out in harmony can sustainable development be realized. Globalization, decentralization, and ecological modernization are the main trends in today's changing world, whether west or east, north or south. Integrative water management has no choice but to follow the ecological principles of integration, adaptation, feedback and self-reliance (Fig.1). Sustainability requires a balance among social/economic wealth, human/natural ecological health and ethical and spiritual faith.

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Integrated, adaptive and domanial water resources management

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Abstract

Arising from concerns that integrated and adaptive water resources management (I/AWRM) may not be sufficiently tailored to certain kinds of complex environments, this article examines their design through a governmentality framework, positing that I/AWRM could be enhanced by increasing accountability and local appropriateness through citizen's actions that address or are situated in three types of domains – spatial units termed 'holons', hydrological regime 'phases' and problem-solving 'tasks' – an exercise termed 'domanial'. For reasons explained in the paper, the geo-economic scope of this paper are countries as in Sub-Saharan Africa where climatic variability and widespread irrigation dominates river basins that in turn have limited capacity for well-financed administration commonly seen in Europe. The need to recognize irrigation in adaptive water management is born from the great proportion of freshwater depleted by the sector and its effects on water shortages and behaviors in other sectors. Because of these characteristics, there is a risk that in irrigated semi-arid environments, IWRM (with a regulatory emphasis on managing water use to effect water allocation between sectors in large river basin units) or adaptive versions of IWRM (emphasizing iterative refinement and wider system complexity) will not engender satisfactory outcomes. The relevance and definitions of domains are explored in the paper, as is a brief policy discussion on domanial water resources management (DWRM).

1 Introduction

Although adaptive water resources management (AWRM) may be distinguishable from integrated water resources management (IWRM) by the degree to which AWRM is adaptive in practice, their *intended* broad objectives and modalities are similar enough for them to be variations on a single theory of adaptive, integrated water resources management (A/IWRM). Thus it is possible to argue that AWRM – explorative, iterative and cognizant of wider complex human, climate and ecological systems (Pahl-Wostl and Sendzimir 2005) – is captured within a wider IWRM family (Mitchell 2004; GWP-TAC 2000; Radif 1999; Allan 2003).

Nevertheless, despite the IWRM paradigm subsuming different versions, the notion that adaptive water resources management might have special qualities raises key *process* questions that illuminate our theorizing of water management. What clearly distinguishes adaptive water resources management from integrated water resources management to lead to improved results? Or put another way, are the only differences between adaptive and integrated water resource management those of on-going adaptation and a wider, more complex set of reference systems? Pertinently, how does AWRM claim to deal with complexity? The analysis here argues that in certain kinds of environments and complexity (that first need to be recognized) we should 'design in' mechanisms for delivering the aspirations of A/IWRM. It proposes to do this by breaking complexity into domains.

A theory of domanial water resources management (DWRM) is generated from the social co-management of three types of 'domains'[1]. This concept is generated from the starting point – where does water resources management (WRM) take place? To answer this, the paper contrasts two countries, United Kingdom and Tanzania, with different water systems; the former constructed from highly-regulated and self-regulating domestic, urban and industrial consumers mediated by financially well-off representatives, agencies and water companies, while the latter is constituted from a disparate array of relatively poor irrigating and domestic users who access water largely from a dynamic environment directly and therefore from each other with much less mediation from intermediary organizations. As explored in the paper, these differences result in separate kinds of complexity to be addressed in different ways.

[1] Domains are; nested sub-units of the basin termed holons; parts of the hydrological regime termed phases; and tasks of work to be completed.

To explore I/AWRM theory it is necessary to consider the institutional design factors that drive the implementation of IWRM in developing countries. This begins with the premise that IWRM has two major dimensions; an upper level as a strategic planning model and a second level as a model of operationalization (Mitchell 1990, 2004). Figure 1 captures these, left and middle respectively, leading to 'outputs' on the right hand side. A problem observed in developing countries where IWRM is being promulgated is that operationalization is taking time and is not necessarily leading to intended results (Biswas 2004). This should not be seen as a failure of 'operators' but more of four characteristics of the upper strategic level of IWRM as currently constructed, explored below.

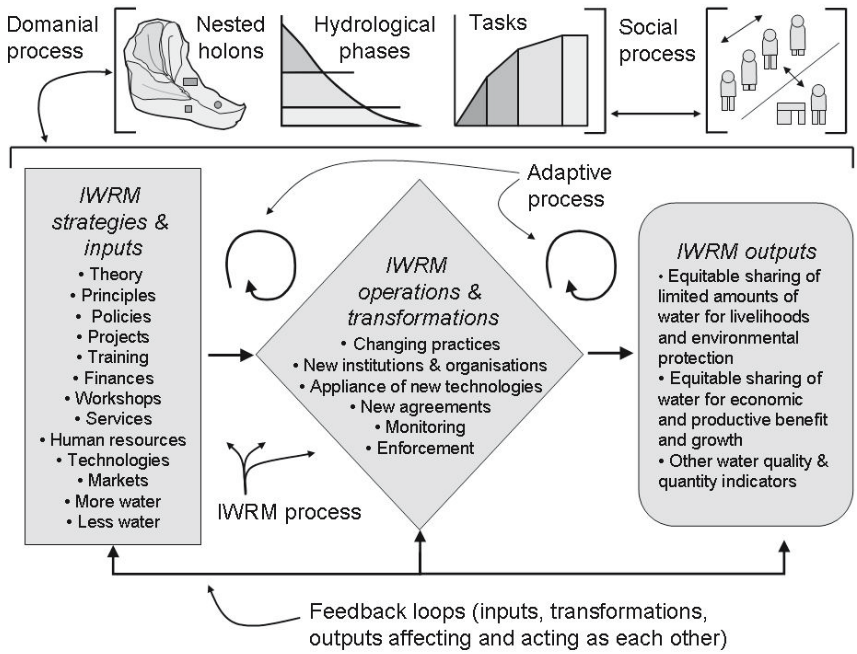

Fig. 1 Integrative, adaptive and domanial components of WRM

Firstly, in adopting IWRM plans, I contend that its operationalization is 'theory-facing' rather than 'problem-facing', or put another way the strategic level is insufficiently context-aware. Both strategic and operational levels too readily adopt principles of water management (such as water as an economic good) without identifying how those same ideas are expressed by users themselves to solve local problems[2]. Secondly, the upper IWRM strategic model, regardless of context, tends towards a regulatory model of dealing with basin-scale complexity, constructed from a mix of measurement, licensing and pricing. Although IWRM purports to be participatory, it does not see devolution and subsidiarity as a means of dealing with complexity at the basin scale. Thirdly, IWRM utilizes high level dissemination processes such as workshops, articles and papers and training of water officers that are relatively ineffective in transforming local user practices. Fourthly, IWRM fails to address the complexity associated with irrigation. This arises partly out of jurisdictional gaps between Ministries of Water and Agriculture because often irrigation is viewed as the provision of water to a crop rather than as a multi-faceted system, and partly because irrigation is seen as one sector amongst many, rather than as a determinant of wider basin behavior and water competition.

It is an analysis of IWRM either through existing integrated regulatory frameworks managed by professional water officers at the basin level or by forms of localized democratic and polycentric management or by mixes of the two (Lankford and Hepworth 2006) that suggests a need to explore alternative forms of governmentality or environmentality (Agrawal 2005) of water resources management.

2 Identifying domains where water is managed

This paper addresses the adaptive management of natural resources to enhance resilience to change arising from economic and population growth, technological transformations and climate change. Adaptive management is “an approach to managing natural resources that encourages learning from the implementation of policies and strategies” (Allan and Curtis 2005, 414; Kashyap 2004). In addition, addressing complexity and uncertainty distinguishes adaptation in IWRM (Pahl-Wostl and Sendzimir 2005). Although accommodating iterative learning and complexity appears sensible, it is necessary to question whether IWRM *applied adaptively* (i.e.

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[2] For example, in Southern Tanzania, local users developed a land-based, village levy of about 10 dollars per hectare deemed more appropriate in reducing water consumption than the flat charge applied through a World Bank supported national water policy (SMUWC, 2001).

inside Figure 1) will resolve the concerns outlined above or whether it is possible to more thoroughly explore the underlying arrangements or governmentality for adaptive and integrated water management.

It is also possible to consider adaptive management via a results perspective (the right hand box of Figure 1); that for poor people the access, predictability, acceptable quantity and quality, and affordability of small amounts of water to meet daily livelihood and environmental needs are provided to levels deemed locally acceptable. These are about livelihood 'protective volumes' implying a micro, household dimension. At the higher end of the sufficiency scale when more water is available, good water management is about equitably sharing of 'productive and consumptive' volumes to provide for economic growth, which in turn provides investments in many kinds of economic activity which can further reduce sensitivity to drought. Greater utilization of more water is reflected in macro dimensions of the economy.

While we have some informed ideas about the inputs and outputs of adaptive water management, we appear less certain about transformations in the central kite-box of IWRM (Figure 1) or about reading the context in which IWRM sits. This is revealed by examining attempts at IWRM in Sub-Saharan Africa (e.g. Nigeria, Tanzania, Zambia) being received with mixed results. While it is possible to suggest that an adaptive style might make headway with IWRM plans, one might critically respond with the argument that if not thoroughly cognizant of on-the-ground problems, in turn driven by a theory which requires this, adaptive water resources management will be insufficiently differentiated from integrated water resources management. There is a great danger that 'learning by doing', sensible it may be, might not transcend the 'developed country' IWRM templates and principles it attempts to adapt.

I argue that developing-country IWRM, largely constructed from sophisticated basin-centered models and experiences in developed countries combined with the Dublin Principles, sets out visions and desirables that cannot inform pragmatic policies that fit current situations in much of Sub-Saharan Africa. A developed-country template of regulatory water management fundamentally misses *where* water management actually takes place in tropical and sub-tropical countries and *who* does it. Moreover, IWRM often fails to read the changes in governance systems when moving from northern country economies to those in the tropics: diversification from irrigated agriculture to urban and industrial growth; a benign political economy; greater capacity to store, purify and reticulate water; monitoring systems; iteratively developed systems of economic pricing; a longer history of water privatization and public-private initiatives; a variety of demand management tools; and well-financed water agencies and services.

While aspects of these exist in countries in Africa, they are not found as comprehensively combined as in Europe.

Research in the Great Ruaha Basin in Tanzania and other SSA countries informs this analysis (SMUWC 2001; Lankford 2004; Lankford et al 2007; McCartney et al 2007). Although there is not room to describe the case study in detail, germane features of the basin are:

- An average of 25,000 hectares of small-scale irrigators leading to depletion of water and inter-sector competition between irrigation, domestic users, wetlands and hydro-power, particularly during the dry season.
- A Sub-Saharan climate that exogenously drives an unpredictable dynamic water supply and a corresponding growth and shrinkage of irrigation from 18,000 ha in a dry year to more than 40,000 ha in a wet year.
- An under-resourced basin office in terms of staff, finances, transport and hydrometrics to cope with the size and regulatory challenges of the 68,000 km^2 basin. Calculations of staff-to-area ratios show that in Tanzania it is one per 11,800 km^2, compared to one per 13.7 km^2 for the UK Environment Agency, the equivalent organization.

Although, the two countries could not be more different, the UK and Tanzania share similar water polices including terminologies, aspirations and legislative and regulatory structures (Hepworth 2007; MOWLD 2002; DEFRA 2003) yet contrast the UK's estimated 2600 irrigators using about 1-2% of freshwater (Weatherhead 2007; DEFRA 2007) with Tanzania's approximate 400,000 farmers[3] involved in water management consuming 86% of water. In 2002, irrigated agriculture was estimated to consume the largest share of water withdrawal with 4417 million m^3 while the domestic sector uses 493 million m^3 or 8% of total (TANCID 2007). Tellingly, Tanzanian water users despite being remote, rural, poor small-scale users who largely negotiate with each other, have to purchase rights denominated in liters per second from a central basin regulator (van Koppen et al 2007).

Unlike basin environments in northern Europe which are subject to oceanic temperate climates and experience predictable rates of usage from largely domestic and industrial users, Sub-Saharan basins are extremely variable. This analysis suggests that where climate drives intra/inter-annual fluctuation, government regulatory authority is so thin on the ground and irrigation shapes behavior and consumption to such an extent, certain kinds

[3] Probably a conservative estimate, calculated from 200,000 hectares of irrigation (Aquastat, FAO 2005) managed on average by one farmer per acre.

of risk and complexity arise. These relate to the mismatch between the nature of the challenge, of our conceptualizations of it and of the resources brought to bear on it. It is not clear that, despite the rhetoric, there is donor or government appetite for upping the formal regulatory budget to achieve what might be required. Leading from this, the process of reforming water management may be better promoted by closely involving the many thousands of farmers and fields in an irrigated sub-tropical basin and be suspicious of regulatory structures that treat them as abstractors of a predictable, carefully controlled and measured resource. This requires recognition at the IWRM theory and policy level in order to create structures to devolve adaptive responsibility and sustainability down to users.

To achieve devolved adaptation two ideas are proposed; the disaggregation of water resources management into domains; and the identification of social and institutional drivers of water management reform within these domains to generate 'balanced performance', acknowledging that water consumption in a sub-unit cannot go unchecked but should meet wider basin concerns. Before these are discussed further, it is necessary to examine the complexity of water and irrigation management, so that its disaggregation into discrete nested problems and localities can be better understood.

2.1 Scale and complexity arising from irrigation

Water is a particularly complex natural resource to manage because of scalar dynamics. Depletion (or pollution) of water in part of a river basin affects users a great distance away – users that are logistically unable to interact with those responsible for the depletion. Solutions to solve one community's or sub-unit's livelihoods can deleteriously affect others. As scale increases, so do the number of interactions, divisions and drivers; e.g. land use, markets, urban growth and political and transboundary borders. Some small-scale technologies, e.g. treadle pumps, thought to be 'sustainable' by dint of an individual small environmental impact, can with rapid adoption cumulatively deplete water and lead to conflict.

Further levels of complexity occur with increasing areas of irrigation that drive behavior and shortages elsewhere in the basin (Lankford and Beale 2007). Consequently, irrigation systems, be they single large systems or large coalesced areas of small systems, are complex to the extent that they need to be seen as arenas where IWRM and basin management are tested. To see irrigation other than as a technology or as a sector means we can treat it more carefully than Tompkins and Adger (2004) intimate; irrigation should *not* be seen as a direct answer to drought or climate change mitigation, but as a possible magnifier of drought and conflict. Irrigation systems have feedback loops affecting efficiency, equity, adequacy and timeliness of supply. Irrigation performance is determined by main canal and in-field practices; the latter determined by farmers who, perceiving unpredictable supplies, hold onto water in turn delaying supply for others and themselves. There are institutional, organizational and livelihood factors which shape these concerns and practices and it is not easy to raise performance in an immediate sense; rather groups of farmers need to experiment with new ways of co-managing water, supported through institutional and technological change by appropriate advice and services.

Irrigation is a dynamic, behavioral system with intimately connected social, technical, agro-ecological, economic and river basin dimensions, categorically different from rainfed and rain-harvesting agriculture. Although there is a continuum of typologies in the 'capture-control-delivery' sense of delivery of water to crop roots, we should not "remove the artificial separation between rainfed and irrigated agriculture" (ASARECA 2006). The relationship between area and complexity is a power one since with greater unit size, the depletion of water connects users in ways that rainfed agriculture or small rainwater harvesting systems do not.

The effect of many irrigators is to make basin-scale governance much more difficult. This obligates irrigators to be more responsible than is recognized and to achieve this requires those users to connect either physically (via canal systems) or via institutional arrangements. This in turn requires a blend of disaggregation of the wider basin into smaller units, and within those units, stronger forms of connection and aggregation.

3 A conceptual framework for domanial WRM

A framework for social domanial water resources management is provided in Table 1. In the top, three disaggregating principles are provided for creating WRM domains; scale and space, hydrological regime and risk-based or conflict resolution approaches. Then, two social drivers are then applied to the discrete management units and objectives; participatory citizens' action and service provision. The following sub-sections explain these.

Table 1. Design for domanial water resources management

Disaggregating WRM into identified domains	Domain nomenclature
1. Scale and space; a spatial unit of management within the river basin chosen at an appropriate scale.	Nested sub-system or holon
2. Hydrological regime; a phase of water sufficiency from high to very low levels; bulk, medial and critical.	Phase (or state)
3. Risk based analysis or via conflict resolution; Identifying and acting on causes of particular problems.	Task
Social drivers for performance with domains	
1. Citizen's action; formation of groups of users able to discern gaps in their knowledge and capabilities and request services accordingly.	
2. Service response and accountability; A demand responsive approach able to elicit and provide resources to fill users' needs.	

3.1 Nested sub-systems: 'stretched holons'

The aim is to promote success in IWRM by nesting and solving problems within sub-systems of a river basin - this stipulates a polycentric approach rather than the basin being the natural unit of management. The term 'holon' (Koestler 1967; Ashby 2003) is apt; a component or unit which is simultaneously a whole and a part (see Figure 2). The design decision is to choose holons that constitute significant and useful building blocks of the bigger river basin. Since holons nest in each other (viz; farm outlet, tertiary irrigation units, secondary units, irrigation system, sub-catchment, river basin), the holon of interest must neither be too small to result in too many units, nor too large so that internal rifts and divisions arise that cannot be managed. The 'correct' size that bridges between the micro and macro scale is dependent on the context and the holon involved but is also related to the 'working' or exercising of the holon as the next paragraph explains.

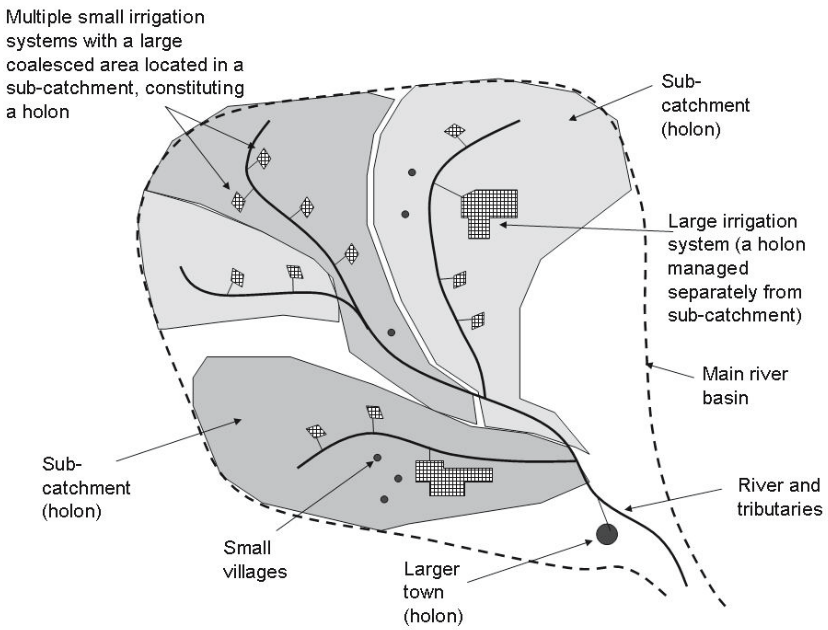

Fig. 2. Schematic of nested holons within a river basin

Likely to be a difficult and certainly site-specific decision, correct sizing is served by selecting units that meaningfully ‘stretch’ or exercise their water users in terms of learning about non-local effects. Thus the size and complexity of holons are slightly beyond their comfortable and normal expression – or ‘stretched’ – so that non-local and scalar expressions of water use can to some extent be understood by users who otherwise would not normally be faced with non-local consequences of water depletion. This is important if we are to enhance performance in recognition of the interconnected nature of water by making internal associations and agreements that are also outward-looking. Although subjective, we can explore some sensible ideas of what might constitute holons. Large single irrigation systems that have a measurable effect on their surrounds and high level of internal complexity can be treated as holons. Areas of coalesced smaller irrigation systems combined with domestic and environmental claims mean that sub-catchments and aquifers are also holons. Thus, examples are: rural towns, or districts of very large towns and cities; irrigation systems approximately 1000 ha (10 km^2) and above; aquifers approximately 200 to 2000 km^2 in size; and sub-catchments of approximately 300 to 5000 km^2.

3.2 Phases of water management

The second type of domain is a water sufficiency phase; generated by dividing a flow regime into three phases of water sufficiency (Figure 3) (Lankford and Beale 2007; Lankford et al 2007). The phases (or states) are; 'critical water' denoting very small amounts of water during droughts and dry season; 'medial water' for scarce to average flow conditions; and 'bulk water' for wet to flood conditions. For each phase it is possible to locally derive priorities and systems of allocation (markets, command and control, local community responses and other interventions). A look at the Tanzania case indicates that critical and medial water require special attention by stakeholders, but each can be addressed by relatively simple, practical and localized solutions rather than by more cumbersome formal regulatory interventions that may best be reserved for managing bulk water.

Inter-phase facilitation of users transiting from a wet phase to a dry phase is also necessary. Drought contingency plans, in defining responses to drought *locally* (enforcement, monitoring and transparency of usage of water) are important aspects of transition facilitation and management during the critical phase. Key challenges are the distribution and sharing of small amounts of surface water, requiring a shift in practices to more stringent schedules of use. Taking a nested sub-systems approach allows users to define these issues locally rather than have external protocols applied.

3.3 Risk-based and conflict resolution approaches

The third domain is work-related, designed to break large issues into more manageable objectives. Although a number of means to achieve this exist, two are proposed here and both are intended to tackle internal holon issues while recognizing external drivers and downstream obligations. Significantly because of the spatial focus invoked by the utilization of holons, problems can be addressed more pragmatically with reduced reliance on the application of global principles of IWRM (Merrey et al 2007).

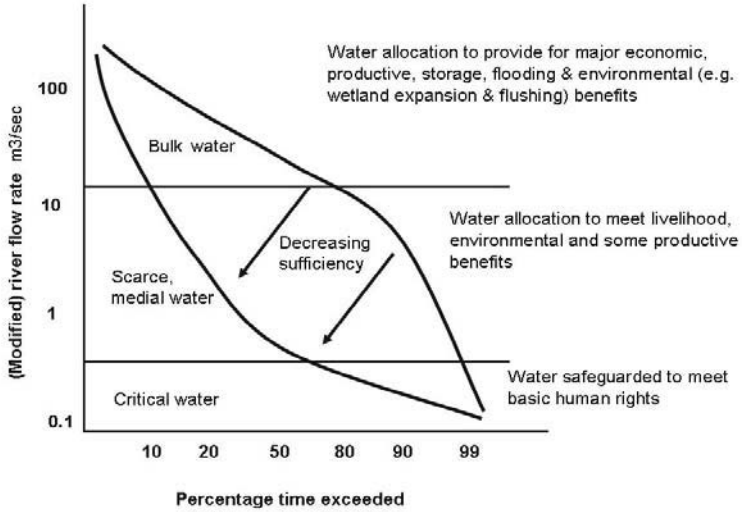

Fig. 3 Phases of water management – bulk, medial and critical

The first utilizes risk-based thinking to identify component tasks and then identify which are effective in cost-benefit terms (Craft and Leake 2002; Haimes 2004) onto which other tasks can later be attached. In simple terms this is modeled in a pareto curve, a phenomenon in management also known as the 80:20 rule where 80% of the benefits may be achieved with 20% effort. An example from Tanzania exemplifies. In the Usangu sub-basin, part of the Gt Ruaha Basin, rather than attempt to manage 120 irrigation intakes to ensure downstream compensation flows, it is possible to identify approximately 15 intakes on four rivers that accounted for 49% of the intake abstraction capacity in the basin (Lankford 2001).

The second means identifies tasks via specific conflict resolution exercises. These exercises and their resulting tasks address locally relevant and socially critical concerns that might take precedence over standard water policy or regulatory principles. In the Usangu basin, local river users managed conflict by agreeing a rotational schedule for distributing water between intakes (known locally as *Zamu,* McCartney et al 2007) rather than adhering to their formal water rights.

4 Fostering performance – a social approach

The next section on a social approach to water management[4] echo the CAR framework (capability, accountability and responsiveness) outlined in recent Department for International Development thinking (DFID 2006, 2007) aiming for greater democratic selection and demand by water communities for services from a range of providers that in turn are professionally delivered to tackle specific hydrological phase-bound tasks within holons. The challenge in water management is to do this in ways that recognizes the scalar and depletive nature of water consumption in basins with high levels of irrigation based livelihoods.

4.1 Citizens' action and service accountability

Having determined appropriate management holons, we need to ask how they can be reformed. There is evidence from education, health programs and water and sanitation that citizens' action and participation combined with appropriate service responsiveness can generate the requisite levels of system progress (Cavill and Sohail 2004). This has been explored within a participatory governance and accountability framework (ibid), and has been termed a Demand-Responsive Approach (World Bank 1998). The approach brings water users into the process of selecting, implementing, auditing and, ultimately financing the long term delivery of water services.

Major proponents of the approach, including the World Bank have supported its uptake. Initiated by WaterAid, the aim of Citizens Action for Water and Sanitation (Ryan 2006) is to support programs to strengthen governments' accountability in service deliveries toward water and sanitation. The program puts communities in charge of their own problems and solutions, utilizing open consultation processes, the use of community scorecards, slum censuses and mapping of water and sanitation amenities.

Thus the issue is about the benefits that accrue from meaningful decision-making and institutional ability to decide and manage local priorities. The reason for this being a priority is that given a rapidly changing situation, an effective way in which provisions can remain 'up to date' is that

[4] See emerging bodies of work on social and technical approaches to water conducted by the Irrigation and Water Engineering Group, Wageningen University and ZEF, University of Bonn.

they are constantly adjusted by people on the ground who are brought together to learn from each other and external advisors.

Experiences in Tanzania (Van Koppen et al 2007) suggest that it is more reasonable and effective to entrust management of water to sub-catchment decision-making networks building on already existing customary arrangements. Their tasks would be, first, regulating allocation in times of low flows, with constraints to ensuring downstream flow advised by Basin Officers, and, second, finding arrangements for dealing with the increasing demands by new users. With the right approach and institutional environment there is no reason why communities should not be able to recognize wider impacts of their water usage and connect productivity gains to conflict resolution both at catchment and irrigation system levels (Vounaki and Lankford 2006; McCartney et al 2007).

4.2 Service responsiveness

An increasingly significant debate examines how to increase the accountability, accessibility, accuracy, applicability, affordability and response times of services for the purpose of improving natural resource management (IIED 2006). This also means engaging and empowering water resource users to demand or purchase services, and to do so in a way that first asks users to critically prioritize solutions to identified problems so that services meet real gaps and not those that can be solved relatively easily by resource users. This suggests a recursive relationship between users and service providers, with the latter fostering the ability of the former to come to them as well as vice versa. The ability of productive irrigators to fund service provision would be key in the sustainability and appropriateness of services provided and may not be too difficult; one percent of the turnover of 1000 hectares of irrigated rice in Tanzania is 10,000 US dollars which could buy services related to mapping, conflict resolution, legal settlement, field trips, re-design, construction, accountancy, climate forecasting and so on.

It may also be appropriate to employ a local conditionality or 'cross-compliance' framework to offer capital, new technologies and storage against progress made with conflict resolution, institutional arrangements and financial systems. Cross-compliance defines mutual agreements for progressively implementing an agreed schedule of initiatives between two or more partners (DEFRA 2006). Cross-compliance wraps all parties in such agreements, motivating and leveraging further action out of the parties involved. For example, appropriately designed conditionalities, such as the establishment of a water user association for a holon, are attached to capital expenditure on a small reservoir.

5 Further discussion

The sub-sections below briefly introduce two other issues related to a nested social approach to adaptive water resources management.

5.1 Pluralist legal frameworks

A locally-nested framework implies that formal regulatory systems need to be counter-balanced with mixtures of formal and customary law, where formal statute law provides a broad framework that helps define ‘equity’ in the legal sense, and where customary and reflexive law (Teubner 1983) resides at the catchment, irrigation and community level to draw up agreements and protocols that bring about equity in the hydraulic sense. In addition should customary agreements not provide resolution, users could then seek to purchase legal services to resolve disputes. In addition, underlying infrastructure could be locally attuned to help users switch from formal to informal agreements and bye-laws (Lankford and Mwaruvanda 2007).

5.2 Catchment and storage infrastructure

The topic of irrigation systems rehabilitation and modernization, a complex and intransigent area, is also relevant at the catchment scale. Existing hardware for accessing water (irrigation intakes and boreholes) should be seen as distributive infrastructure at the catchment scale that facilitates or otherwise the apportionment of water as it varies in supply from bulk to medial to critical. As catchments’ demand and supply rapidly change, the question of how to enhance, re-tune, remove, or build upon existing water infrastructure that facilitates water provisioning in this dynamic context becomes critical. It was clear that the standard irrigation intake designs employed in Tanzania under the ‘irrigation improvement programmes’ of donor agencies had widespread support with farmers, engineers and district staff. However, they encouraged upstream farmers to abstract large amounts of water (Lankford 2004). Concrete intakes could be better designed, adopting proportional flumes with high levels of transparency (Lankford and Mwaruvanda 2007). In addition, there are particularly problems in dealing with 'momentum' in uptake of or existing prevalance of technology adoption and practices.

A number of donors and countries are considering afresh dams for beneficial storage and release (World Bank 2003). Aside from climatic vagaries, benefits such as electricity generation are not always assured because although dams have operating rules developed by hydrologists and engineers, these are subject to political capture. Applying a nested and citizens' approach might usefully develop counter-balances to elite and political capture. Three other nested linkages also potentially occur.

Storage could be tied to improved water management and institutional conditionalities. In other words, stored water is released for beneficiaries provided systems are developed for managing this equitably and efficiently. Alternatively, indirect linkages could be developed; as an example from Tanzania shows, resource users explored the idea of a small storage dam for dry season domestic usage alongside agreements to share water and release water downstream during the wet season.

Secondly, a holon-based approach can be taken to extending or protecting the benefits of storage to the local environment and economy. This is not particularly new, but such projects would be in response to local requests and fit with the third point which is that investing in storage must be gauged carefully against capacity to manage that for increasing uncertainty and drought periods or insufficiency arising from increasing demand. An outcome would be that an increasing proportion of storage should be reserved for contingencies and shortages, and by taking a local frame, this could be matched more easily to rapid change within the vicinity (Lankford and Beale 2007).

5.3 Policy support

It is useful to identify some policy challenges raised by the putative A/IWRM framework if program aid dominates donor assistance, as is the case with DFID. Because of the use of spatially bounded holons, the domanial approach would require services that match one or more holons, and thus program aid would have to generate these – via geographically delineated projects. Modalities can be copied from citizens' and accountability approaches in water and sanitation funded via program aid, and some NGO's (e.g. WaterAid) have expertise in this. Nevertheless, there are risks here for donors given that domanial ideas represent new kinds of IWRM for basins and irrigation systems, requiring organizational change to a responsive mode. In addition, skills and expertise in water resources and irrigation management have not equaled progress made in water and sanitation. The prognosis for knowledge 'catch-up' is worrying; a lack of donor funding in the sector means that some University degree programs in irrigation have closed in the last 10-15 years and that relatively few training and research programs address irrigation in sufficient depth.

Other narratives in IWRM need further deliberation if policy is to be effective. A questionable one is that river basin and irrigation system management 'should be kept simple'[5] (different to the question of how to make basin and irrigation management more simple which is what this paper tackles). Furthermore, orthodoxies that appear to have a straightforward technical basis should be contested (witness the widespread belief that irrigation efficiency can be addressed by shifts to micro-irrigation or with canal lining). These brief examples indicate the need for 'systems' research of these topics and wider dissemination of findings to a professionalized body of engineers and water officers.

Although there is not the space to outline detailed policy implications, some key issues can be identified, including the shift from a largely regulatory basin-wide model of managing water to a domanial one. This would require the establishment of appropriately skilled government officers, NGO's, academics and consultants to identify stretched holons and analyze the structure, properties, behavior and social composition of these sub-systems so that risk-based approaches and conflict-based entry points can be identified to initiate citizen's actions.

6 Conclusions

In considering the adaptive management of basins with significant irrigation, a governmentality analysis was applied to disaggregate complexity into discrete management domains. The model, captured by the term 'domanial water resources management', is built on devolved polycentric nested holons, principally sub-catchment and irrigation systems. Using these units of co-management, the following can be considered:-

- The management of water within and transitions across water sufficiency phases drawing up objectives for each phase; bulk, medial and

[5] A refrain heard during debates at a recent DFID water policy day, 24 May 2007, DFID Head Office, London.

critical, with a particular focus on the distribution and access to small volumes of water during critical drought periods.

- The identification of key tasks via risk-based and conflict resolution approaches and utilization of conflicts to build co-operative competition and enhance productivity.
- The promotion of a social process for their management involving services that respond to collective stakeholder analyses of activities, issues, successes and problems.

It should be re-iterated that a domanial approach is proposed for where regulatory approaches to river basin management, while seemingly normative within water science, may in fact be the riskier model. This is a fruitful area for research – how to raise performance in ways by using systems and livelihood approaches that are theoretically accurate, meaningful and sustainable, particularly alongside competing water management narratives (e.g. rainwater harvesting) that vie for policy-makers' attention.

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Can adaptive management help us embrace the Murray-Darling Basin's wicked problems?

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Abstract

In this chapter I explore the potential value of adaptive management of wicked problems, using Australia's Murray-Darling Basin as a focus. The Murray-Darling Basin is one of the largest and most economically important catchments in Australia. Being large and eco-socially-politically very complex, resource managers face many 'wicked' problems- including dryland salinity, biodiversity decline, waterway eutrophication and competition for use of surface and groundwaters, all against the backdrop of climate change and increasing understandings of systems. Narrowly focused 'rational' approaches are proving insufficient to address these issues, so government policy discourse has turned, in part, to adaptive management. Adaptive management enables managers to learn about whole systems as they are managed, and so is expected to cope with complexity and uncertainty. As an observer of adaptive management of natural resource management in the Murray-Darling Basin I question whether adaptive management as it is currently practiced is reflecting the ideal. I suggest that current adaptive management projects are concerned with 'taming' problems to enable them to be addressed with conventional management. Ironically, this appears to be in response to complexity and uncertainty, a function of the risk averse cultures in which management operates. To use the full potential of adaptive management to address eco-socially-politically complex natural resource management issues requires an acceptance that

risk and uncertainty are inevitable. The first step to achieving this could be to support leaders who can construct cultures conducive to more courageous adaptive management.

1 The Murray-Darling Basin and its wicked problems

In this chapter I explore the value of adaptive management of wicked problems, using Australia's Murray-Darling Basin as a focus. Covering over one million square kilometres of south-eastern Australia, the Murray-Darling Basin is referred to as Australia's 'food bowl', although this obscures the significant role that other industries play in creating wealth and wellbeing for the country's 20 million residents. The total annual economic output of the Murray-Darling Basin is around 12.5 billion Euros (Department of the Environment and Water Resources 2004). This great bounty has come, however, at a substantial environmental cost. Many subcatchments are seriously degraded and the Murray-Darling river system itself has the dubious 'honour' of appearing on the World Wildlife Foundation's top ten rivers at risk list (Wong et al. 2007). Australia's "environmental report card", the State of the Environment Report, sums up the current situation:

> "Overall, the state of the inland waters environment in the southern and eastern part of Australia is not very healthy. Significant areas of major inland and coastal catchments are degraded (including vegetation, aquatic habitats and water quality), the pressure on water resources continues to be high, and many indicators show that aquatic ecosystems and biodiversity are degraded across large areas of the continent. Water use and infrastructure development continues to grow and there is little indication that key indicators have improved in the last decade. The indicators that do exist are bedevilled by climate variability and periods of low rainfall, population growth, and changing land use patterns."
>
> (Harris 2006)

Many of the issues currently facing natural resource managers in the Murray-Darling Basin could be described as 'wicked' problems. In their influential paper Rittel and Webber (1973) used "wicked" as a synonym for "tricky", rather than "ethically unacceptable", and suggested that most social planning problems fall into this category. They describe wicked problems as neither definable nor solvable in the ways in which mathematical problems or engineering tasks (so called 'tame" problems) are, because the consequences of management actions are uncertain, and could be worse than the original problem. Similarly, Waddock (1998) describes problems that have emergent patterns but no predictability as wicked and (Ludwig 2001) suggests that addressing wicked problems will invariably involve players from many disciplines, and with many knowledges. Durant and Legge (2006) add that responses to wicked problems are necessarily controversial. Freeman (2000) notes that, worldwide, water management problems tend to be wicked, because addressing them requires increasing levels of interdisciplinary collaboration and integration of different types of knowledge to address a common property resource. Some of the wicked problems that are currently exercising natural resource managers in the Murray-Darling Basin are listed in Table 1.

As this chapter was being written the Murray-Darling Basin was experiencing its worst drought in recent history- worst by many measures including geographic and temporal spread and record breaking low rainfalls and runoffs (Bureau of Meteorology 2007). Even the usually well buffered citizens of cities such as Sydney and Melbourne were impacted, with legislated restrictions on outdoor water use, and intense moral pressure for wise water use indoors (see for example Melbourne Water 2007).

The complex ecological systems of the Murray-Darling Basin are matched by complex governance arrangements, which in turn reflect complex social expectations. Bickering between governments over use of water in the Murray-Darling Basin has been prevalent since before Federation in 1901, but from the 1980s a desire for an integrated approach to water management within the Basin emerged. New institutional arrangements known as the Murray-Darling Basin Initiative were developed. This resulted in the creation of the Murray-Darling Basin Ministerial Council, a partnership between the Commonwealth Government, and the three states and one territory that have jurisdiction over part of the Basin, in 1985 (Reeve et al. 2002). The Murray-Darling Basin Ministerial Council has presided over a number of important policy instruments including "The Cap" on further surface water extractions from the Murray River (Connell 2007).

Water policy in the Murray-Darling Basin occurs within the Australian wide context. The prolonged drought has heightened public awareness of water policy, but the management of water resources in Australia has been undergoing intense reform since 1992, when the heads of all Australian governments adopted the National Strategy for Ecologically Sustainable Development, committing them to more effective and integrated water management policies and practices (Pigram 2006).

Table 1. Some 'wicked' problems in the Murray-Darling Basin, Australia

'Wicked' problem	Manifestation	Source
Freshwater allocation	Increasing competition for scarce water resources	(Fullerton 2001)
Dryland salinity	Predicted that areas of dryland salinity in the Basin will reach equilibrium at 9 million hectares in the future.	(Murray-Darling Basin Ministerial Council 1999)
Irrigation salinity	Predicted that all irrigation regions within the southern Basin will have water tables within 2 metres of the surface by the year 2010, without new interventions.	(Murray-Darling Basin Ministerial Council 1999)
Biodiversity decline	More than half of the ecosystems in the Murray–Darling Basin are under severe pressure and significant declines are likely	(Beeton et al. 2006)
Water quality	Freshwater algal blooms cost Australia between $180 m and $240 m each year.	(Land and Water Resources Research and Development Corporation 2000)
Surface and groundwater connectivity	In the Murray-Darling Basing groundwater extraction for irrigation rose by around 310 gigalitres a year after the cap on surface water extraction was introduced in 1994. The impacts of this are not well understood.	(Evans 2007)

In January 2007 The Prime Minister John Howard announced that the Commonwealth Government would invest $10 billion dollars (around $6 billion Euros) in reforms to rural water management across Australia (Connell 2007), an action designed to give impetus to the National Water Initiative which was launched in 2004. The National Water Initiative will, among other things:

> "provide for adaptive management of surface and groundwater systems in order to meet productive, environmental and other public benefit outcomes"
>
> (National Water Commission 2005).

2 Adaptive management

This is not the first time that Australian governments have invoked adaptive management to address wicked problems. Two major natural resource management initiatives – the Natural Heritage Trust (NHT), and the National Action Plan for Salinity and Water Quality (NAP)- are underpinned by bilateral agreements between the State and Federal governments which place adaptive management as a founding tenet (for example see Commonwealth of Australia 2003).

Adaptive management in its broadest sense is learning from experience. Adaptive natural resource managers deliberately set out to learn from policy implementation to improve their future practice. Adaptive management complements reductionist scientific management by situating learning in real world, complex situations. Adaptive management was conceived in a technical-ecological context (eg Holling 1978; Walters 1986), but it has increasingly become as much a social and civic undertaking as a technical one (Lee 1993). Two main forms of adaptive management are recognised today. Passive adaptive management has a strong focus on implementation, in particular the implementation of an historically informed best practice or policy, followed by review of that implementation. Active adaptive management is also about implementation, but there is a more structured and sustained emphasis on learning. Within an active adaptive management paradigm implementation of policy and strategy is designed to test hypotheses. In theory both forms of adaptive management should be sound responses to wicked problems, as both passive and active adaptive management acknowledge the need to work with complexity and uncertainty. Much of the literature on wicked problems has focused on 'taming' planning problems so that they can be addressed by conventional management approaches. (Churchman 1967) suggests that attempts to present aspects of wicked problems as 'tame' is not only unhelpful, but is actually immoral as it hides inherent wickedness. Adaptive management is one of the few management approaches with the potential to work with complexity and uncertainty, making it more likely to succeed both practically and ethically.

3 Reflection on some current adaptive management projects

I have studied adaptive management in action in Australia since 2001. My contribution here is to reflect on whether adaptive management as I have seen it operate is really an effective response to the wicked problems that challenge the catchment and water managers in the Murray-Darling Basin. To do this I draw on my own qualitative research with two catchment management projects, and on two adaptive management focused discussions with natural resource managers. I will not go in to great detail on any of these as the full findings are published elsewhere (see citations in following section); rather I will present selected results that shed light on the capacity of adaptive management to address wicked problems.

My first example involves a government supported project, the North East Salinity Strategy Implementation (NESSI), that addressed dryland salinity on private farmland in the south of the Murray-Darling Basin. The objective of NESSI was to control dryland salinity for the benefit of the environment, local communities and downstream users for future generations (North East Salinity Working Group 1997). The major tools available to address dryland salinity were revegetation of recharge areas with trees or perennial pastures, and groundwater pumping. The project was not badged as adaptive management, but it was acknowledged that there was some uncertainty about the causes of the salinity problem, and the efficacy of the current management activities. Because of its apparent intent to create new knowledge while applying current best practice NESSI can be viewed as an attempt at passive adaptive management. NESSI, led by government agency staff supported by an active, community based working group, had been operating for over five years when I invited some of the participants to reflect on the project. A recurring theme in these discussions was the need to manage the real and perceived risks of the project. The main suggestion for addressing risk was to provide high levels of certainty about projected outcomes. For example, one community adviser to the NESSI stressed that *"...the single most important thing is to be able to assure the public, I think, that we're not guessing, in the causes of salinity, and therefore have the skill to target more specifically the areas that are causing salinity."* Certainty such as this, many interview participants claimed, could only be obtained through continued scientific investigation, undertaken by research scientists. This view was apparent in the development of separate research and implementation strategies within the NESSI, with monitoring only occurring as part of the research aimed at describing the hydrogeology of the region. As there was no direct monitoring of the outcomes of the implementation activities the opportunity to learn from them was lost. Thus a focus on 'science', risk aversion and a particular type of learning, combined with limited resources, resulted in very little social learning occurring, despite the range and number of onground implementation activities supported by the project (see Allan and Curtis 2003b for details).

The Heartlands project, 2001-2004, was also located in the southern Murray-Darling Basin. While similar to the NESSI project in its focus on dryland salinity management via revegetation, and its reliance on community participation, Heartlands explicitly badged itself as an attempt at active adaptive management. Heartlands aimed to design and implement landscape scale land use changes in order to learn from those changes (CSIRO Heartlands Core Group 2000). As with the previous example the funding came from Federal and State governments, but the project was managed by an alliance of scientists, agency staff and farmers. I was a participant observer over the life of one of the major Heartlands sites, in the Billabong catchment, and I noted that anxiety about uncertainty, and a feeling that complexity added to uncertainty, were apparent over the project life. This anxiety manifested as a desire to gain certainty through narrow scientific investigation, as in the NESSI project, but also in quite ferocious 'gate keeping'. The Billabong project management team actively sifted information and requests for collaboration before passing them on to the wider project community, in an attempt to protect their community from too much and too varied information, and to avoid losing credibility by being seen to be associated with a project that may fail. The management and decision making functions were restricted to what they called the 'core group' within the management team, with the 'fringe' team members having limited duties and powers. Anxiety about uncertainty and complexity also influenced the perception of increased risk of project failure. This was managed in part by careful wording of reports to the funding bodies, as the annual funding was contingent on acceptable performance in the previous year. No lies were told, but the reports, following the guidelines, emphasised progress towards the funding bodies' targets, rather than any lessons learned from surprises or mistakes. To the credit of the Heartlands management team a key 'learnings' report was produced and distributed at the conclusion of the project (Earl and Cresswell 2005), but there was no clear mechanism for the lessons documented in the report to inform future policy. The other major response to complexity was to reduce the size of the active adaptive management components of the project. While implementation of landscape management works continued over the entire Billabong project area, the landscape experimentation was restricted to two small sub-catchments with a limited variety of landform and only a handful of farmers with whom to negotiate. This was a pragmatic decision, driven in part by the need to recruit the goodwill and cooperation of farmers within a short (two to three years) project time frame, and within the restrictive guidelines from the funding bodies. As one agency member of the project team noted at a planning meeting "…*Government wants to keep an eye on what's being spent. The pressure is on you guys*". This articulated the subtle but constant pressure exerted by levels of government and community to reduce risk and treat the Heartlands project as a conventional management exercise rather than an experiment (see Allan 2004; Allan and Curtis 2005 for details).

In 2002 I organised a meeting of natural resource managers and academics to discuss adaptive management. While much of the two day meeting focused on defining adaptive management and formulating ways to incorporate it into current and new projects, there was also some discussion on perceived constraints. The major constraints were identified as uncertainty and the associated risk of failure. In particular participants noted that funding bodies and policy makers were unwilling or ill prepared to support new approaches such as adaptive management fear of it failing to achieve the desired onground improvements (Allan and Curtis 2003a).

Uncertainty and complexity, viewed from within a risk averse management culture, were clearly operating as major constraints on adaptive management in the southern end of the Murray-Darling Basin at this time, but was this simply an Australian response? And might things be different now? In 2006 some colleagues and I led a panel session at the American Water Resources Association's Summer Speciality Conference on adaptive management. At that session, attended by over 100 conference delegates, the need for certainty in the midst of complexity was identified as a major constraint on undertaking adaptive management (Allan et al. in press). This echoes findings from the Adaptive Management Areas in the forests of the US Pacific NorthWest, where project participants identified organisational reluctance to support experimentation because of the uncertainty inherent in this activity (Stankey et al. 2003). Complexity of itself is also cited as a reason for avoiding adaptive management, as in the Columbia River adaptive management plan which was seen to have 'failed' the threatened salmon in the river because the project was too large and had too many players (Ladson and Argent 2002).

A strong desire to manage complexity and uncertainty through reduction and simplification is also apparent in some of the current ecosystem system adaptive management projects in the Murray-Darling Basin. Adaptive management is apparently working well for individual rangeland managers who set their grazing patterns on observation of rangeland condition, so much so that one Australian University is offering training for rangeland managers specifically on adaptive management (University of Queensland 2007). However, "success" is a harder claim to justify in larger scale adaptive management projects. Large scale "adaptive management" projects exist, but they focus on a single, easily contained problem, albeit a large scale, real world one. For example, the Adaptive Environmental Water in the Murray Valley project focuses on rewatering wetlands on private land to restore biological function. Water held within the existing irrigation supply system is used to flood wetlands which have been dewatered through river regulation and farm practices. The diversity and abundance of wetland plants and animals, and water salinity concentrations, are monitored to learn about the impacts of each watering event (Nias 2005). In this case complexity is managed by focusing on single watering events in a discrete landuse type. The Murray-Darling Basin Commission also has an adaptive management project on the Murray River. The Living Murray Environmental Flows project aims to learn from the impact of returning controlled flood events to reaches of the River Murray itself (The Murray-Darling Basin Commission 2007). The Living Murray reduces complexity by focusing on single 'environmental' flood events, and by restricting its activities to six "icon" sites along the 2530 km length of the river. These examples suggest a trend toward simplification and/or reduction to enable the production of apparently clear boundaries, definable problems and endpoints that are achievable within the constraints that are set by conventional policies.

4 Implications for the management of wicked problems

So, we have a paradox. Adaptive management is proposed as a way to tackle wicked problems, because it is defined in part by its ability to accept, rather than tame, wicked problems. However, current adaptive management projects are functional because they reduce complexity and uncertainty by being small scale and/or by limiting themselves to single questions. In other words these adaptive management projects, like more conventional approaches, are attempting to tame the wickedness in the problems rather than embrace it.

I do not want to suggest by this observation that adaptive management can never provide the means for us to embrace uncertainty and complexity, but I do suggest that to do so adaptive management needs to be radically different from the way it is enabled to manifest today. A tendency for adaptive management projects to slide towards conventional management is understandable given the powerful social and institutional constraints on managers. There are strong societal expectations of management, nurtured by more than a century of rational planning and reliance on scientific expertise. These expectations include that issues and problems can be clearly defined and that responses can be equally clearly articulated to allow targets and milestones to be set. For example, Poff et al. (2003, p299) suggest that "*Although society is often willing to invest in the restoration and pro-*

tection of rivers, there are also huge expectations of measurable ecological returns". Adaptive management is also constrained in cultures which reward activity but not reflection on that activity, and which promote competition and self congratulation within management and scientific communities. Short project time frames, rigid targets and a focus on 'success' prompt managers to continue with conventional, reductionist and controlled management approaches, even when 'encouraged' by government rhetoric to manage more adaptively (Allan and Curtis 2005). Indeed, despite the rhetoric, government funding is clearly tied to safe and restrictively managed projects. If the potential of adaptive management is to be harnessed to address wicked problems in catchments such as the Murray-Darling Basin some serious support needs to be provided. (Grint 2005) suggests that wicked problems are best addressed through leaders defining the context in which appropriate management actions can occur. Gunderson and Light (2006) make this point specifically in relation to moving to adaptive governance of complex ecosystems. It follows then that one of the most important activities for achieving adaptive management will be the selection and support of appropriate leadership which has the courage and capacity to acknowledge risk, and the opportunity for learning that risk presents.

5 Conclusion

The Murray-Darling Basin, in company with many of the world's large and productive catchments is so complex, and the call for integrated approaches is so intense, that many resource management problems within it fall into the category of wicked social planning problems. Since conventional, rational planning models cannot fully address the wickedness, and since it is both futile and unethical to present parts of wicked problems as 'tame; approaches that accept and work with complexity and uncertainty need to be developed and supported. Adaptive management has been developed and described for many years, but there is little evidence that it is fully supported. Without courageous leadership that supports a desire to learn and change, adaptive management in the Murray-Darling Basin will, by social necessity, slide back to conventional management and the opportunity to work within the complex, wicked and wonderful world will be lost.

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The NeWater Management and Transition Framework – state and development process –

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Abstract

This paper presents the first completed version of the Management and Transition Framework developed in the NeWater[1] project. The framework is an interdisciplinary conceptual framework supporting the analysis of water systems and management regimes to improve the scientific understanding of system properties and to give practical guidance for the implementation of transition processes towards more adaptive systems. The framework integrates a range of concepts to develop a more coherent understanding of the complexity of water management regimes. Specific emphasis is given to adaptive capacity and learning processes. The framework has been developed in a participatory process involving a wide range of researchers from different disciplines. The framework development process made thus an important contribution to the process of integration within the project.

The current version of the MTF is a combination of graphical representation and narratives and divided into three components for the usage in research or practical implementation. The framework will be tested and re-

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[1] NeWater: New Approaches to Adaptive Water Management under Uncertainty, an integrated EU project funded under contract No 511179 (GOCE)

fined in an interactive process between case study implementation, comparative analyses and generic concept development.

1 Introduction

Integrated and adaptive water resources management poses considerable challenges to the water management community. Water management has been dominated by a technical tradition where the human dimension was treated as external boundary condition rather than an integral part of the system to be managed. The established planning approaches within water management developed in industrialized countries rely heavily on the ability to predict the effect of management measures and assume that design systems can be controlled. Uncertainty has largely been reduced to what can be managed with formalized techniques. Correspondingly concepts and methods and a comprehensive knowledge base for integrated and adaptive approaches are largely missing and have yet to be developed. Numerous projects have been initiated to fill these gaps. Many of them face similar challenges to integrate concepts, methods and knowledge to develop a sound understanding of complex water systems as base for development and implementation of appropriate management strategies.

NeWater (New Approaches to Adaptive Water Management under Uncertainty) is such a complex project with ambitious goals for scientific achievements and the practical implementation of insights in water policy and at the operational level of water management. Researchers from more than 35 organizations with different disciplinary background work on the development of concepts and empirical investigation in seven river basins in Europe, Africa and Central Asia. The size of the project and the presence of a wide range of scientific disciplines, different cultures, methodological and case study research, involvement of stakeholders at different political levels make integration a particularly challenging task.

In order to achieve integration a process was started to develop an operational and integrated framework approach to implement system analysis and knowledge representation and communication, in support of the process of knowledge production and integration within NeWater and, in particular, to answer the following questions:

- What are the essential elements needed to understand the complex dynamics of water management regimes and their ability to cope with future challenges such as climate change?
- How can one analyse and assess the adaptive capacity of water systems and the role of management strategies for its enhancement?

- What determines the dynamics of a transition to adaptive management, what are barriers and what are drivers?
- What is an appropriate methodology for the participatory assessment and implementation of transformation processes and evaluation of progress that can be applied to a wide range of different contexts?
- Which kind of guidance and tools are required for policy and practitioners to implement integrated and adaptive management regimes.

The challenges for integration highlighted above translate into the following requirements for an integration framework:

- Be open to include a wide range of different scientific concepts and world views.
- Include and address different types of local knowledge and stakeholder perspectives.
- Be able to handle all types of data from quantitative information to fuzzy data and qualitative analyses.
- Consider multiple spatial and temporal scales and their interdependence.
- Be credible in the scientific world and deliver tools useful for practitioners.
- Be realisable within a limited time period.

The framework need to comprise a multi-level representation for the:

- Characterization of Management Regimes.
- Characterization of Transition Processes.

This is quite a remarkable list and shows the complexity of the task which has to be tackled. A specific process has been designed to develop and implement the framework in an interactive process with the NeWater consortium. The process supports social learning and integration of different scientific frames. Insights from an analysis of the initial project phase have been included in the design of the integration process. This chapter gives an overview over the Management and Transition Framework (MTF) and the process how it has been developed.

2 The Management and Transition Framework

2.1 Conceptual Basis entering the framework

This section summarizes key concepts that have been integrated in the NeWater MTF (Management and Transition Framework). A comprehensive framework which would allow analysing the properties and the dynamics of complex water systems to develop appropriate strategies for their management is largely lacking. Correspondingly a major task is the integration of different conceptual approaches into a meaningful whole. The most important concepts that have informed the MTF are:

- Adaptive management and characteristics of adaptive and integrated water management regimes
- Social learning and adaptive governance.
- The IAD (Institutional Analysis and Development) framework to analyse collective choice processes.

2.1.1 Adaptive Management

The concept of adaptive management has a long history in ecology (Holling, 1978). Adaptive environmental management was developed as response to the insight that ecosystems are complex adaptive systems which can be predicted to a limited extent only (Walters, 1986). In order to learn more about ecosystem response to management measures, experiments are designed that allow distinguishing between different hypotheses derived mainly from model simulations. In recent year more attention has been given by adaptive management scholars to integrating the human dimension (Lee,). The concept of adaptive management used here adopts a broader perspective with a strong emphasis on the human dimension (see also Pahl-Wostl et al, in press; Pahl-Wostl, this volume). Adaptive management is defined here as a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies. Such a systematic approach can but must not necessarily imply the design of experiments. Specific emphasis is given to the analysis of different kinds of uncertainties that need to be addressed in the management process (see also Brugnach and Pahl-Wostl, this volume).

Adaptive management can only unfold in an integrated and adaptive water management regime that provides an enabling environment. A water management regime refers to the whole complex of technologies, institutions (= formal and informal rules), environmental factors and paradigm that together form the base for the functioning of the management system targeted to fulfil a societal function. Due to the high interconnectedness and internal logic, individual elements of a regime cannot be exchanged arbitrarily. Therefore much emphasis is given to analysing processes of structural change, barriers and drivers for and the dynamics of transitions towards integrated and adaptive management regimes. Given the complexity of the systems under consideration one cannot expect to be able to ever derive a predictive theory for regime dynamics, in particular during processes of major change. Much attention needs to be devoted to understanding the requirements for learning and decision making processes under conditions of high uncertainty.

2.1.2 Social Learning processes

Social learning has been identified as essential requirement to develop and implement integrated and adaptive management (Pahl-Wostl, 2007; Pahl-Wostl et al, in press; Pahl-Wostl, this volume). Social learning refers to capacity of all stakeholders to deal with different interests and points of view and to collectively manage resources in a sustainable way. Important are issues such as the development of a shared problem definition and shared understanding of the physical system at stake, perception issues and mental frames, negotiation processes and strategies, and the quality of communication. Pahl-Wostl et al (2007) identified as key processes of social learning framing, leadership, boundary setting (who is in, who is out, what is included in the learning process) and the agreement on ground rules.

Social learning is of critical importance in the initial phases of a transition process where it is necessary to build trust and to search for innovative solutions to current and anticipated future water management problems.

2.1.3 IAD (Institutional Analysis and Development) Framework

The IAD (Institutional Analysis and Development) framework has been developed by Elinor Ostrom and colleagues over the past decade (Ostrom 2005). The IAD framework was integrated into the MTF as base for a structured approach to analysing the role of institutions in water management regimes and processes of change The IAD framework offers a base to analyse institutions and collective choice processes at different levels. Since it is not closely linked to a theory it is open for extensions and offers itself for conceptual integration. The IAD framework has mainly been applied to analyse common pool resource dilemmas with the goal to find rules for institutional design to overcome and prevent such dilemma situations.

Fig. 1 summarizes the focal level of analysis of the IAD framework – the action arena.

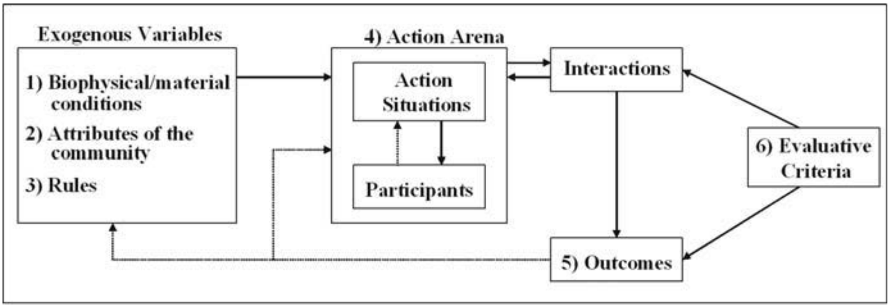

Fig. 1 Focal level of analysis in the IAD framework: action arena. (Ostrom 2005).

The action arena comprises an Action Situation and Participants. In an Action Situation participants with diverse preferences interact, exchange goods and services, solve problems, dominate or fight one another or develop new rules. Participants and an action situation -interact as they are affected by exogenous variables (at least at the time of analysis at this level) and produce outcomes that in turn affect the participants and the action situation. Biophysical conditions, attributes of the community and rules are treated as exogenous to the action situation. This implies that they are assumed not to be changed during learning and negotiation processes taking place within an action situation. They may however, be changed by outcomes of a process.

The IAD framework has mainly been applied to analyse static representations of social systems. The evolution of rules over time may be analysed by comparing different representations.

By integrating IAD with concepts of transition and learning processes we expect to be able to gain important insights in processes of institutional change.

3 An integrative development process

The framework is the central output of an interdisciplinary research project including 37 partners and ~ 140 researchers. Thus, the framework needs to comprise knowledge, concepts, and approaches from various disciplines. Since this environment encompasses complementary and competing approaches for adaptive management, each regarded to be a basic fundament of the framework, a broad involvement of project partners is a prerequisite for a successful development process. For this broad participatory process a graphical representation is required that documents agreements on the basic structure of the framework and helps to understand and to apply the framework without reading elaborate written reports. A graphical representation also supports the integration of partial views. In contrast, natural language is richer and better capable to express the meaning of concepts. Therefore a combination of narratives and graphical representation was considered most beneficial.

The procedure to facilitate the development process of the MTF has been developed based on ideas from the Rational Unified Process (Versteegen 2000, Pahl-Wostl et al. 2007). The Unified Modelling Language (UML) has been used to create the framework in order to avoid ambiguity inherent in not standardized graphical notations. UML comprises various types of diagrams able to shed light on different aspects which are applicable to different levels of detail. This is considered useful since water management regimes are large and complex systems and “the” representation of a regime does not exist. The MTF makes use of the capabilities of UML to develop various diagrams and to describe their linkages which facilitates a comprehensive overview but also detailed insights into water management regimes. However, to simplify the process and to reduce complexity it has been decided to limit the number of diagram types to class and activity diagrams - two out of the eight possible kinds of diagrams in UML.

UML is a standard notation for modelling real-world objects and situations in object-oriented analysis and design. It is derived from and unifies the notations of different object-oriented approaches (Jacobson et al. 1998; Ambler 2004). Experiences during the development process have shown that it is important to point out that UML is not a running model processing data. It is used for the limited purposes of specification and graphical representation.

The usefulness of UML as a notation is evaluated based on two criteria: (a) how usable is UML for the representation of the MTF and (b) what benefits for NeWater as a large-scale integrated project result from using UML.

The current draft of the MTF has been developed in an interactive design process including workshops and online meetings with representatives from most project partners. The following conclusions for both perspectives are drawn from authors' observations and from feedback discussions during development workshops.

The usability for the MTF representation can be evaluated as moderate. The complexity of UML allows the representation of all real-world situations as dynamic elements (time-, message-, and activity-oriented) or static structures with objects, attributes, operations, and associations. But this complexity on the other hand leads to a high number of diagrams with different levels of detail. Nevertheless, it can be concluded that an introductory explanation of UML notation enables workshop participants to interpret existing and develop new MTF-elements independently. With support of some facilitation UML novices are able to "translate" sectoral concepts and models into UML diagrams. In fact, some workshop participants reported that it was the first time they were able to fully interpret processes that have been nebulous to them in other notations. The enforced formalisation of MTF elements, however, also has drawbacks. On the one hand, a well-grounded specification in UML allows an implementation as database facilitating comparative analysis of various water systems for research and practical application. On the other hand, participants seem to feel constrained while trying to integrate their own knowledge and concepts. In fact, those constraints are due to the limitation to develop only class- and activity diagrams and can be eliminated by the introduction of further UML diagram types, e.g. collaboration diagrams. However, this would increase complexity and require a profound UML expertise. The most undisputable argument for UML is a lack of alternative notations that can cover such a broad and easy to understand variety of views.

For the project management and the integration within NeWater UML is judged to be extremely useful. The following observations and conclusions represent this perspective:

- The enforcement to be precise and concrete forces domain experts to clarify their own concepts and models and to make choices in otherwise fuzzy approaches.
- The incorporation of concepts as part of an interactive implementation process requires mutual explanations of concepts as part of a new project communication.
- Complex system structures can be communicated unambiguously.
- It can facilitate the comparison of competing concepts.

4 State of the framework

The MTF is an interdisciplinary conceptual framework supporting the understanding of water systems and management regimes and transition processes towards more adaptive management. Its current generic and normative nature supports a broad range of application fields from analysis of concrete management examples to guidance for transition processes. It has a modular structure to address different perspectives for research and practical application in water management.

The *static representation* (class diagram) of the water system includes an environmental and a societal system with objects, attributes, and relations within and between both sub-systems. The *process view* or *dynamic view* (activity diagram) is a representation of combined concepts with a sequence of activities for the management cycle and learning and transition processes linked to it. These two modules provide two different but semantically consistent views of the same aspect but are each only a partial representation of a system. The level of detail and the amount of elements (e.g. objects) to be shown depends on the degree of information that is required to understand, analyse, or present a certain management problem. Consequently, while applying the MTF to a specific case, the level of detail can successively be increased.

4.1 Class diagram

The MTF class diagram (Figure 2) defines classes of elements and their relations, attributes, and applicable methods that have been identified as important to describe water management systems. While it is assumed that all water management regimes share this basic structure of general elements and relations between the elements, they are assumed to differ in the specification of elements, as for instances represented by different attribute values. The institutional analysis and development (IAD) framework devised by Elinor Ostrom (2005) provided the basic structure for the representation of collective choice processes with emphasis on actors and institutions. The IAD has been extended by concepts of social learning. The different elements characterizing water management regimes (Pahl-Wostl, this volume and Pahl-Wostl et al, in press) have been integrated into the overall structure. During this process some elements of the IAD framework have been reinterpreted or changed (e.g. instead of positions, roles have been introduced). The assumptions that have entered in building the framework are documented in the history of each class. The current MTF class diagram consists of 20 classes that are introduced in the following:

Water System: The ‘water system’ is the central class comprising all environmental and human components. Direct components of ‘water system’ are ‘institution,’ ‘ecological system,’ ‘societal system’ and ‘action arena’. It is affected by ‘actions’. Important attributes of a ‘water system’ are its geographical scale, its population density, and climate class (Köppen and Geiger (1972)).

Ecological System: The ecosystem class comprises abiotic and biotic components of the water system. Components of ‘ecological system’ are ‘environmental service’ and ‘environmental hazard’. Important attributes of ‘ecological system’ are water availability, biodiversity, degree of human influence, water quality, and natural storage capacity.

Environmental Service: ‘Environmental services’ capture the role of the ecological system to serve as resource or sink for human activities. Environmental services may have the nature of public or private as well as collective or toll goods, depending on the ease of exclusion and their subtractability (Ostrom 2005, 24). In addition to ease of exclusion and subtractability, further attributes of ‘environmental service’ are economic value and variability.

Environmental Hazard: ‘Environmental hazards’ are the threats posed by an ecological system. **‘**Environmental hazards’ are characterized by the distribution of likelihood of occurrence (frequency) and intensity of events, as well as the potential damage caused, and the affected target groups which can be biota (e.g. fish) or human beings.

Technical infrastructure: This class refers to infrastructure of relevance for the water management issue under concern. This can include dikes, dams, reservoirs and dominant design patterns for flood management. Attributes characterizing technical infrastructure are scale, lifetime, and ownership.

Institution: One ‘institution’ can comprise more than a single ‘rule’. The European water framework directive or other formal transboundary agreements are regarded as institutions. ‘Institution’ may be broader than rules which are often formalized. A rule set is part of an ‘institution’. A ‘strategic management goal’ is a specialization of ‘institution’.

Rule: The characterization of a ‘rule’ follows the ADICO framework of Sue Crawford and Elinor Ostrom (Ostrom 2005, chapter 5). In addition to attribute, deontic operator, aim, condition, and or else part, rules in the

MTF also have a level, referring to constitutional, collective-choice, and operational level as defined by Ostrom (2005, chapter 2) and a rule class, referring to the classification of rules according to which elements in an action situation they target (Ostrom, 2005, chapter 7) Important characteristics of rules are their formality, effectiveness and rigidity. Which rules are negotiable in their meaning? What are the characteristics of rules that are negotiable?

Action Arena: An issue specific political arena focused on a 'water management issue' and characterized by 'strategic management goals', 'actors' and a number of 'action situations.' An 'action arena' is defined by governance scales (including hydrological scales such as river basins that have been defined as "administrative" scale by promoting river basin management with new institutions at basin scale) and a dominant issue framing.

Action Situation: An 'action situation' is a structured social interaction context that leads to specific outcomes. Actors have to make decisions in a social context taking into account socio-economic and environmental boundary conditions. 'Action situation' is the regime element where 'actors' take certain 'roles' and perform certain 'actions'. Also, 'knowledge' is part of 'action situation'. 'Action situation' are the main link to the process view. Attributes of 'action situation' are its level (constitutional, collective choice, or operational) and the rules which are, for the sake of analysis of a specific 'action situation', considered temporarily fixed and external to this 'action situation'.

Situated Knowledge: It is assumed that actors activate 'situated knowledge' within the context of a specific 'action situation.' It is, therefore, linked to an actor and the situation. Situated knowledge captures the importance of framing and reframing and the embeddedness of knowledge in a social context.

Strategic Management Goal: A 'strategic management goal' is a special kind of 'institution'. It is a component of an 'action arena'. Its attributes are normative goal and degree of integration, indicating whether sectors are analysed separately or cross-sectoral analyses are carried out to identify emergent problems and integrate policy implementation.

Water Management Issue: 'Water management issues' refer to important topics that have historically defined governance arenas around which activities cluster and on which legal frameworks have been based. These include: flood protection, water supply, water quality, etc. The characterizing attribute of an issue is one out of a number of predefined categories.

Actor: An ‘actor’ is an individual or collective ‘actor’ populating an ‘action arena’. Furthermore ‘actors’ build up ‘societal systems’ and take part in ‘action situations’ in which they hold certain ‘roles.’ ‘Mental models’ are representations of the world in the minds of actors. For assessments of the water system ‘actors’ apply ‘evaluation criteria.’ Attributes of ‘actors’ Are their values, goals, and whether they are collective or individual.

Role: ‘Roles’ are based on a shared understanding of their meaning and function. A ‘role’ is held by an ‘actor’ during an ‘action situation,’ whereas ‘roles’ belong to the ‘action situation’ and not to the ‘actor.’ ‘Role’ has been derived from “position” as used in the IAD framework. Given the link to game theory, position in IAD is linked to distinguishing players according to the pre-defined rules of the game. Similarly, a ‘role’ is linked to a range of possible actions and entitles actors holding this role to certain knowledge.

Mental Models are representations of the world in the minds of ‘actors’. One attribute of ‘mental model’ is an action outcome link, which links expected outcomes to specific actions. This is characterized by uncertainty and dependence on other actors. Action outcome links include cognitive maps, causal loop diagrams, Bayesian Networks, and Heuristics. A second attribute of ‘mental model’ is the expectation about other actors’ behaviour.

Evaluation Criterion: With this class criteria used by ‘actors’ to evaluate the degree of satisfaction with the ‘observed state of ‘water system’ are described. Attributes of ‘evaluation criterion’ include the scale of operation and analysis, and weights for costs and benefits.

Observed State of Water System: This is a specification of knowledge used in an ‘action situation’ to evaluate the state of the ‘water system’. It is, therefore, linked to ‘evaluation criterion.’ The choice of what is used reflects the perception of ‘actors’ about what is important for them to make a judgment about their individual satisfaction and the achievement of ‘management goals’. The evaluation is based on ‘evaluation criteria’. Attributes of ‘observed state of water system’ are indicators for environmental sustainability, indicators for economic sustainability, indicators for social sustainability, and indicators for system performance, referring to system properties like adaptive capacity, resilience.

Knowledge refers to meaningful information and experience. Tools may be used to produce ‘knowledge’. Tools may support the generation of information (e.g. cognitive mapping), access to information (e.g. reports) and communication in the context of an ‘action situation’. An attribute of ‘knowledge’ is its accessibility.

Action: An ‘action’ refers to an activity that leads to changes in the ‘water system’ or any of its components (‘ecological system’, ‘social system’, ‘institutions’, ‘action arenas’). An attribute is the cost of an action.

Societal System: This is the social system in which an ‘action arena’ is embedded. Depending on the level it may be characterized by different attributes or attributes may have a different weight. Community attributes define the structural context (together with institutions). Of key importance is the choice of attributes to better understand the influence of structure on agency. ‘Societal system’ has been introduced to replace the community class from the IAD framework. Community is too much derived from local conditions. ‘Societal system’ reflects better the general nature and is a major element of the ‘water system’. It is built up by ‘actors’. Attributes of ‘societal system’ are: resilience, social and economic adaptive capacity, culture, extent of homogeneity, extent of inequality of basic assets, size of community, and economic growth.

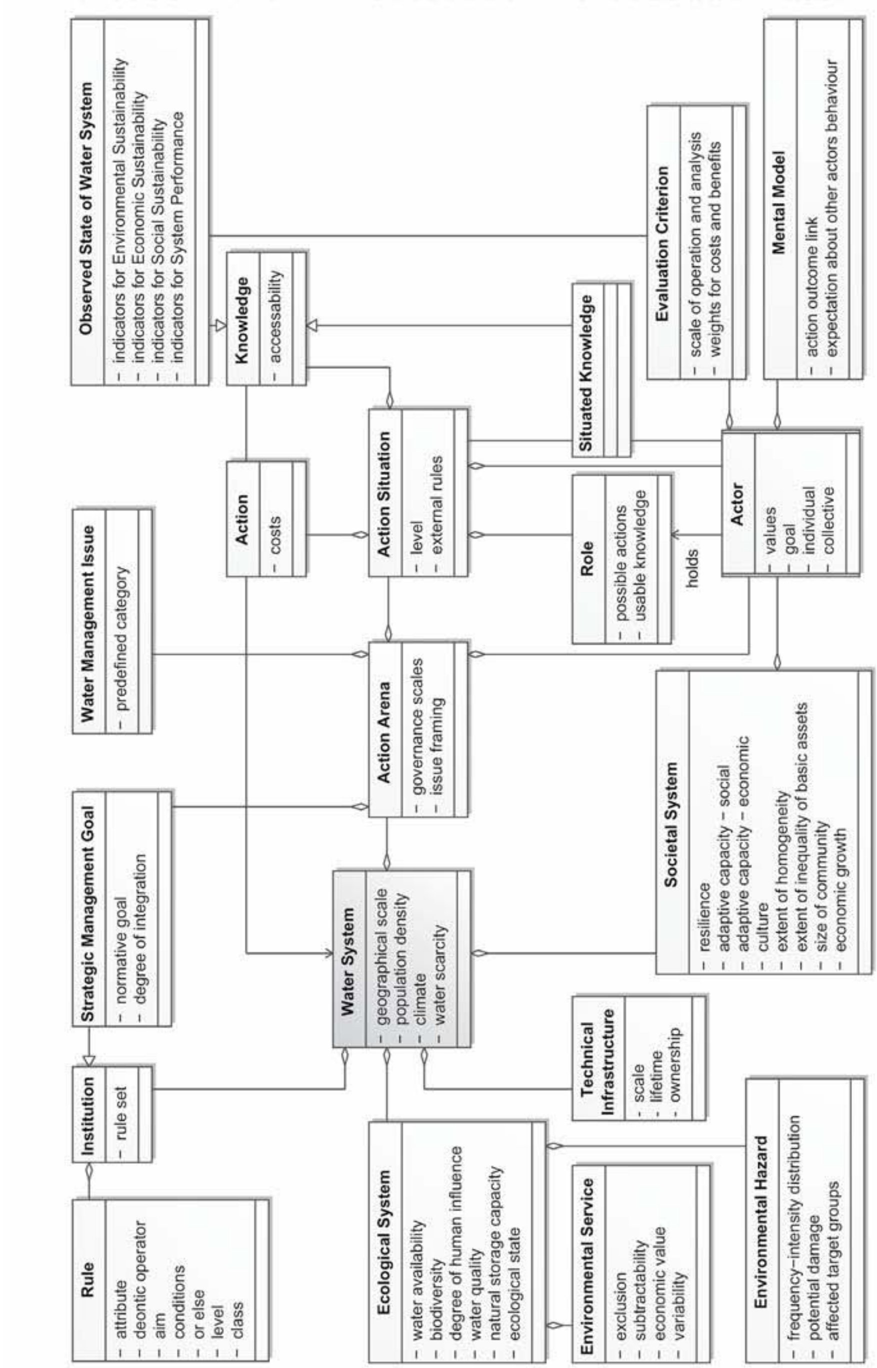

Fig. 2 MTF class diagram

4.2 Activity diagram

Learning in water management and transitions to new water management regimes seem to be closely linked to processes in informal actor networks. Pahl-Wostl (figure 5, this volume) argued for the need to integrate learning cycles into water management. Such dynamics are represented in the activity diagram (fig. 3). The formalized conventional management process is shown on the left side of the diagram. The right diagram represents an informal process of initiating change based on a learning cycle. Learning cycles may be introduced at the level of implementation as part of operational adaptive management, to test new approaches where significant uncertainties prevail, for example, the introduction of water trading or decentralized technologies at the household level. Often new approaches may require major transitions. This may be realized during the implementation of innovative measures when structural barriers are encountered (e.g. rigid legislation, prevailing habits of consumers, dominant technologies) or even in an anticipatory fashion at an early planning stage. Structural changes imply learning cycles at the early stage of goal setting and policy development.

I In the idealized case, the need for a transition would be identified in a first comparison of the current state with the strategic goals to determine the degree of deviation from the desired state and estimate the need for action. At this state a learning cycle may be initiated if the responsible authorities hold the opinion that development and implementation of policies requires major structural changes and the involvement of a wider stakeholder community. Such a learning cycle may be the start of a transition management process. Typical examples are the implementation of IWRM in basins without fragmented water management or even without any operational water management, the transition from “control floods” to “living with water” as currently attempted in the Netherlands and other countries, the transition towards integrated and adaptive management in areas with a prevailing command and control regime. All transitions examples involve a major paradigm shift.

A learning cycle provides the possibility for “reflection”, i.e. restructuring of the management regime itself: These two processes are linked, in particular in the beginning where dissatisfaction with the current management approach and the perceived need for innovation triggers a process of change. Another crucial link is in a latter stage when windows of opportunity develop where innovative approaches developed in the change process can be fed back to the formalized management process.

Usually the sub-processes in the learning cycle occur in shadow networks with loose or no connections to the formal management process. In order to manage transitions is it essential to integrate such a learning process in the formal management process. Hence, the learning cycle should be read as an idealised management process in an adaptive environment.

All steps in the activity diagram are identified as "Action Situations" (see class diagram). For each of these Action Situations further diagrams – Action Situation diagrams - can be drawn[2]. Action situation diagrams go into greater detail and specify the following aspects of Action situations:

- In class diagrams: which actors are involved in this specific step, which institutions define roles, which actions are taken, are there different roles for the same actor, etc. For the analysis the class diagram can be applied as a template for analysis. Here the decision for the level of detail and for the selection of required MTF objects is taken.
- In activity diagrams: which sub-processes exist and how do sub-processes interact.

Action situation diagrams may include further Action situations that represent sub-processes that are initiated and terminated during the process described in this Action situation (e.g. "draft policy" is a sub-process of "policy development"). Action situation diagrams are designed to be as generic as possible but are based on a normative view of "good" adaptive management.

In the following both cycles, the formalized conventional management process and the learning process, are briefly introduced based on steps in fig. 3.

[2] Such diagrams have already been developed constituting generic templates that can be used as base for case-specific diagrams.

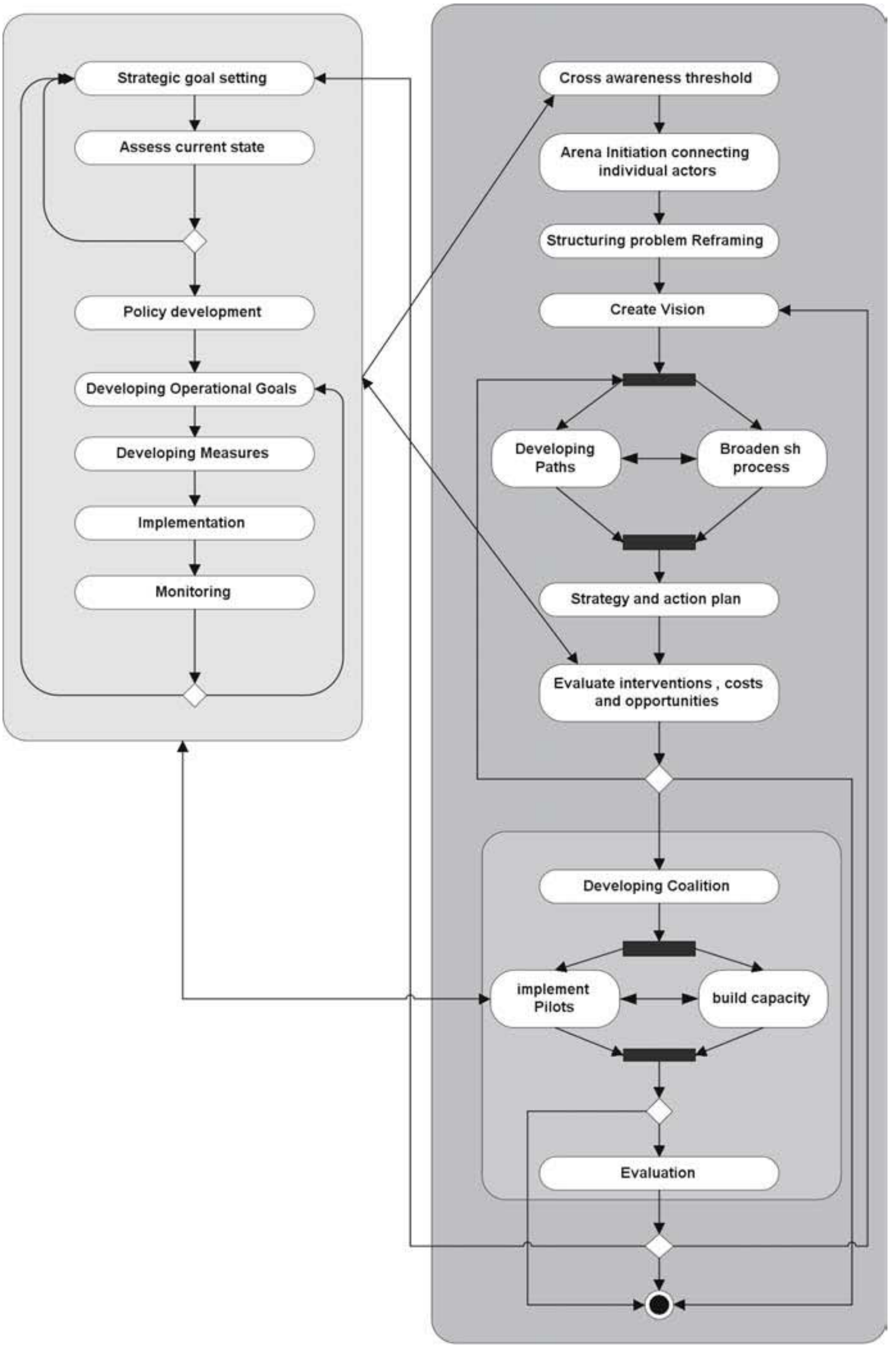

Fig. 3 Activity diagram representing the formal management process and in parallel an informal learning process initiating structural change.

Conventional management process:

Strategic Goal Setting: The strategic goals for the management process are set to determine a desirable state of the water system.
Assess Current State: The current state of the water system is assessed to estimate the distance of the current state from the desired goal state.
Policy Development: Policies are developed that represent coherent approaches how and in which time frame improvement of the current state of the water system is initiated.
Developing Operational Goals: Operational goals are defined that allow assessing efficiency and effectiveness of measures and that are the basis for monitoring programs.
Developing Measures: A plan with specific measures including an assessment of their effectiveness is developed.
Implementation: In this phase the measures are implemented on the ground at the appropriate level.
Monitoring: Monitoring serves to assess if the implemented measures lead to the achievement of the set goals and to detect potential unexpected and undesired consequences. At this state the process may go back to the first step and strategic goals may come under scrutiny.

Structural Change Cycle: The right side of the Double Loop shows a management cycle that aims to introduce a structural change to management:

Cross Awareness Threshold: Dissatisfaction with the current management approach beyond a threshold where the management decides to act. This may arise from a need to implement new kind of measures due to change in management policy (e.g. new legislation), major uncertainties in the process. It may also derive from failures, new insights about future development (e.g. climate change).
Arena Initiation, Connecting Individual Actors: A selected group of actors engages in a moderated process of social learning. They may succeed in reframing the problem. They have a certain degree of freedom in the process design to be able to adapt the process to the need of the problem to be addressed (e.g. agree on ground rules).
Structuring Problem and Reframing: The actors in the learning platform have succeeded in reframing and restructuring the problem.

Create Vision: Discussions are synthesized and brought into a single and inspiring vision.
Developing Paths: Scenarios are developed that illustrate barriers and bridges how to realize the visions.
Broaden Stakehoder Process: Bring in other stakeholders to get access to different kind of knowledge and build critical mass for support.
Strategy and Action Plan: Choosing viable paths, assess the resources required (and make a plan on how to get the resources to go down these paths).
Evaluate, Interventions, Costs and Opportunities: The participants in the learning platform analyses specific possibilities along these paths. This is the first stage of more intensive discussions with the overall management board (Windows of opportunities – in particular important if change needs support from higher political levels external to the management regime).
Developing Coalition: More stakeholders are involved in the process as a whole. This requires new methods to structure participation and information campaigns. A tactical campaign is launched.
Implement Pilots: Demonstration projects with prototype experiments at an experimental smaller scale.
Build Capacity: Sustain momentum by continuing to gather resources (e.g. money) and inspire people; system can still die if not more substances are added (money or other resources).
Decision: Based on earlier steps the process may be stopped completely, linked to running conventional management process or the new opportunities are further realised and moved forwards.
Evaluation: Evaluate success of pilots and think about up scaling and adjustments to actor coalition, the visions and the next round of experiments.

Once a real structural change is initiated the conventional management process does not cease to exist, but continues and is influenced and enriched by the outcomes of the learning cycle.

5 Conclusion and further development

The NeWater Management and Transition Framework (MTF) has been developed to integrate insights generated by researchers from various background and to allow generalizations of results found across different case-studies embedded in diverse contexts. It is used to represent highly complex systems. UML is a very flexible language allowing representation of a broad bandwidth of scales and levels of detail. On one hand this flexibility makes UML an ideal tool for such applications. On the other hand, first applications of the MTF have shown that it is a major challenge not to get lost in the wide range of possibilities offered by the language and in the level of detail chosen for the representation.

The further development of the MTF will address this challenge by continuing along the following route: the MTF will be used to develop normative guidelines for the design of adaptive management regimes in terms of both, structure and processes. Hypothesis on social learning and institutional change will be used as conceptual base for these diagrams. The MTF will be used to specify these hypotheses and to make them comparable to the structures actually found in the NeWater case studies. Key aspects of (social) learning like re-framing, re-definition of roles or change in access to information can be represented in the language provided by the MTF. The classes of the MTF class diagram will be used to describe structural requirements (e.g. existence of Roles, participation of certain Actors in certain Action situations) while Activity Diagrams will be developed to describe management workflows.

Such diagrams can then be compared to diagrams representing the situation in NeWater case studies. This comparison facilitates a two-way road of mutual exchange and learning: hypotheses can be tested and refined while at the same time weak points in the organization of a specific case-regime can be identified and highlighted. To better facilitate comparisons of concrete examples (for research and management purpose), a web-based database will be developed that incorporates all relevant aspects from the MTF. Current research refers to the development of performance indicators that can run into the database. The structured approach chosen provides also a sound base for the comparison of empirical results with model simulations.

The development and application of such an elaborate framework will allow analysing which kind of insights on the performance of adaptive and integrated water management regimes and processes of change to develop and implement them can be generalized. It will further allow to determine under which conditions certain assumptions hold.

Based on these activities insights will be used to find convincing arguments and examples and practical guidance for practitioners to engage in processes of change and to support them in adopting new management approaches into their daily praxis. To find those entry points is probably the most important and challenging task in order to bring concepts from research into practice.

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Groundwater protection in urban areas incorporating adaptive groundwater monitoring and management - Reconciliation of water engineering measures along rivers

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Abstract

This study investigates groundwater systems and their usage related to interference during flood events and water engineering activities along rivers in urban areas. In the context of river training for flood protection a multitude of river engineering measures are currently planned in Europe. Due to the experience gained from hazardous flood events in the last twenty years, most countries have acquired a more comprehensive view of rivers. This includes the consideration of processes at the catchment scale as well as ecological aspects. Multiple interests concerning groundwater use and protection challenge the intentions of water engineering and groundwater protection schemes that can only be solved by simultaneously considering all of the various interests.

Extending current protection concepts with process-based approaches that consider the interaction between surface and subsurface waters could enhance sustainable development of groundwater resources. Knowledge of the composition of groundwater quality, including an adequate consideration of variable hydrologic boundary conditions and fluctuations of loads in rivers, is therefore of great importance.

Previously, decisions concerning impacts on urban groundwater flow regimes were typically taken at the level of the individual project. However, it is the sum of all impacts, and their interaction in time and space, that has to be considered. To accomplish this, it is necessary to develop instruments that facilitate to adequately quantify the consequences of the cumulative effects of numerous decisions concerning the groundwater flow regime and groundwater quality. At the same time, system profiles must be identify together with the delineation of boundaries and specific targets that lead to defined overall goals for specific groundwater areas.

These instruments form part of groundwater management systems, comprising among others, the setup of groundwater observation systems, high resolution numerical groundwater modelling, and the development and evaluation of scenarios. Applying methods of scenario development facilitates the assessment of effects of water engineering measures on riverine groundwater and its usage for drinking water. The implementation of these process-based approaches is illustrated by selected examples in the agglomeration of the city of Basel, Switzerland.

Key words: urban groundwater, groundwater management, groundwater protection, water engineering, river restoration, protection concepts, scenario development

1 Introduction

Groundwater in urban areas is under increasing pressure: According to the European Environmental Agency about 70% of the European population lives in urban areas, which cover in total about 25% of the total territory (EEA 1999). With over 40% of the water supply of Western and Eastern Europe and the Mediterranean region coming from urban aquifers, efficient and cost-effective management tools for this resource are essential to maintain the quality of life and ensure that water is available for use by future generations (Eiswirth et al. 2003; Eiswirth et al. 2004). Sustainable use of soil and groundwater resources and protection and conservation of their quality are hence a key issue of European environmental policy and an enormous challenge for European research (Prokop 2003).

The challenge to develop and implement integrated and adaptive water management in urban areas requires innovative approaches that take into account the full complexity of the systems to be managed (Pahl-Wostl 2006). The basic principles of these approaches, including groundwater monitoring and modeling, are already established (Eiswirth et al. 2003;

Fatta et al. 2002; Pahl-Wostl et al. 2005). However, their application in urban planning processes has rarely been accomplished.

Although legal frameworks for groundwater protection as well as groundwater policy strategies have continuously been adjusted in the last decades, considerable damage to groundwater flow regimes still occurs. There are several reasons for this: (1) more attention is paid to purely technological problems concerning groundwater management rather than to issues dealing with sustainable groundwater use; (2) site selection for extraction wells has been undertaken under outdated legal frameworks and would not be approved today because more restrictive laws pertaining to groundwater, as well as changed perceptions and policy concerning groundwater, now apply; (3) realization of groundwater protection is still oriented mainly towards documentation of changes in the groundwater flow regime and groundwater quality, whilst less attention is paid to the prediction of future demands and to the management of groundwater resources; and (4) until now, the impacts of engineering measures on groundwater systems were only regarded as solitary limited impacts and examination of the interactions between them and other activities as well as changing boundary conditions were not attempted. The term **groundwater flow regime** includes all groundwater flow patterns, velocities and budgets for a defined region in a temporal context.

The purpose of this paper is to understand and predict the cumulative effects of the numerous single impacts on groundwater resources during flood protection and river restoration as well as to discuss strategies at the regional scale of the agglomeration of Basel. In a first step of the proposed conceptual approach, current profiles of groundwater systems are identified. Hereby, hydrogeological boundary conditions and already existing or possible impacts concerning the groundwater flow regime are considered. Following the identification of system profiles, specific targets are defined that lead to overall goals for particular groundwater areas and a desired long-term development of urban groundwater resources. As individual targets may interfere with qualitative aspects of groundwater production, techniques that facilitate the comparison of interference must be applied. This can be accomplished by the development of scenarios and the implementation of equivalence and acceptance criteria (Bedford 1996). The conceptual approach could be accomplished by the combination of instruments that facilitate to adequately identify the influences of the various single impacts on the complete system. Core elements of such adaptive groundwater management systems include groundwater monitoring networks and numerical groundwater models. Based on these elements, comparative studies as well as scenario development are focused on predefined development goals. Furthermore, both impacts that only affect the system in its immediate vicinity and impacts with influence on the system on a regional scale have to be investigated (Epting et al. 2006).

Selected examples show how the proposed conceptual approaches can be applied. These focus on river-groundwater-interaction, quality-oriented groundwater monitoring as well as adaptive groundwater management, and consist of the following case studies: (1) groundwater modeling and scenario development along the river Wiese, suggesting differentiated solutions when considering river restoration in urban areas; (2) groundwater modeling and scenario development along the river Birs suggesting extensive groundwater monitoring before, during and after water engineering measures; and (3) data analysis from these monitoring programs during flood events along the river Birs, including the results from transient groundwater modeling. Whereas the results from examples 1 and 3 are derived from already completed investigations, example 2 is an investigation that is currently underway (Fig. 1).

2 Settings

In Switzerland, about 40% of the drinking water is derived from gravelly aquifers in river valleys. Contemporary flood protection involves objectives on the catchment scale such as the mitigation of effects from hazardous flood events and to provide rivers the required space. At the same time it was recognized that groundwater and the aquifer are habitats of a natural biocenosis that interacts with surface waters. That is the reason why there are currently some efforts to reestablish some of the natural functions of riverine landscapes. A sustainable, integrated water management thus will play an important role on local as well as on regional and national levels.

The interaction of surface and subsurface waters are subject to continuous dynamics involving water budgets, water quality and flow patterns. Riverine groundwater consequently does not have a uniform and constant physical, chemical and biological signature. The composition can temporally vary significantly depending on the dynamics of particular systems and the location within the riverine groundwater. In addition, groundwater quality may be degraded due to sporadic impact loads from surface waters, i.e. caused by urban storm water drainage or by effluents from sewage treatment plants. Furthermore, in Swiss river floodplains an important part of groundwater recharge is formed by artificial recharge (infiltration) of river water.

When rivers are able to exert their natural dynamics, sediment erosion, transport and deposition processes are influenced. As a consequence, the variance of the riverbed permeability is increased temporarily, influencing infiltration rates and groundwater mixing ratios as well as residence times of groundwater of different provenance. A detailed, site-specific understanding, including the consideration of various hydrological boundary conditions as well as careful and comprehensive evaluations of riverine groundwater and its usage, is the basic requirement for water engineering measures along rivers.

Our concept for adaptive groundwater management during water engineering measures is illustrated by selected examples from two rivers that are located in important groundwater production sites in the context of park-like environments in the urban agglomeration of Basel (Fig. 1). The first example is from the floodplain of the river Wiese near the confluence of the river Rhine and covers an area of about 6 km^2. The second and third examples are from the river Birs in the lower Birs valley, and cover an area of about 12 km^2, bounded by tectonically influenced higher ground to the east and to the west. In both areas the drinking water supply competes with other interests and demands such as river training, flood control, recreation and change of land-use.

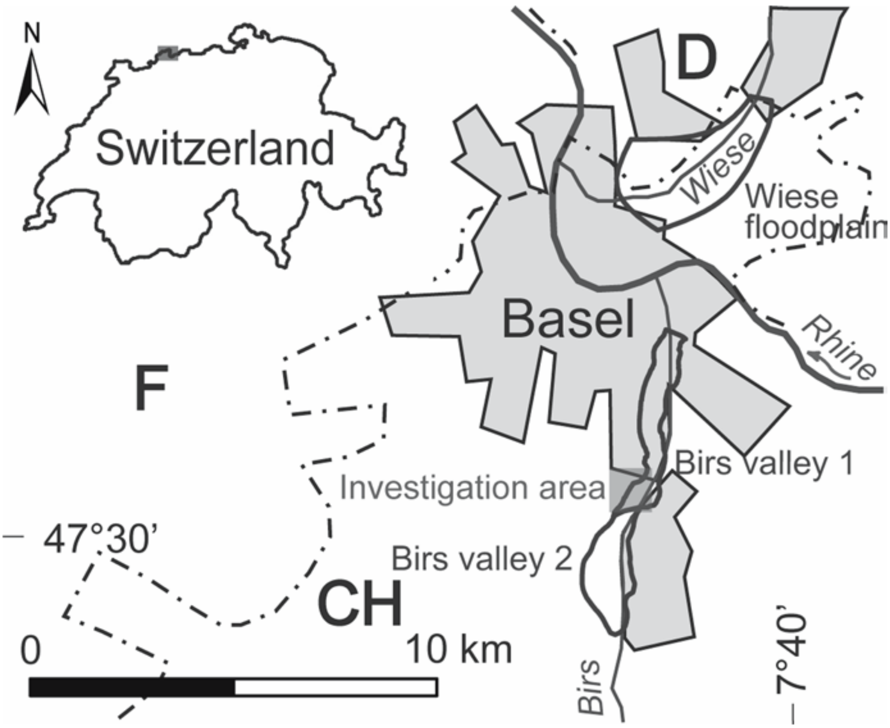

Fig. 1 Investigation areas in the agglomeration of Basel.

3 Concepts and methodologies

3.1 Concepts

3.1.1 Resource Protection

The principle of resource protection is based on prevention and reduction, respectively, of contaminant release into the environment and on the conservation of groundwater resources. Protection goals involve the preservation of the physical properties of the aquifer, the aquiclude, the overlying stratum and of the natural hydrodynamics as well as the conservation of the natural chemical composition and biocenosis of groundwater. Criteria for the dimensioning of groundwater protection are among others the formal separation of surface and subsurface water systems, the protection properties of the overlying stratum as well as the groundwater residence times and the minimum distance in the direction of inflow. In accordance with Regli and Huggenberger (2007), important factors or processes of river-groundwater-interaction influencing exploitable aquifers in urban environments are:

(1) Formal separation of surface and subsurface water systems

In the 19th and far into the 20th century the canalization of rivers progressively limited the transversal and vertical interconnectedness of rivers with their floodplains and groundwater together with a reduction of the thickness of the hyporheic zone. Furthermore, the longitudinal connectivity (river continuum) between the various river reaches and the main river was restricted. In many places this lead to an entire loss of the natural dynamics of river systems. Canalization measures lead to uniform flow patterns and increased peak floods. Bank and bed protection prevented the erosion of sediments and, therefore, relocation within the active channel-belt. Mostly this has lead to a lack of bed load and a clogging of the riverbed and the interstitial. As a result, river-groundwater-interactions are reduced along with a decreased filtration of surface water in the pore space of gravel beds (Kozel 2005; Regli and Huggenberger 2006).

(2) Protection properties of the overlying stratum (protective soil cover)

In the context of river-groundwater-interaction the basic concept of protection capacity of the soil cover is not valid. In riverbeds the soil cover is missing and the infiltration rates can show strong spatial and temporal changes according to the leakage, thickness and permeability of the riverbed, the structure and permeability of the river bank and the relationship between flow depth and groundwater table. In addition, in the presented examples river-groundwater-interaction can be reduced or enhanced by riverine groundwater extraction or artificial recharge.

(3) Groundwater residence times

In the past, groundwater extraction wells were often constructed very close to rivers. The reason for the site selection near river banks were high conductivities and storage properties that were favorable for drinking water production. Nowadays, the proximity to the rivers is disadvantageous, because groundwater residence times and filtration capacities are often below or close to threshold values. During flood events a part of the infiltrated river water stays only a few days in the subsurface before it enters the extraction well (Hoehn 2005).

(4) Groundwater mixing ratios

Due to the different infiltration rates, the mixing ratios of riverine groundwater are controlled by dynamic changes. The consideration of transient infiltration and the resulting changes in groundwater mixing ratios during different hydrological conditions enhance the understanding of the interaction processes between surface and subsurface water systems. Furthermore, they are a necessary basis for estimating the risk of pollution for riverine groundwater and its usage, resulting in site-specific, adequate protection measures and adapted groundwater management strategies for extraction wells.

(5) Filter capacity between river and extraction well

The elimination of particles in the subsurface passage due to filtration, sorption and biochemical processes is the determining factor for the microbial quality of groundwater. These processes mainly occur in the soil and subordinate in the non-saturated and saturated zone (BUWAL 2004).

3.1.2 Determination of groundwater system profiles

In the first step of the proposed conceptual approach (Fig. 2), the investigation area has to be delineated, encompassing an inventory of all relevant hydrogeological boundaries characterizing current regional groundwater flow regimes as well as all possible impacts to it. In the next step, the hydrogeological boundaries and impacts have to be identified that may be subject to changes during water engineering measures at specified times. These groundwater system states can be described by profiles, comprising the identification and description of initial profiles, as well as the definition of desirable future profiles. Together with the identification of groundwater system profiles, specific targets can be defined that lead to overall goals for specific groundwater areas and a desired long-term development of urban groundwater resources. Whereas goals focus on a sustainable system development after water engineering measures, targets also comprise groundwater protection issues during the development of projects (Epting et al. 2006).

In order to achieve qualitative and quantitative goals for groundwater systems the present profiles of systems have to be recognized and future profiles have to be defined. Targets to reach these goals could comprise: (1) minimization of changes to the groundwater flow regime during water engineering measures, including the maintenance of (a) position of groundwater divides, (b) longitudinal and lateral extent of capture zones, (c) groundwater budgets for selected cross-sections and (d) groundwater flow fields and velocities; (2) finding technical solutions guaranteeing groundwater quality standards; (3) safeguarding groundwater quality issues during water engineering measures; and (4) ensuring groundwater supply (quantity and quality).

As the individual targets may interfere with each other they may not necessarily lead to a desired overall goal. Therefore, techniques that facilitate the comparison of interferences can be applied. This can be accomplished by the development of scenarios and the implementation of equivalence and acceptance criteria (Bedford 1996). They allow assessment of the technical benefits of the different monitoring or optimization concepts, the development of the groundwater flow regime and the improvement of overall groundwater quality.

Formulated goals for a sustainable development of groundwater systems guide mitigation strategies and refer to defined standards, i.e. natural composition of groundwater or quality standards defined by existing regulations. They also establish a standard against which individual decisions are made. Goals with respect to the groundwater flow regime should be based on knowledge of the physical properties governing the system. General goals could be, e.g.: (1) minimization of river water infiltration during high flows; (2) enhancement of the interaction between surface and subsurface waters; (3) maintenance of groundwater flow regimes; (4) quality-oriented groundwater management; (5) consideration of future groundwater use; and (6) long-term improvement of groundwater quality.

3.2 Methodologies

To identify groundwater system profiles in urban hydrogeological cycles, methodologies to quantify and control these profiles must be developed and applied. This can be achieved by the setup of groundwater management systems that involve following elements among others: (1) groundwater observation systems and (2) setup of numerical groundwater models combined with scenario development. Besides a simple documentation of changes in groundwater quantity and quality, the goal of the management system is to predict undesired developments.

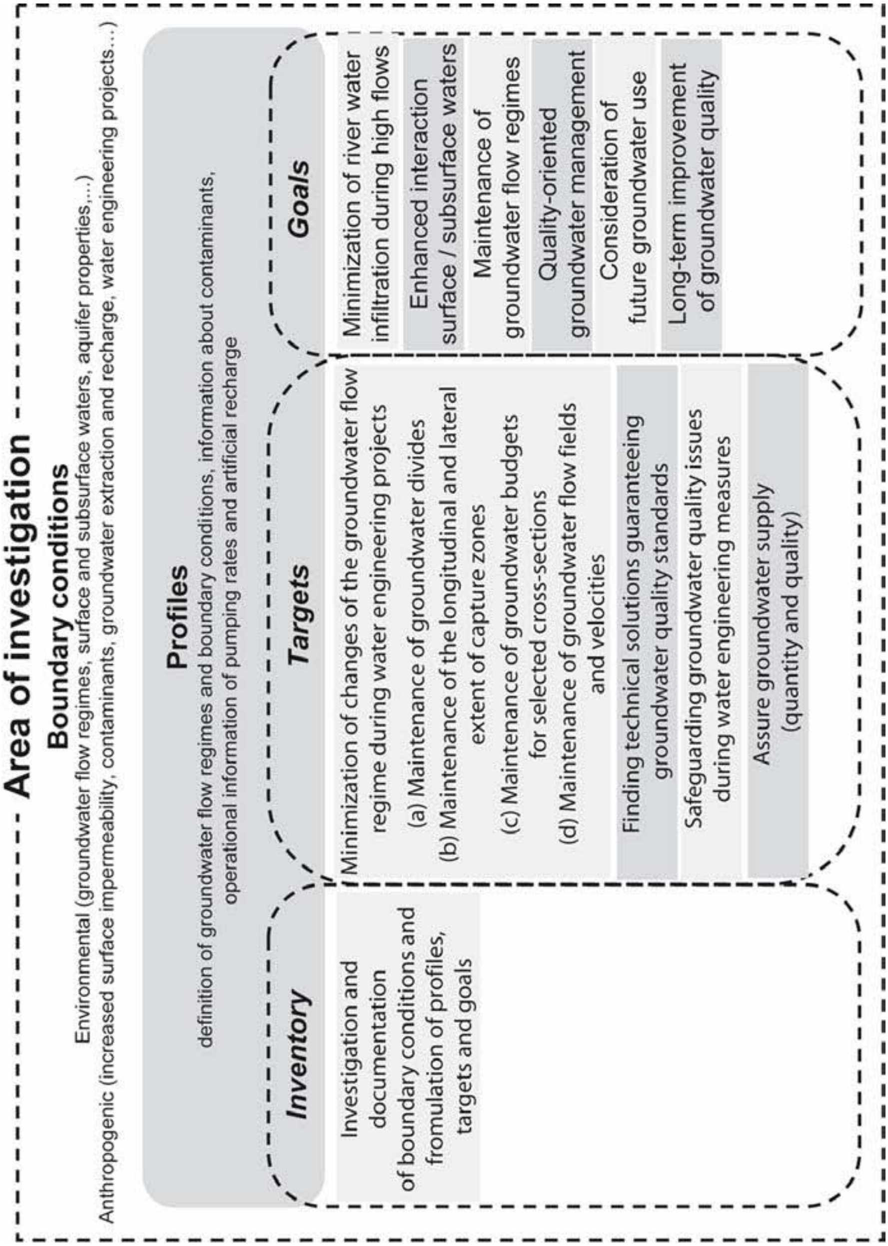

Fig. 2 Conceptual approach.

3.2.1 Groundwater modeling

For the illustration of effects of water engineering measures on groundwater flow regimes as well as for the quality-assessments of drinking water supplies, the use of numerical simulation models is suited to several project phases. Groundwater models are valuable tools, to simultaneously include hydrological and hydrogeological as well as operational data and to assess the related groundwater flow regimes with respect to groundwater extraction for drinking water. They facilitate the evaluation of system sensitivities, allowing the investigation of certain parameters and boundary conditions. The combination of groundwater models with hydrodynamic river models, when considering transient problem solving in particular, can be very useful and facilitates the development and application of different scenario techniques.

3.2.2 Scenario development

By means of scenario development, possible impacts of water engineering measures along rivers and from flood events on riverine groundwater and its usage can be acquired and corresponding endangerment and risk assessments can be conducted. Furthermore, these scenarios have to include the relevant operation-states of the extraction wells. Scenarios represent possible real events and event sequences and serve to acquire and illustrate a representative selection of possible dispositions and process sequences. Scenario development also involves the simplification and restriction of essential boundary conditions that affect the system (Regli and Huggenberger 2007).

Scenarios can be assigned to four groups: (1) simulation and optimization of groundwater management strategies; (2) comparison of water engineering measures, with respect to feasibility and impact on water systems during construction and after completion; (3) investigation of changing hydrogeological constraints; and (4) worst case scenarios.

4 Examples

A combination of groundwater modeling and scenario development is exemplified by case studies in the agglomeration of Basel (Fig. 1). To define the specific profiles of groundwater systems high-resolution groundwater models are applied that have been calibrated with time-series of groundwater head data and river stages as well as extraction and recharge rates. In the presented examples, the strongly transient character of river-groundwater-interactions in urban areas is illustrated. Scenario techniques have been developed to assess consequences of decisions and to optimize particular measures such as channel widening and their influence on groundwater quality.

4.1 Wiese floodplain

The first example illustrates the application of scenario techniques for evaluating solutions for river restoration, with emphasis on conflicts with groundwater protection issues.

Before entering the river Rhine, the river Wiese flows through its former floodplain that widens towards the river Rhine. Whereas the position of the active channel migrated considerably at earlier times, the river bank has been fixed for the last 150 years. Due to the vicinity to major urban areas (Basel, Lörrach and Weil) the floodplain area of ca. 700 ha is primarily used as groundwater production area. Plans to reconnect the headwaters with the river Rhine and to provide a habitat for salmon were the main reason for an ongoing controversy on river restoration versus groundwater protection. This was the starting point for the setup of a groundwater monitoring system together with a high resolution groundwater model for the whole area (details are given in Huggenberger et al. 2006). Based on this model the current profile of the groundwater system was determined, including the present risk of river-groundwater-interaction. Based on the modeling tool different scenarios that also allowed increasing the degree of freedom for river restoration measures could be calculated. Scenarios could be grouped into conceptual-, technical- and hydraulical-oriented scenarios (Regli et al. 2004).

Examples of conceptual-oriented scenarios are: (1) investigation, planning and dimensioning of groundwater extraction areas; (2) enhancement of surface water quality; (3) optimization of urban drainage, e.g. sewage drainage into larger receiving streams; (4) reduction of water consumption, which would allow some of the extraction wells to be abandoned; and (5) planning and investigating alternative well locations.

Examples of hydraulic measures and their influence on the river-groundwater-interaction are illustrated in Figure 3 (above). By adequate arrangement and operation of groundwater recharge areas, hydraulic barriers can be generated. Thereby, groundwater recharge areas would function as temporarily wetted floodplain surfaces. However, minimum groundwater residence times must be ensured according to defined threshold values.
Examples of technical measures and their influence on the river-groundwater-interaction are illustrated in Figure 3 (below). The insertion

of sealing walls in the vicinity of riverine groundwater wells result in vertical barriers that prevent the infiltration of river water into the aquifer. A more reasonable ecological alternative could be technical solutions such as geo-textiles that decrease infiltration rates as well as amounts of fines and reduce seepage velocities.

Calculated scenarios include the consideration of several minor creeks with adapted infiltration capacities, the relocation of extraction wells and groundwater recharge areas (Fig. 4). For the evaluation of the various scenarios the capture zones of groundwater extraction wells were evaluated and compared. For the consideration of conceptual-oriented scenarios several riverine wells were abandoned and new wells at locations more distant to the river were introduced. This allowed the influence of inflow from infiltrated river water to be reduced.

Figure 4a shows the profile of the groundwater system in its initial state. Figure 4b illustrates the hydraulical-oriented scenario including an alternating operation of possible groundwater recharge areas along the river Wiese. Optimization of capture zones can be achieved by alternative arrangement and operation of groundwater recharge areas and the location of extraction wells, taking into consideration the river hydrograph. Figures 4c&d show the capture zones of the extraction wells, when considering technical-oriented scenarios with vertical and horizontal barriers. The conceptual-oriented scenarios shown in Figure 4e illustrate the influence of reducing and relocating groundwater extraction wells.

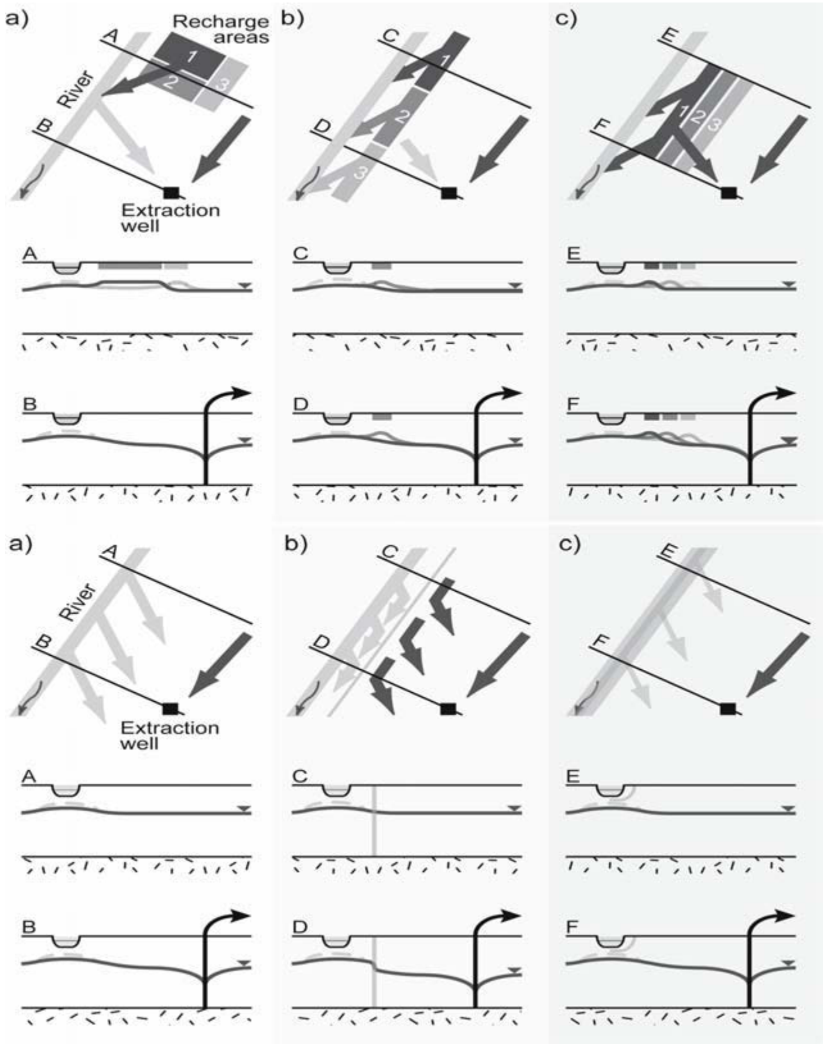

Fig. 3 Above: Hydraulic measures and their influence on river-groundwater-interaction: a) Current status in the Wiese floodplain; b) groundwater recharge areas parallel to the river; c) several groundwater recharge areas parallel to the river. Numbers on the recharge fields indicate alternating time periods of recharge operation.

Below: Technical measures and their influence on river-groundwater-interaction: a) Current status in the Wiese floodplain; b) vertical barriers parallel to the river; c) horizontal barriers of single river segments

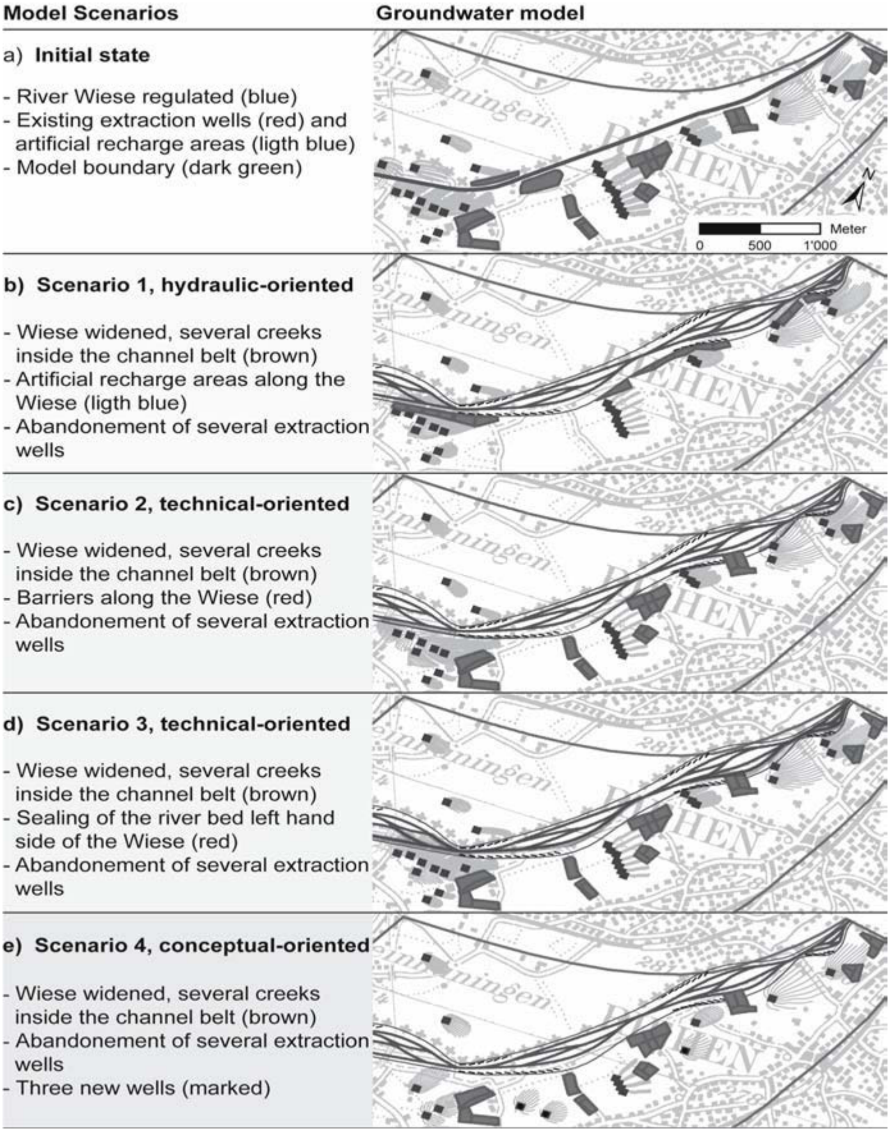

Fig. 4 Model scenarios and capture zones (yellow) of groundwater extraction wells in the Wiese floodplain (10-day-period including a flood event).

4.2 Birs valley 1

The second example illustrates current profiles of a groundwater system in an urban environment that is influenced by artificial groundwater recharge and river-groundwater-interactions as well as agricultural and industrial activities. Extensive analytical groundwater monitoring programs during and after a water engineering project allowed the definition of particular profiles of the groundwater system. This was accomplished by the setup of a transient groundwater model and the evaluation of various scenarios in the Birs valley (Münchenstein, Switzerland; Fig. 5, see Fig. 1 for location). The technical measures focus on flood protection and the protection of the river bank (erosion) as well as on an ecological reassessment of the river Birs. Therefore, a 250 m section of the river board will be restored. Additionally, a groundwater extraction well is located within 50 m of the river. However, the proposed changes should not degrade the quality of extracted groundwater. The groundwater models allowed to define critical river reaches and capture zones of wells during different hydraulic conditions. Based on this information construction measures are proposed that reduce, or at least do not increase, the infiltration of river water into groundwater. A monitoring concept is proposed, that allows detection of changes to the composition of raw water quality in the extraction well during the construction phase. The concept comprises continuous groundwater monitoring in the extraction well by incorporating measuring sensors (electric conductivity, turbidity/particles, UV-extinction, temperature) that should allow detection of the signature of infiltrated river water that only remains a few days in the subsurface. Furthermore, the monitoring program includes extensive analysis of the raw water for selected microbiological contaminations before, during and after the water engineering measures.

For groundwater modelling and the developed scenarios, different hydrological and operational boundary conditions are considered. Based on average hydrological boundary conditions, average extraction rates (10 l/s) and average river infiltration rates, several boundary conditions were changed to evaluate the influences on the capture zone of the groundwater extraction well (Fig. 5): (1) For overall average boundary conditions, the inflow to the extraction well is mainly from the agricultural area to the southwest. This is supported by groundwater quality data (high nitrate and microbiological content). (2) When elevating the groundwater extraction rates, the capture zone is widened and includes parts of the river Birs. This might reduce the nitrate concentration but elevates the risk of microbiological impacts. (3) When considering low hydrological boundary conditions, less groundwater is derived from the agricultural area to the southwest whilst more comes from southern areas. This should not change groundwater quality significantly. (4) When elevating the riverbed conductance the capture zone of the groundwater extraction well moves away from the river. Considering average hydrological and operational boundary conditions as well as an elevated riverbed conductance, more groundwater exfiltrates into the river (and no river water infiltrates into the groundwater). Thus no effect on the groundwater quality is expected. (5) During flood events the extracted groundwater is derived from short passages to the river. Thereby significant microbiological vitiations can be expected.

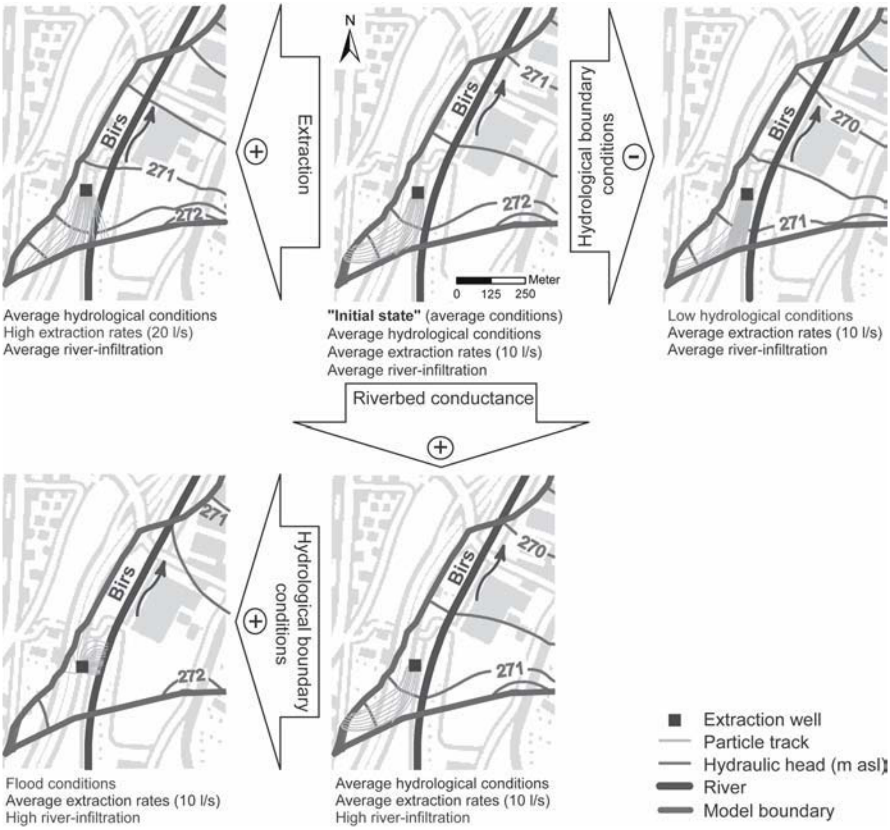

Fig. 5 Groundwater modeling and scenario development in the Birs valley (see Fig. 1 for location; + increase, - decrease).

4.3 Birs valley 2

The third example illustrates the transient character of river water infiltration (Reinach, Switzerland; details are given in Huggenberger et al. 2006). Figure 6 shows the flow stages at average discharge conditions of the river Birs (Situation A) and during a flood event (Situation B). The effect of the artificial groundwater recharge in the southern part of the model area is distinct. During flood events this groundwater recharge is stopped. Although the hydraulic head distribution is comparable for both discharge situations, the development of the groundwater levels in observation wells 24J20 and 24J22 is more complex (Fig. 7). Preceding the flood event, groundwater levels are beneath the river stage (- 0.4 m) and afterwards above the river stage (+ 0.6 m). During the flood event the potential difference between the river stage and the groundwater level is rapidly increased. In addition, the permeability of the riverbed has changed. Thereby, the infiltration rate increases and the groundwater levels rise.

Figure 8 shows the comparison of measured and calculated groundwater levels in observation wells 24J20 and 24J22. Until the beginning of the flood event the progression is in good accordance. However, during and after the flood event the calculated groundwater levels are considerably beneath the measured ones. In order to consider an increase in river infiltration during and after flood events, the leakage-coefficient of the riverbed must be treated as a transient parameter in groundwater models.

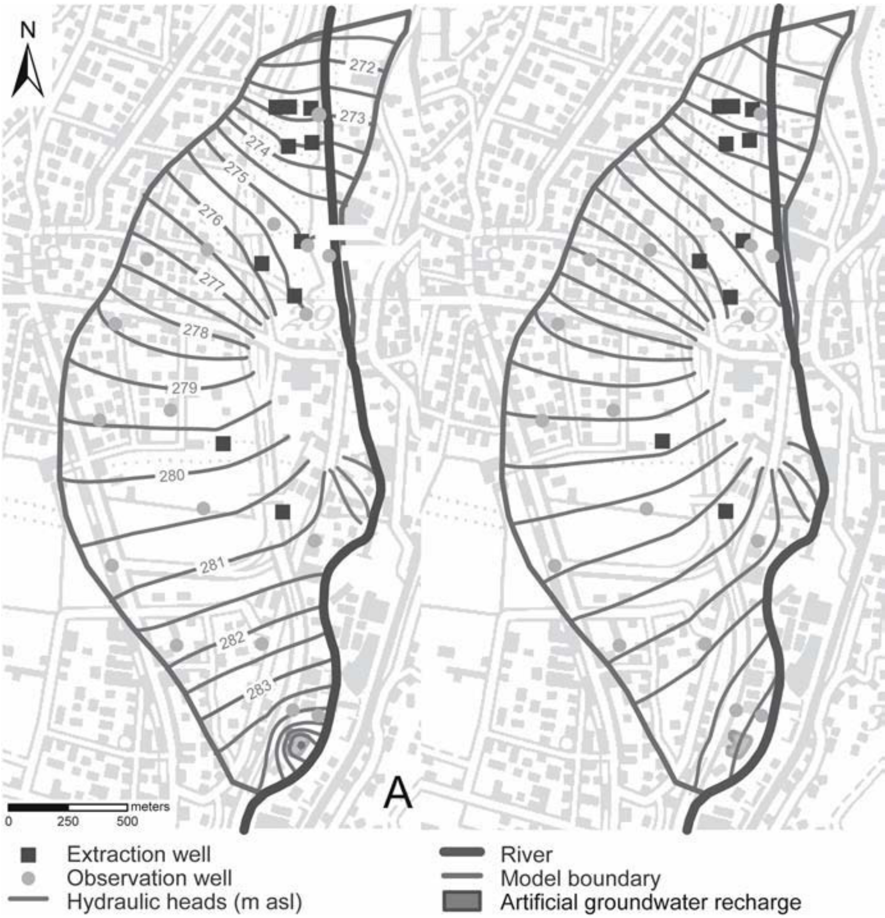

Fig. 6 Flow stages in the lower Birs valley (see Fig. 1 for location). Situation A: average river discharge, 24 October 2004, 10 m^3/s; Situation B: flood event, 27 October 2004, 148 m^3/s.

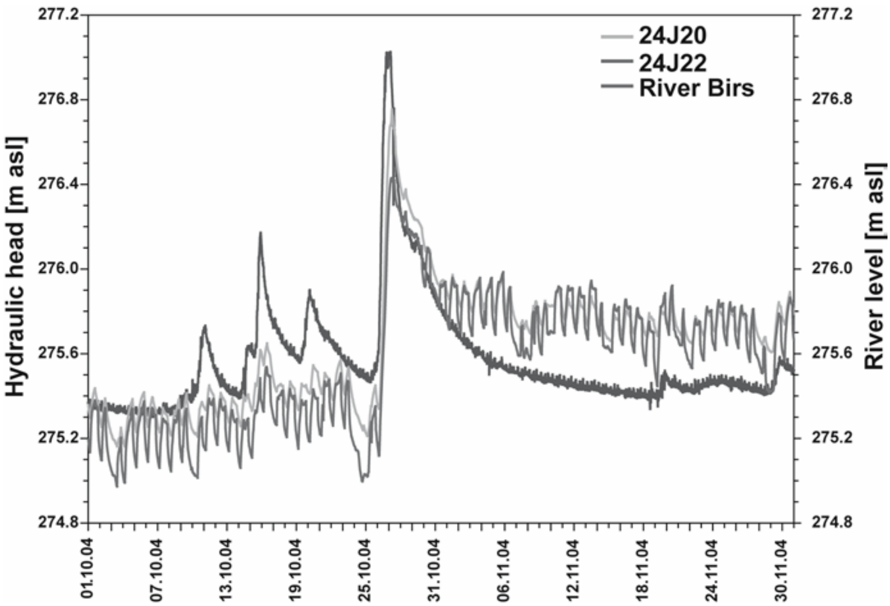

Fig. 7 Groundwater levels in riverine observation wells 24J20 and 24J22 (location of observation wells see Fig. 6) compared with the river stage in the Birs (BAFU river gauge 2106).

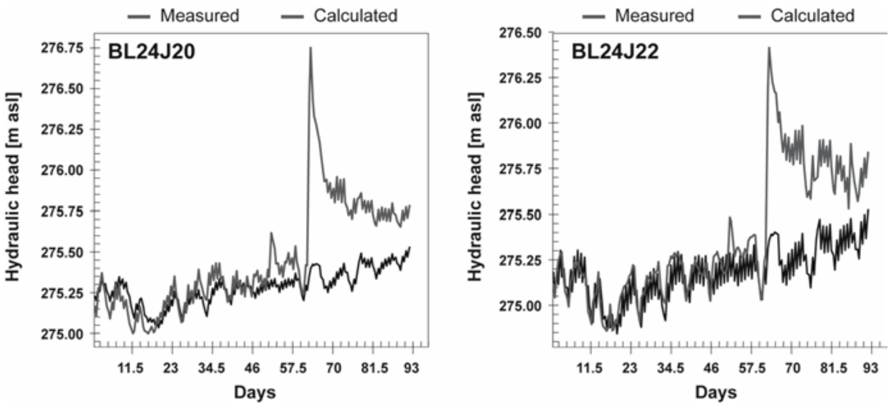

Fig. 8 Comparison of measured and calculated groundwater levels in observation wells 24J20 and 24J22 (location of observation wells see Fig. 6).

5 Discussion

Many engineering projects along rivers that could affect riverine groundwater production lack efficient groundwater protection concepts. Also it has to be accepted that, in particular cases, changes in river structures can not be completed without endangering groundwater quality.

The multitude of strongly transient processes makes risk assessment for particular well locations difficult. A clear definition of the present groundwater system profile, including its transient character, would help to define realistic goals and targets for site specific conditions. Considering the bandwidth of possible solutions, from the abandonment of riverine groundwater wells to the foregoing of corresponding interferences to water systems, there should be options of adequate measures (Hoehn 2005). In some cases the goal is to work out options that provide adequate space for groundwater usage as well as for river systems. These challenges increase the requirements for investigation and assessment methods.

A prerequisite for sustainable groundwater protection is the knowledge of the development of the groundwater quality at a specific location. Results from site-specific hydrogeological investigations of extraction wells and their operation are the basis for the evaluation of possible interferences. This includes impacts of water engineering measures on groundwater flow regimes and its usage, and also facilitates flood protection and land use authorities to take the various interests into account and make coordinated decisions.

Effective and efficient groundwater protection during flood events and water engineering measures along rivers demands detailed hydrological and geological knowledge as well as the willingness to suggest dynamic changes of hydrological conditions and load variations in rivers. By means of planning, organizational and technical measures the options for water engineering measures along rivers increase. If, in a specific case, both goals (efficient groundwater protection and water engineering measures) are not achievable, one goal has to be favored.

5.1 Holistic perspective

In general, decisions to compensate for negative impacts are often made at the level of the individual project. Mitigation in an urban river-groundwater-interaction context should primarily shift the scale used to establish regulatory criteria from the individual project to a broader aquifer scale. The effect of mitigation policy on the groundwater flow regime in urban areas depends in part on how the regulatory community defines "equivalence." The basic premise of compensatory mitigation is that measures taken compensate for, or at least reduce, the effects of local damage. However, cumulative effects of water engineering measures could have an influence at considerable distances from the specific impact location. This required the development of instruments that facilitate to adequately quantify the consequences of cumulative effects arising from the numerous decisions concerning the groundwater flow regime and groundwater quality (Epting et al. 2006).

An enhanced reconciliation of the various usage demands with groundwater protection issues includes, along with aspects concerning water quality and quantity, the restoration of rivers in their function as species-rich ecosystems that form landscapes and interlink different habitats. Water engineering measures along rivers have to be accomplished to mitigate the impact of hazardous flood events and the conservation and recovery of natural functions of water systems. Therefore, such projects have to incorporate the interests of qualitative, quantitative and ecological groundwater protection issues. The development goals for natural or near-natural rivers (sufficient space for rivers, sufficient discharge and reasonable water quality; BUWAL 2004) thus have to be coordinated with those of groundwater protection. Furthermore, it must be considered that water engineering measures along rivers not only locally affect the groundwater system, but can also influence the groundwater flow regime, groundwater quality and the ecology downstream. The spatial context is hence not only restricted to the vicinity of planned impacts on water systems, but can often concern system dynamics covering large areas of the floodplain (Huggenberger et al. 2006).

5.2 Endangerment and risk assessment

A schematic illustration of the quality of infiltrated river water (e.g. a substance concentration in the river) against the filter performance in the region between the riverbed/foreland and the extraction well allows the designation of different areas (Fig. 9; Regli and Huggenberger 2007). The illustration facilitates the formulation of requirements for water engineering measures along rivers. The separation of these areas is defined by a line, marking the threshold value of a substance (dotted line, exceeding a threshold value or substance concentration). The choice of one or several parameters (e.g. E.coli), that are considered for safety evaluations of drinking water supplies, should be accomplished in accordance to problematic substances in the river or in the catchment areas. The filter performance, defined as the ratio of the substance concentration in the extracted groundwater to that in the infiltrated river water or river water, is particularly dependent on the load of the river water, the structural properties of the riverbed and the aquifer (infiltration rates, groundwater mixing ratios, residence times) and groundwater flow patterns, as well as the properties of substances and of the groundwater.

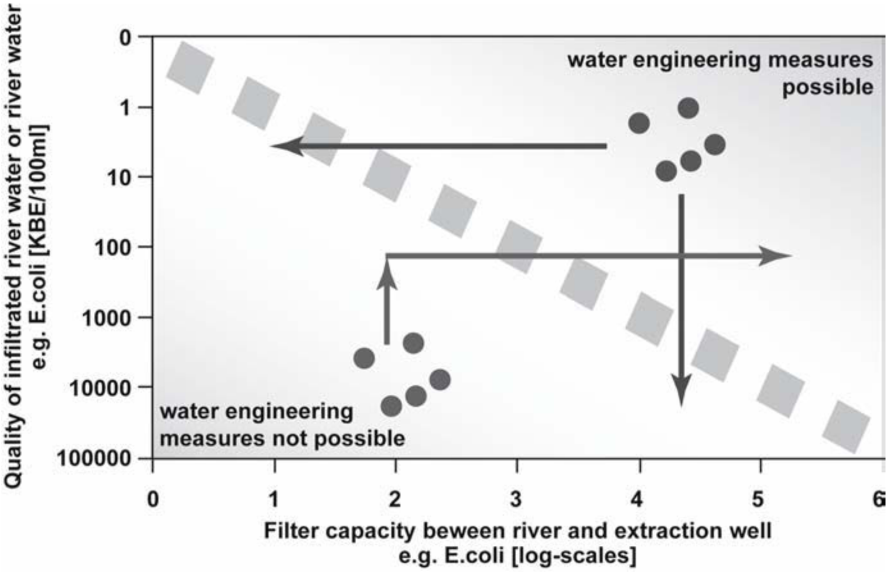

Fig. 9 Conceptual diagram for the evaluation of water engineering measures along rivers. Dotted line: definition of target size, e.g. adherence of threshold values in the extraction well.

Due to strong heterogeneities of aquifers and the transient character of hydraulic conditions during flood events the attenuation of specific compounds or particles can vary considerably. Figure 9 illustrates which measures of water quality might, at least temporarily, be increased (blue horizontal arrow). To achieve quality objectives for drinking water supplies, falling below the line that marks the threshold value for a specific substance in the drinking water should be avoided. When the quality of infiltrated river water or river water, is degraded (impact loads during flood events) the threshold line could also be undercut (blue vertical arrow). If for a riverine extraction well, a scatter plot can be characterized that lies beneath the threshold line (quality objectives for drinking water can not be achieved), the quality of the infiltrated river water or river water, and/or the filter performance have to be improved (red arrows). This would result in a better chance and higher degree of freedom to facilitate water engineering measures. Furthermore, it must be considered that when improving the ecological state of rivers, the filter performance of the riverbed and the interstitial is also enhanced. The quantification of the achieved quality improvements, however, is difficult. In river segments with permanent exfiltration, water engineering measures are unproblematic.

The challenge is to define protection goals with a basic reflection on possible risks. Accordingly, impacts from water engineering measures and flood events for riverine groundwater usage can effectively and efficiently be reduced to an acceptable degree. For risk assessment of water engineering measures and forthcoming flood events the magnitude of floods must be defined that restrict the operation of extraction wells (e.g. frequency of events or discharge quantities; maximum substance concentrations in rivers; duration of accepted usage restrictions).

The consideration of the elimination or attenuation capacity between river and extraction well and groundwater mixing ratios facilitates an estimation of the endangerment for riverine extraction wells caused by planned water engineering measures and flood events. The risk results from the frequencies of corresponding flood events and the involved extent of damage to drinking water supplies.

5.3 Possible measures

To increase the degree of freedom for water engineering measures along rivers, planning, organizational and technical measures are possible and should be considered during the early phase of planning and when evaluating different options. Thereby, the discussion of drinking water consumption should be focused on the regional level (separation of groundwater production concerning drinking and processing water for industrial use). Measures on the catchment scale include, e.g. the optimization of settlement drainage, target an improved river water quality. Considering organizational and technical arrangements on extraction wells, such as updated concessions, linked systems, adaptation of groundwater extractions in relation to discharge combined with load variations (impact loads) or the shutdown of extraction wells (adaptive groundwater management), UV-installations, etc., the smallest irreversible constructional measures are necessary. Possible technical measures are, e.g., the adaptation of the planned interferences in the river, the relocation of riverine extraction wells (enlargement of the filter passage and consequently the filter performance), the injection of groundwater or the installation of geo-textiles (hydraulic and technical barriers, changing the groundwater flow regime). All these measures require elaborate reconcilement among the various authorities (Regli and Huggenberger 2007).

6 Conclusions

The changes in interactions between surface and subsurface water systems, when applying engineering measures along rivers often cannot be adequately evaluated based on existing groundwater protection concepts. Thus the protection concepts could be extended by process-based approaches. These approaches should involve a comprehensive management on the catchment scale, i.e. surface and subsurface waters, wetlands and terrestrial ecosystems as well as the consideration of issues concerning water quality, water budgets and the structure of aquatic systems. Together with the setup of extensive groundwater monitoring systems, field experiments and groundwater models that allow the definition of specific groundwater system profiles and scenario techniques, the dynamics of capture zones to groundwater extraction wells should be optimized, thereby considering changing hydrological and operational boundary conditions.

Furthermore, a holistic perspective is necessary to consider all solitary impacts on the regional groundwater flow regime simultaneously, recognizing that impacts should not only be taken as locally limited but could have effects on the regional scale. Therefore, all stresses on the system, such as groundwater extractions, injections and recharge as well as water engineering measures and their impacts on the groundwater flow regime have to be taken into account. The definition of goals could help to evaluate the impact of individual measures on a larger scale of the groundwater system.

A systematic consideration of groundwater in urban development and the implementation of groundwater management systems can serve as a decision tool for project planners and official departments. This allows ongoing adaptation dealing not only with current issues but also with future demands. One step towards a better mutual understanding among the various involved authorities is the foundation of the river-groundwater-interaction working group within the Swiss Hydrogeological Society in the year 2004.

The knowledge of local geological and hydrological conditions as well as the understanding of the groundwater flow regime can considerably contribute to solutions for regional problems (Huggenberger 1999). However, many innovative technologies proposed for groundwater management are confronted with enormous implementation barriers. Confidence in their success is often low, and conventional but more expensive technologies are preferred (Prokop 2003).

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Adaptability of International River Basin Regimes: Linkage Problems in the Rhine

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Abstract

The literature addressing international river basin regimes has largely focused on either local institutional arrangements or international institutional arrangements. The focus has been primarily on the linkages between the national layer and the international layer but not between local and international layer. This is consistent with the dominant international relations theories that focus on inter-state relations. Consequently, there is almost no systematic study of how actors at the local layer link to international layer and vice versa. In the Rhine River Basins, both practitioners and scholars have assessed the crucial role of local actors and industries in governance of international river basin regime. However, these assessments fall short of addressing how local actors are crucial and how they are linked to the international layer. This paper investigates how institutional drivers at the local layers link to the international layer and how the linkages characterize vulnerability and adaptability of international river basin regimes.

Key words: institutional interplay, vulnerability, adaptability, local-international linkages, the Mekong, and the Rhine.

1 Introduction

The literature addressing international river basin regimes has largely focused on either local institutional arrangements or international institutional arrangements without paying much attention to dynamics of institutional linkages between these two layers. The focus has been primarily on the linkages between national and international layers or local and national layers. The institutional dynamics of local institutions in relation to international institutions have not been paid much attention in the literature on international river basin governance although there are studies focusing on dimensions of conflicts and cooperation among riparian states over international river basins (LeMarquand, 1977, Bernauer and Moser, 1996, Browder, 1998, Mason, 2003). This is consistent with the dominant international relations theories that focus on linkages between national and international layers under the assumption that member states control institutional arrangements above and below national layers. Consequently, there is almost no systematic study of how institutional drivers at the local layer link to international layers and vice versa. Perhaps this linkage problem is not only isolated to river basin governance but also apparent in global environmental governance issues and international affairs in general (Fonseca, 1999; Auer, 2000).

Vulnerability and adaptability of international river basin regimes are closely associated with institutional dynamics at multiple layers of these regimes ranging from local to international layers. On the vulnerability and adaptability studies of international river basins, the attention has been paid more on the ecological dimensions of biogeophysical systems of river basins such as flood control or climate change related issues (IUCN and START, 2003; Aerts and Droogers, 2004).

This paper investigates how institutions at the local layers link to the international layer and how these linkages characterize the vulnerability and adaptability of international Rhine River Basin regime. In so doing, the paper analyze the cases of 1976 Chemical Convention and the 1976 Chloride Convention of the Rhine River Basin regime. Three questions guide this assessment. First, how did the current state of institutional arrangements evolve at the international layer in Rhine River Basins? Second, what are the environmental governance issues at the local layer that divulge linkage problems between two layers? Third, how might we assess vulnerability and adaptability of international river basin regimes? I first present institutional development and evolutions in the Rhine. Second, I discuss briefly the analytical framework applied to organize investigation of institutional drivers and environmental issues in the Rhine. Institutional drivers are defined in this paper as issues, interests, and actors who compositely shape emergence and transformation of rules. Third, I discuss institutional drivers at the local layer, which amplified linkage problems of the Rhine River Basin regime. Finally, I argue that identifying the vulnerability and adaptability of international river basin regimes have to start with the investigation of linkages of issues, interests, and actors between local and international layers because the outcomes of these regimes is mainly dependent on local institutions.

2 Institutional Development in the Rhine River Basin

Looking at the historical evolution of the relationship between the ecosystem of the Rhine and human inhabitants, the end of World War II marked the beginning of a new chapter in the Rhine's history. On July 11, 1950, with the initiatives from the Netherlands, the riparian countries of the Rhine downstream of Lake Constance—France, Germany, the Netherlands, Switzerland, and Luxembourg—joined forces by establishing the International Commission for the Protection of the Rhine on an informal basis. As the name of ICPR conveys, the main issue that pushed riparian states to engage in cooperation was the issue of water pollution in the Rhine.

During the first decade after the founding of ICPR, it served as a common forum for discussing questions and seeking solutions relating to pollution in the Rhine. However, in 1963, the ICPR parties concluded that the existing tools for cooperation among governments should be strengthened and, therefore, they formalized ICPR's existence by signing the Convention on the Protection of the Rhine against Pollution on April 29, 1963, widely known as the Bern Convention. The Bern Convention formalized ICPR's work by establishing a permanent joint secretariat to be based at Koblenz, Germany (de Villeneuve, 1996, p. 444; Garritsen et al., 2000, p. 40). The Bern Convention became the legal basis for future international cooperation among the Rhine riparian states, and ICPR was entrusted with the following tasks: (1) studying the nature, volume, and origins of Rhine pollution; (2) proposing to the governments of the parties appropriate measures to control pollution; (3) preparing further agreements between the government of contracting parties; (4) undertaking any other task jointly entrusted to it by the governments of contracting parties; and (5) drawing up a yearly report on its activities.

The riparian states worked under the 1963 Bern Convention to determine what chemicals were causing the Rhine's pollution. After the data collection stage, ICPR moved further to solidify commitments among riparian states. It took more than ten years, from 1963 to 1976, to reach some level of agreement on how to proceed with the cleanup of the Rhine. The first Rhine Ministers' conference on the pollution of the Rhine was held in 1972 to recommend further actions to reduce pollutant chemicals. In 1976, the member states of ICPR concluded two important conventions: (1) the Convention for the Protection of the Rhine against Chemical Pollution; and (2) the Convention for the Protection of the Rhine against Pollution from Chlorides. These two conventions were the first detailed provisions as to what to do about reducing pollutant chemicals. It took 20 years of evolution of ICPR to be able to provide this important first step toward institutional arrangement to produce a cleaner Rhine.

Meanwhile, in 1976, the 1963 Bern Convention was amended to enable the European Economic Community (EC) to join ICPR. The EC's accession to ICPR became inevitable in view of its newly developing environmental regulations, particularly in the field of water pollution within EC jurisdiction (de Villenueve, 1996, p. 445). Because of the new development of an environmental regulation regime within EC jurisdiction, its member states can no longer conclude agreements with non-EC states, such as Switzerland. Therefore, EC's participation in ICPR was important for ICPR's future as well as for the uniformity of EC's environmental regulation regime itself. The EC Commission, since then, fully participates in ICPR and shares its costs. In matters falling under EC competence, it exerts its voting right on behalf of EC member states in ICPR (all ICPR states except Switzerland). However, it is important to note that EC does not function as a member state within ICPR in matters for implementation and administration of ICPR agreements and functions, since these are left to the member states.

3 Analytical Framework

Within the Rhine international environmental regimes, there are at least three layers of governing institutions: (1) local institutions composed of individuals, community organizations, and industries; (2) national institutions in each member state composed of ministerial and municipal governments; and (3) international institutions composed of national delegations at the international layer and other non-state actors such as donors and environmental NGOs. These layers are institutionally interconnected in the governance processes of chemical pollution in the Rhine River Basin. Within each layer, issues, interests, and actors shape political processes. The presence of these issues, interests, and actors in each layer as well as the strength of networks among them is a dynamic political process. I define this entire dynamic process as a "governance process," which might also be referred to as an "action arena."

3.1 Drawing Insights from IAD and Policy Sciences Approaches

Within each layer of institutional arrangements in the Rhine, the collective desires of individual actors influence governance processes at varying degrees. In analyzing the ways in which an individual actor's choices or preferences are shaped within a layer of institutional arrangement, the Institutional Analysis and Development approach lends insightful analytic compartmentalization of governance processes where individuals make strategies to pursue their interests. The IAD framework dissects four nested levels to analyze governance processes: (1) operational-choice level; (2) collective-choice level; (3) constitutional-choice level; and (4) metaconstitutional choice level (Kiser and Ostrom, 1982; Ostrom, 1999,pp. 36-39, Ostrom, 2005, p. 59). In governance processes of river basin governance in the Rhine, issues, interests, and actors shape these four levels within each layer of the regimes, from local to international.

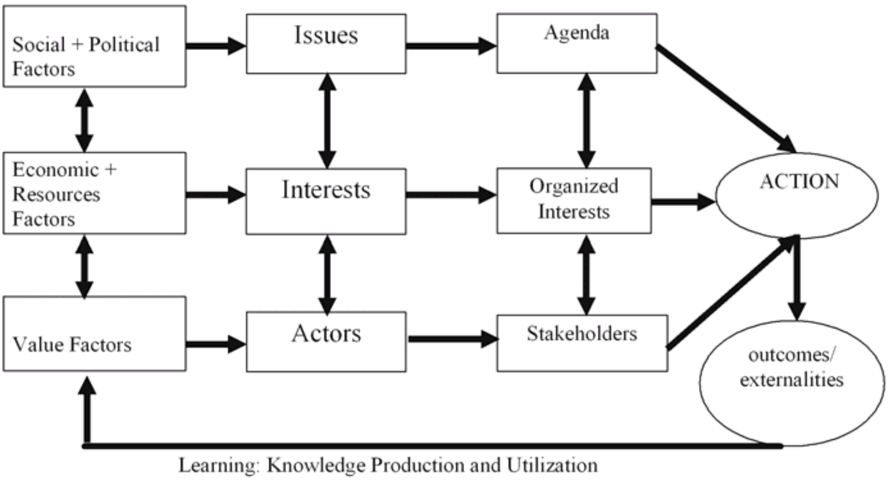

Fig. 1. Issues, Interests, and Actors Network in Governance Process

Complementary to the IAD framework is the Policy Sciences approach. With the Policy Sciences approach, I zoom into the ways in which individuals' motivation shape governance processes (or social processes) in pursuing their values in society. The Policy Sciences framework organizes the analytical dimensions of governance phenomena into three groups: (1) social process; (2) decision process; and (3) problem orientation (Lasswell, 1971; Clark, 2002: 9). Social process helps me elucidate the ways in which actors emerge and influence governance processes of the Rhine to seek their perspective values. Decision processes help map the ways in which actors' interests are shaped and promoted to influence the governance processes of the Rhine. Problem orientation lends the analytic lens to dissect how policy issues become political problems, and how they become public agenda for decision making in the Rhine.

4 Issues, Interests, and Actors in the 1976 Chemical Convention

The aim of the 1976 Chemical Convention, officially registered in the United Nations treaty series as the Agreement for the Protection of the Rhine against Chemical Pollution, was to reduce the pollution of the Rhine by gradually eliminating discharges of hazardous chemical pollutants including heavy metals from chemical industries, community sewage systems, and agricultural land. The means of achieving these goals was to begin with the formation of a black list and a gray list of pollutants that were to be regulated. Articles 1(a) and 1(b) of the 1976 Chemical Convention require ICPR to establish Annex I and Annex II lists of substances that are responsible for the Rhine pollution.

Annex I is the black list that was to include the most toxic chemical substances to be dealt with as a priority to reduce discharge into the Rhine. Annex II is the gray list that included chemical substances that were less toxic compared to the Annex I list but still needed to be regulated under the national legislations by means of effluent limits. The secretariat office of ICPR was to draw up a list of chemicals in accordance with the Article 1 of the Chemical Convention.

Initially, ICPR drew up a list of 83 chemicals that needed to be listed in Annex I. The secretariat office of ICPR then had to recommend to member states certain levels of effluent limits to be applied in national regulations. These recommendations on effluent limits by ICPR had to be unanimously passed and adopted by the member states. However, the implementation processes of the Chemical Convention were met with resistance (Rest, 1979, p. 85; Kiss, 1985, p. 637; Bernauer and Moser, 1996, p. 392; Verweij, 2000, p. 83). In reality, although the 1976 Chemical Convention was put into effect in 1979, the processes of implementation ended at the point when ICPR drew up a list of 83 chemical pollutants but did not issue the recommendations of effluent limits to member states (Verweij, 2000, p. 83). Why did the Chemical Convention fail to proceed with eliminating black- and gray-listed chemical pollutants? It is important to investigate the ways in which issues, interests, and actors interplayed in the processes in order to answer this question.

4.1 Actors in the Governance Processes of the Chemical Convention

Actors in the processes of the Rhine pollution cleanup regime in general can be categorized into multiple groups. Actors can minimally be categorized into individuals, private industries, businesses, nongovernmental organizations (NGOs), and government organizations ranging from community, township, municipal, provincial, ministerial, and national to international layers. They share and shape values in official and non-official ways in the social process. For a policy analyst, it must be understood that actors in social processes are not just participants as stakeholders in an explicit sense at the point of an actual action situation, but they include opinion leaders and shapers such as media, writers, poets, and novelists.

In parallel with the formation of the ICPR forum among the riparian states with the initiatives of the Netherlands government in 1950, the private drinking water companies began to organize themselves as associations to protect their interests. The first such association, known as the International Association of River Waterworks, or Rijncommissie Waterleidingbedrijven (RIWA), was established in the Netherlands in 1951. The counterpart associations in Germany, known as the German Association for Water Protection, or Verein Deutscher Gewasserschutz (VDG), and the caucus of Rhine waterworks, or Arbertsgemeinschaft Rheinwasserwerks (ARW), were established in 1953. Similarly, the caucus of waterworks for Lake Constance and the Rhine, or Arbeitsgemeinschaft Wasserwerk Bondensee-Rhein (AWBR), was established in 1968. These regional drinking water companies intensified in organizing their interests on the Rhine pollution issues and finally formed an umbrella international organization known as the Foundation of the International Association of Waterworks in the Rhine River Basin, or Internationale Arbeitsgemeinschaft der Wasserwerke im Rheinneinzugsgebiet (IAWR), in 1970 (IAWR, 2001, p. 10). IAWR became an influential organization in raising the Rhine water pollution issues to the international layer by lobbying national governments. Some scholars who study the Rhine regime development have even asserted that the associations of the drinking water companies in the Netherlands and Germany, namely RIWA, ARW, and VDG, “broke the ground for international cooperation” in the beginning of the ICPR regime development (Dieperink, 1998, p. 477).

Even before the first ministerial-level meeting was launched among ICPR countries in 1972, non-state actors, especially drinking water companies in the Netherlands, began to organize associations and lobby to push the Rhine pollution into international cooperation among states. During the early 1960s, the Rhine’s pollution issue became a serious economic and political issue, especially for the downstream country—the Netherlands. The farmers and flower growers were losing their lands due to salinization caused by the chloride-based chemicals in the Rhine. The ports in the Netherlands were facing corrosion, and the maintenance costs for the ports began to reach beyond normal wear and tear. Drinking water companies especially in Germany and the Netherlands were finding it costly to clean the polluted Rhine water that carried upstream chemical industries’ wastewater. Chemical industries in upstream countries, especially in Germany and Switzerland, were unable to reduce pollutant chemicals in their effluent wastewater due to lack of technology and capital.

Meanwhile, with the help of scientists and researchers, the media and NGOs such as Greenpeace and the local World Wildlife Fund were reporting various environmental problems of the Rhine such as loss of fish species and flood plain conditions. National governments were occupied with the economic and political issues such as unemployment problems in France and further intensification of European integration issues, especially in Germany. Among all of these individuals and groups, nation-states were the only ones officially recognized and allowed to have participants at the official decision-making level of ICPR. The international NGOs, epistemic communities, individual farmers, local NGOs (e.g., Stiching Reinwater in Amsterdam), chemical industries, and drinking water industries were not considered as important actors in the official decision-making mechanism, although all of them were actors in the social process addressing the Rhine pollution problem. Other participants were novelists and poets who were at that time writing about the Rhine shaping public perspectives about water pollution of the Rhine.

4.2 Issues and Interests in the Governance of the Chemical Convention

Issues associated with the governance process of the 1976 Chemical Convention can be traced by examining perspectives of the actors and situations in which actors framed their problems. The Policy Science approach identifies perspectives based on value applied by actors, their expectation, and their identities. To understand perspectives further we might examine participants' myths, such as doctrines, formulas, and miranda or symbols. For instance, the "Salmon 2000" slogan in the case of Rhine Action Program is indicative of the perspective of the ICPR expecting the Rhine to be clean to a level where salmon can live in it by the year 2000.

Perspectives of actors in the Rhine case can also be examined in their scope values, identities, and expectations. For Dutch farmers and flower growers, they were loosing the quality of their soil, which in turn was causing the loss of income (wealth). They knew that they were powerless to stop upstream countries' discharge of chloride into the Rhine. However, they viewed that their government should do something to stop the upstream countries' discharge of chloride. They expected their government to provide their well-being by exercising authority (power) to raise the issue to the responsible participants at the international layer, which was mainly France. The Dutch government was pressured by the farmers and their association at the local layer. Thus, the government was apprehensive about losing trust and support votes (respect, affection, and power) from its citizens if it failed to act.

The Dutch government's perspective was to act in proper and official ways to approach and solve the problem. Therefore, the government first sought scientific understanding (enlightenment) about the pollutant chemicals in the mid-1960s. With the mission to enlighten themselves about the Rhine water pollution, researchers in the universities in the Netherlands, and scientists hired by the government used their skills to find out facts about chemical and chloride pollution responsible for salinization. Scientists and researchers first expected to gain critical understanding (enlightenment) about the chloride issue and consequently expected to gain respect from students and colleagues in the field in further hopes of promotion (affection, wealth, power, and influence) by participating in such important, policy-relevant research. Their perspective therefore was to be as accurate and unbiased as possible in presenting the facts and findings.

For drinking water industries and brewers, all kinds of pollutant chemicals (not just chloride) discharged by the upstream countries' industries were causing them to find better cleaning technology (skill), which in turn cost capital (wealth), to clean the polluted Rhine water to produce drinking water and beer (Stoks, 2000, p. 499). Their perspective was that the increasing cost for drinking water production was a direct result of pollutant chemicals discharged by upstream chemical and other manufacturing industries. They expected somewhat natural water from the Rhine. They believed any additional pollution besides natural pollutants in the Rhine should be reduced to a reasonable level at which they could keep cleaning costs to a minimum. Their expectation about the Rhine pollution was mainly driven by the cost of production (wealth) rather than anything else. They believed that responsible polluters should be paying their additional costs. Drinking water industries and brewers in the Netherlands and Germany, on the other hand, expected their governments to address the problem of transboundary water pollution at the international layer.

The French government, at the same time, was interested in making tougher regulations against all kinds of pollutant chemicals into the Rhine.. There are two reasons behind France's perspective: (1) the chloride problem would not be a focus of ICPR; and (2) France would not face as strong political pressure from its industries as Germany, where the majority of chemical industries were located (LeMarquand, 1977, p. 121; Bernauer and Moser, 1996, p. 392). The first reason was shaped by the assumption that if chemical pollution were a focal point of the Rhine pollution problem, then pressure on its government from chloride issues would be weakened (fear of threat to its power and wealth). The second reason was framed by the assumption that France would not have to pay as large cost as Germany (or face political pressure from its industries) because it did not have as many chemical industries on the Rhine as did Switzerland and Germany. France's perspective can be interpreted as somewhat reflective of the identity of the French being nationalistic, at least at that time. These perspectives in fact later shaped the strategies of the French government's position when ICPR ministerial discussions began to lead to the signing of the 1976 Chemical Convention. For the French government, in order to downplay the intensity of chloride issues for which it was responsible for 35 to 40 percent of the discharge into the Rhine, it was willing to lead further discussions about the Chemical Convention because it would not be strongly affected by it (LeMarquand, 1977, p. 121). In addition, the Chemical Convention was the opportunity for France to display its environmental concerns (or image) to the international community by supporting and promoting it and taking it to the European Community (EC) level.

Germany's position and perspective was also shaped by its economically and politically influential chemical industries. Germany's perspective was that the chemical pollution of the Rhine water should be measured in terms of the EC water standard rather than the Rhine-specific case. Germany's demand reflected that if its chemical industries were to be regulated by the stricter regulation, then all EU industries should be under the same standard of regulation (see also Verweij, 2000, p. 83). The assumption of the German delegation (which was perhaps a calculated assumption) was that German industries would lose their comparative advantage to other EU industries, especially England. In addition, if chemical pollution were to be reduced as desired at the time, Germany would bear the economic burden because it had the largest industries along the Rhine (LeMarquand, 1977, pp. 120-121; Bernauer and Moser, 1996b, p. 3). These perspectives indeed shaped negotiations and issue-framing leading toward the 1976 chemical and chloride conventions.

In addition to the perspectives of actors, another key area in which to trace the ways issues and interests are framed by actors is the situation in which the governance process took place. The situation refers to "zones" in which social interaction takes place. A situation can be characterized by four dimensions: (1) ecological or geographical; (2) temporal; (3) institutional; and (4) crisis (Clark, 2002, pp. 39-40).

First, situations can be identified by ecological and geographic dimensions, referring to spatial dimensions and related features in the area of concern (Clark, 2002, p. 39). In terms of ecological condition, it was recorded as early as 1885 that the "excessive" fishing "resulted in the conclusion of a treaty" known as the Salmon Treaty or the International Treaty on Salmon Fishing in the Rhine (still in legal force on paper). Only beginning in the early twentieth century did the Rhine countries start to realize the ecological death of the Rhine by pollution. Beginning in the 1960s, the media and writers described the Rhine as no longer a river but the "sewer" of Europe (ICPR, 1994, p. 9). By the beginning of the 1970s, the level of oxygen in Rhine water was deteriorated which resulted in the invasion of certain smaller salt-tolerant crustaceans and the dying out of sensitive insects and fishes such as salmon (ICPR, 1994, p. 11; Huisman et al., 1998, p. 66).

Geographically, major manufacturing industries and cities were located throughout the banks of the Rhine and its tributaries, which also contributed to Rhine pollution from human wastes and utility waters. Generally these diffused sources of pollution coming from residential and runoff water into the Rhine are difficult to locate as opposed to industrial waste discharges, which are point sources where the locations of discharges are known, thus providing the opportunity to identify pollutant chemicals from them. Therefore, when actors engaged in Rhine pollution, the issue of the Rhine water quality was to solve pollution problems at the point sources. ICPR and its mandate cover most of the Rhine's physical river basin area, beginning from the point at which the Rhine leaves Lake Constance in Switzerland and continuing northward to the North Sea. ICPR's problem situation is as wide as its river basin in terms of geographic boundaries. Within this geographic boundary, the classic downstream and upstream nature of the river dominate in framing the ways in which the Rhine pollution is perceived, understood, and solved.

Second, the situation also can be identified by temporal dimension, referring to timing of events and processes (Clark, 2002, p. 39). In terms of temporal dimension, global environmental issues reached into the political agenda through the signing of the Stockholm Declaration of UN Convention of Human Environment in 1972. It is not unrealistic to draw inference that the situation in which Rhine riparian countries finally reached to sign binding treaties on both chemical and chloride pollutions in 1976 had some level of influence from surrounding global events. In fact, the first ministerial conference of the Rhine was held in 1972, the year the Dutch government proposed to have meetings for further discussion about the pollution problem. Certainly, the focus of the media on the environmental issues, especially the Rhine pollution, was significantly increased after 1970. Due also to the protests of farmers associations and local NGOs in Amsterdam and Rotterdam in 1972, the Dutch government was preparing to make the 1976 signing of treaties happen.

Agreed at the 1972 ministerial meeting, ICPR itself organized a survey of water quality between Reinfelden and Rotterdam between June 24 and July 1, 1974, as a preparation for the 1976 treaties. The Flood Plain Institute, a local NGO based in Rastatt, Germany, was founded after the Stockholm declaration, where the director herself was a participant in the 1972 Stockholm conference. All of these pockets of events in the early 1970s indeed were describing the extent to which the situation of the Rhine pollution had been set on stage, resulting in the symbolic and historic event of signing the Chemical Convention and the Chloride Convention in 1976. These were the first legal recognitions of riparian countries on the issue of Rhine pollution after a long push by drinking water industries, brewers, citizens, and environmental groups. According to Mr. Huisman, for the Netherlands government, the fact that the issues of Rhine pollution were legally accepted as a problem that needed to be solved by international cooperation was a success at the beginning.

Third, the situation can also be determined by what Clark (2002, p. 39) calls "institutionalization," referring to the structure of how values are allocated in particular contexts; that is, whether institutions are centralized, decentralized, fragmented, plural, or singular (Clark, 2002, p. 39) in terms of the structure of decision power at all layers. At the ICPR layer, the decision structure is centralized; the French government as a nation is also centralized; other member states of ICPR are federal systems or decentralized legal and political structures. For instance, Switzerland might be called fragmented or a polycentric structure with many decision-making centers.

The structure of the decision-making system had an impact on the social process in terms of which country got treaties ratified first (i.e., how they treated the situation). Switzerland and the Netherlands scored speedy ratification of treaties and ICPR policies because the Swiss national delegation only needed to consult with three cantons that resided on the bank of the Rhine, and the Netherlands as a downstream country had a key stake in implementing what was agreed upon at the ICPR level as soon as possible. In addition, the Dutch delegation was given full authority by its central government on the Rhine issue, which was a decentralized structure. Throughout, the negotiation processes for the Chemical and Chloride Conventions, the Dutch Ministry of Transport, Public Works, and Water Management played an important role in leading the negotiation. The long-time head of the Dutch delegation, Ms. Neelie Kroes, had been recognized as one of many key actors who led the framing of the Rhine pollution issue across three layers; local, national, and international (Verweij, 2000, pp. 92-96), instead of keeping it as either an international or national problem.

In the case of Germany, the opposition of German industries to the Chemical Convention was strengthened by the federal structure of Germany (LeMarquand, 1977, p. 122). The provinces within the federal system had major constitutional authority on water resources issues. Therefore, industries located in provinces along the Rhine had access to the sources of policy making for water pollution abatement at both the federal and provincial levels. According to the German federal constitutional structure, the federal government had to receive support from provinces for its international commitments to be signed at either the Rhine or EC level. Otherwise, Germany would not have been able to honor the international agreements because the provinces were key actors in implementation of such agreements at the provincial layer. This nature of institutional structure of the German federal system was a critical determinant of Germany's position in the Chemical Convention.

Fourth, the situation also is shaped by crisis. It is important to understand the extent to which the environmental crisis (reaching the level of the "Sewer of Europe") and political crisis (the miners' strike in France) shaped, in some way dictated, the situation and consequently framed the nature and intensity of Rhine pollution issue. Consequently, governance issues were subject to prioritization by means of reallocation of values to be pursued. Indeed, the case of transformation of the Chemical and Chloride Conventions into the Rhine Action Program was mainly triggered by the highly cited Sandoz chemical accident, a crisis that "shocked" ICPR states into "action" (Glass and Snyder, 1996, p. 48). The RAP has been reported elsewhere as a successful case of institutional arrangement (Bernauer and Moser, 1996, pp. 404-405; de Villeneuve, 1996, pp. 451-452; Gurtner-Zimmermann, 1998, p. 241; Dieperink, 1998; Verweij, 2000, pp. 12-121, Weber, 2000) and it is a case of institutional adaptation from the Chemical and Chloride Conventions.

4.3 Issues, Interests, and Actors in the 1976 Chloride Convention

The main difference between the Chemical Convention and the Chloride Convention was the way in which ICPR placed the issue on the policy landscape of the Rhine regime in a general sense. ICPR placed the central issue of the Chloride Convention at one specific geopolitical place—the Alsatian mines in northeastern France. In other words, the Chloride Convention focuses the sources of Chloride discharge as the center of governance for Rhine pollution in lieu of the overall pollution of the Rhine water pollution at the basin level. This placement of the chloride pollution issue on the Alsatian mines as the center of the Chloride Convention put the French government into a defensive position. The French defended its interests with unyielding attitude, as we will observe in the following analysis.

4.3.1 Outcomes from the Governance Processes of the Chloride Convention

The 1976 Chloride Convention is the least favorite topic that leaders of ICPR today want to discuss. When asked about the 1976 Chloride Convention, Dr. Anne Schulte-Wülwer-Leidig, the current deputy secretary of ICPR, indicated it was "the worst experience" of the ICPR regime because it caused many obstacles for other issues that were far removed from the chloride case. As if the whole ICPR regime was stalled, no other issues could be discussed due to the intense diplomatic conflict between the Netherlands and France on the chloride issue. The key problem with chloride was the lack of political will within member states, especially in France. On top of that, the low levels of trust and cooperation among the member states also prevented any progress with the Chloride Convention.

During interview with Mr. Pieter Huisman, he stressed that the Chloride Convention was a failure as an international law but he praised its contribution to the processes that were a part of trust building and institutional evolution. When he was an insider, being secretary of ICPR, he felt that the Chloride Convention was a disappointment and a complete failure of

ICPR. He then explained that after he left the position and looked back to the history, he realized that crises were sometimes needed in view of overall regime development, because the crisis between the Netherlands and France on the chloride issue "tested" the trust between two countries and among ICPR members. Mr. Huisman's reflective assessment of the Chloride Convention and the ways in which it challenged the issue of trust among ICPR member states is consistent with the findings of researchers who study the international cooperation aspect of trust and reciprocity on the chloride issue of the Rhine (LeMarquand, 1977, pp. 119–120; Bernauer, 1995; Verweij, 2000, p. 84).

The Chloride Convention dominated international relations among member states of ICPR between 1970 and 1985. As in the case of the Chemical Convention, states were the only actors in the decision-making at the formal level of the international and national layers. Actors other than states were not recognized as actors in the formal decision-making structures of ICPR and national governments. Local and non-state actors were not considered as important actors in the formal structures of the decision-making mechanism within ICPR. As a result, there were missing links among multiple issues, interests, and actors across layers of the Rhine regime on the chloride issue.

Table 2. shows actors who were decision makers at each layer. The actors in each layer were not institutionally linked, especially between local and international layers, as we can see that none of the actors from the local layer was listed in the international layer. In fact, reading the text of these two conventions confirms that the only actors these conventions considered as responsible decision makers at the international and national layers were the states. The fundamental assumption was that states were unitary actors who had all powers to carry out the conventions within each state. This nature of international legal mechanism for the Rhine was responsible for creating the missing links among multiple actors and multiple layers, especially between local and international layers. This missing-link problem encompasses both theoretical and policy challenges demonstrated in the case of both the Chemical Convention and the Chloride Convention.

Table 1. Issues, Interests, and Actors Network in Chemical Conventions

Institutional layers	Issues	Interests	Key actors
Transnational	•Chemical pollution of the Rhine •Building international cooperation •Industrial compliance	•Downstream pressure •Cost of effluent limit •Regional approach for cost sharing	•ICPR •Germany and Switzerland •The Netherlands •National delegations
National	•Lack of political will •Lack of trust to other member states •Perceived as international problem	•Cost of regulation •Pressure from chemical industries •Pressure from water supply companies (The Netherlands)	•Ministerial •Municipal •Industries
Local	•Drinking water supply •Public health •Sewer image	•Cost of compliance •Cost of drinking water •Health risk •Recreation	•Chemical industries •Water supply industries •Communities of interests •Local NGOs

5 Linkage Problems in the Rhine

The state-centric international conventions amplified the missing linkages between local and international layers in both the Chemical Convention and Chloride Convention. This local-international linkage was assumed achieved through the delegations of the national governments of riparian states in ICPR and these two conventions. As such, almost all of the discussions and policymaking at the ICPR layer were conducted exclusively by member states' delegations. The relevant issues, interests, and actors besides those of states' leaders were not in the whole process of the negotiation and implementation. Neither NGOs nor the industries were invited and regarded as legitimate actors at national and international layers in the processes of making and implementing both Chemical and Chloride Conventions. National delegations were the only actors who discussed and made policies at the international layer. The key missing links were apparent between local and international layer institutions. The strong links were present between national and international layers which is consistent with dominant international relations theories. Consequently, issues, interests, and actors were not linked across at least three layers (Table 1. and Table 2.). The ICPR regime was functioning with a state-centered approach as if states were the most important players in the international environmental governance.

Table 2. Issues, Interests, and Actors in 1976 Chloride Convention

Institutional layers	Issues	Interests	Actors
Transnational	•Conflict between NL and FR •International co-operation •ICPR's role challenged	•Cost of operation •Downstream pressure •Defining responsible party to pay for cleanup	•ICPR •France •the Netherlands •National Delegations
National	•Lack of political will •Unemployment and labor strike in France •International problem	•Damage to farm land •Pressure from water industries •Pressure from Alsatian mine workers •Status of ICPR regime	•Diplomats •Ministries •Municipals •Water supply and mining industries
Local	•Drinking water supply •Public health •Agriculture	•Cost of water purification •Loss of agricultural land from salinization in NL	•Local farmers •Alsatian mining industry in FR •Water supply industries in NL •NGOs

Some actors attempted to break traditional lines of thinking about solving Rhine pollution problems by states alone. A good example of such an actor is the head of the Dutch delegation, Ms. Neelie Kroes. Her efforts to bring private and non-government actors into the equation of the Rhine pollution problem across local, national, and international layers were recognized by some of the actors at that time, such as Mr. Pieter Huisman and current Deputy Secretary of ICPR Dr. Anne Schulte-Wülwer-Leidig, and reported in the literature (Verweij, 2000, pp. 92-99, p. 102). However, those alternative, minority voices were not recognized until the crisis hit—the Sandoz accident in 1986.

In addition, having to establish the binding nature of regime design to implement objectives was an indicator that member countries did not trust each other, or there would have been serious free-rider problems. The problem of such a binding international law, micromanaging implementation at the local layer, was articulated by the current Deputy Secretary of ICPR Dr. Anne Schulte-Wülwer-Leidig during interview, as follows:

> You need international convention to establish legal basic for cooperation. Therefore, a framework is necessary to set the rules of the game to organize the most important things so that there will be a reference when problems arise. But the environmental issues such as Rhine pollution change so fast at the local [layer] that you need a lot of possibilities and options to change your smaller goals, to implement the measures, and to change these goals.

However, the 1976 Chemical and Chloride Conventions were not flexible enough to meet the challenges at the local layer. These conventions considered states as unitary actors who would have all sorts of powers and the capacity to implement the convention at the local layer. As a result, there were various missing links among actors and across layers. The linkages between national and international layers were stronger than the linkages between local and international layers (Table 1. and 2.). This is because the international regime, ICPR, was initially crafted by states and their delegations with the assumption that state actors' participation consequently grants local and non-state actors' participation.

Consequently, granting formal participation of local and non-state actors at the international layer is structurally harder for a legally binding international regime because states are only actors who are granted legal personality in international affairs. The assumption is that the states will have sovereign power to execute international environmental law within its boundary while, in reality, states do not have practical sovereignty power within their boundaries. As a result, local-layer issues, interests, and actors were not allowed to participate in governance processes at the international layer. A clear lesson from the 1976 Chemical and Chloride Convention is that state-centric international laws and policy thinking hinder the adaptability of international river basin regime to become more inclusive and integrated institution.

6 Conclusion

The riparian states initiated and structured the Rhine regime. The relationship among riparian states is a crucial platform for addressing governance issues at the international layer. However, what we have observed in the case of the 1976 Chemical and Chloride Convention in the Rhine is that these regimes did not consider local-international linkages to be crucial for the governance of the Rhine. Evidences in the Rhine suggest that the challenge to become more adaptive and integrated international river basin regimes lies in this missing link between local and international layer.

The lessons from the failure of the Chemical and Chloride Conventions is that the linkage between local and international layers needs to be established to achieve objectives and to attain goals of international regimes. The outcomes of international regimes are essentially dictated by how local actors are capable and how they are integrated into international regimes. The strong link that exists between local and national layers should not be assumed that the local layer is automatically linked to the international layer. In fact, it has to be assumed that the strong link between local and national layers can hinder the achievement of objectives and goals of international regimes. Therefore, this strong link between local and national layers has to be loosened up by bringing the local layer into the international layer.

In sum, this analysis suggests that institutional adaptability of international river basin regimes such as the Rhine will largely depend on how these regimes are able to break through dominant practices of international institutions that treat national governments of member states as central actors. This means, these regime have to reconsider the assumption that linkages between national governments and international institutions will automatically address environmental problems that are local intensive. For analysts, assessment of institutional adaptability of international river basin regimes will have to consider whether and how institutions are linked across multiple layers.

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Institutional elements for adaptive water management regimes. Comparing two regional water management regimes in the Rhine basin

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Abstract

In times of rapidly changing physical and regulatory environments, adaptiveness is one of the central parameters of sustainable water management. To investigate how different institutional settings are able to adapt to new conditions, two organisational settings in the Rhine basin are compared: the German water association Wupperverband and the Dutch water board Hoogheemraadschap De Stichtse Rijnlanden (HDSR). To facilitate comparison, the institutional settings of both regulatory systems are analysed based on empirical data, and using the Institutional Analysis and Development framework (IAD) (Ostrom 2005).

Historical development, Institutional settings for membership, roles and decision making of responsible water management agencies are analysed and compared in view of important adaptive management prerequisites. We argue that combinations of different institutional elements influence the capacity of both water agencies to adapt to changing conditions in an effective and legitimate way. Special focus is put on the role of emergent leadership, social learning, and both formal and informal forms of participation by stakeholders outside of the regulatory system.

1 Introduction

Regional water management agencies in Europe are currently facing considerable environmental and institutional challenges. Climate change is causing major deviations in the supply and discharge of surface and ground water quantities. Changing regulatory requirements, such as the European Water Framework Directive, are causing deviations in the institutional objectives and organisational arrangements. The way regional water agencies will respond and adapt to some of these challenges is crucial for managing European water resources in a sustainable way.

Adaptiveness is increasingly recognised as one of the central parameters for sustainable water management in rapidly changing physical and human environments (Pahl-Wostl 2007). The complexity of water management and an increase in uncertainties linked to key drivers, actors and boundary conditions require approaches enabling management to readjust to changes in the system being managed (also see Gunderson and Holling 2001). Adaptive management can be considered as a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies (Walters 1986) and explicitly acknowledges uncertainties and complexity.

In this article we examine different elements of institutional settings of two water management regimes on a regional scale in order to investigate some of the prerequisites for adaptive management. We understand institutional settings as a broad umbrella of sets of rules, decision making procedures, and programs that define social practices, assign positions to participants in these practices, and guide interaction among occupants of individual positions. Organizations can be thought of as collective actors, who typically emerge as players whose activities are guided and constrained by the rules of the game of institutions in which they participate (also see Young 2002: 5; Ostrom 2005).

Special focus is put on the positions and responsibilities of different actors in planning and decision making processes. In order to facilitate the comparison of the two management regimes, we use the Institutional Analysis and Development framework (IAD) (Ostrom 2005) and elaborate it using empirical data from the two cases. The IAD framework is used for discussion purposes in order to highlight similarities and differences in the institutional settings. We analyse how different organisational structures and membership settings shape positions and actions of different actors as well as outcomes of planning, decision making processes, and the effects on the outcomes with regard to effectiveness and flexibility.

The management regimes analysed here are both located in the Rhine basin: the German sub-basin of the Wupper and the Dutch Kromme Rijn region. Thus, they have several similar settings and background conditions, but also strongly differing ones, especially due to their historical background.

The structure of this paper largely follows the different steps taken during the analysis. After the theoretical background and methodological considerations, important exogenous variables such as the natural background conditions of the case study areas as well as the common European obligations set out in the Water Framework Directive are briefly described. Afterwards, the different elements under discussion are presented in view of the IAD framework. Selected elements of the analysis are democratic feedback and effective decision making, the position of leadership, and the participation of relevant non-members in the respective management regimes. Leadership has two aspects: On the one hand it is structural leadership, manifest in powerful positions. On the other hand it takes the form of salient acts of contributing to social order. These acts need to be acceptable to others in order for leadership to emerge from these acts. Participation is seen as the active involvement of actors in the management process.

2 Theoretical and methodological considerations

2.1 Institutional comparative analysis with the IAD framework

In her IAD framework (Institutional Analysis and Development), Ostrom (2005) proposes to study institutions by focussing on action situations in which participants with particular positions make choices under different institutional settings. A simplified internal structure of an action situation is set as follows: Participants are assigned to positions, which allow them particular actions. Action situations are influenced by exogenous variables, such as the biophysical environment, attributes of the community and the various rules that apply to an action situation. The internal structure of an action situation is displayed in Figure 1, simplified for use in the present study.

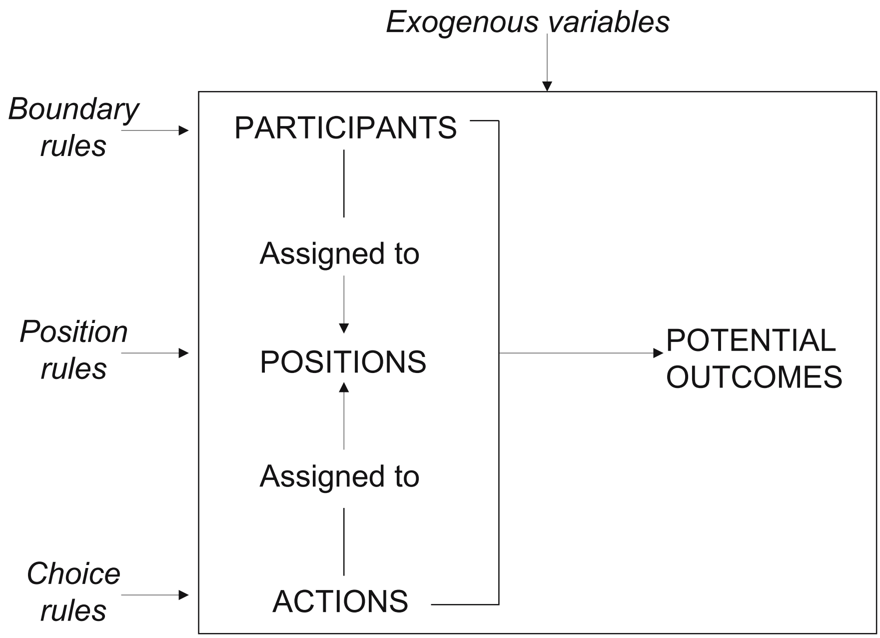

Fig. 1. Internal structure of an action situation and external rules. Adapted from Ostrom 2005, 33 and 189.

Participants evaluate expected outcomes according to their own individual evaluative criteria, such as economic efficiency, equity, or conformance to general morality (Ostrom 2005: 66). Thus, the action chosen in a given situation is influenced by the positions filled by participants, the participants' expectations about outcomes, and the external influences.

For the sake of the analysis, rules that are in effect in a given action situation, can be treated as temporary fixed and external to the action situation. Changing these rules would take place in another action situation. Following Ostrom (2005) we distinguish between boundary, position, and action rules, albeit in a simplified version. Boundary rules regulate who participates in an action situation, position rules define which actions are associated to certain positions, and choice rules determine how actions may or must be chosen.

The IAD framework allows investigating action situations at different levels. The meta-constitutional level sets the rules for the constitutional level, which in turn sets the rules for the collective choice level, which then sets the rules for the operational level, on which the physical system is actually altered (Ostrom 2005: 58ff). Thus, action situations are considered to be nested by multiple levels of institutional rules and organisational procedures. The main focus of this paper is the regional level with the collective choice action situation of the respective water agency.

2.2 Methodological aspects

Research leading to this article is part of the NeWater-project[1] (Pahl-Wostl et al. 2002) and the ACER[2] project, in which a broader comparative research between different basins takes place.

Apart from document research and involvement of the authors in participatory processes at both water agencies, this article builds on interviews conducted with experts from the Wupper and the Kromme Rijn region management regimes from late 2006 to spring 2007. Interview partners were selected upon their function and chosen among members and heads of water agencies, expert personnel, higher level water authorities, and non-members affected by water management. In both agencies five in-depth interviews were held, additionally interview results from broader interviews in the Wupper basin are being drawn on.

While concept and interview guidances were developed jointly and adjusted for both cases, interviews were conducted in a semi-structured way, leaving open the possibility for closer examination of aspects perceived to be central for only one of the cases.

3 Case study research in the Wupper and Kromme Rijn region

The institutional settings studied for this research are two regional water management agencies, one in the Wupper basin in Germany and the other one in the Kromme Rijn region in the Netherlands. In both cases, a specialised agency is responsible for water management. In case of the Wupper this is the water association "Wupperverband", in the Dutch case it is the water board "Hoogheemraadschap De Stichtse Rijnlanden" (HDSR). These two agencies are the central structures for the following comparison.

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[1] FP 6 European Research Project. "New Approaches to Adaptive Water Management under Uncertainties". www.newater.info.

[2] Dutch research project on "Adaptive Capacity to Extreme Events in the Rhine basin". www.adaptation.nl.

Both are embedded in broader scale governmental structures, with competencies spread on State and Provincial or Länder level that are intertwined with the regional water management institutions.

Both study areas are part of the Rhine basin, which is among the biggest and most important river basins in Europe, encompassing a catchment area of 185 000 km2 (see Fig. 2) (Hofius 1996: 3). The Wupper is a small river basin in the middle part of the Rhine and the Kromme Rijn region lies within the downstream part of the basin. Whereas the Wupper basin is part of the central German uplands including hilly areas, the Kromme Rijn is situated in a lowland region characterised by prevailing drainage. These different geographical settings result in different hydro-political situations and influence the nature of the study areas.

The Wupper catchment in the Land North Rhine-Westphalia (NRW) encompasses about 814 km² (MUNLV 2005: 1.1-1) with 890.000 inhabitants (MUNLV 2005: 2-6). The Wupperverband is one of several water associations in North Rhine-Westphalia, which were enforced by a special law. It was founded in 1930 by the "law on the Wupperverband" and established to cover interdependent water management tasks in the catchment, which were formerly dealt with by the municipalities. The Wupperverband holds responsibility to deal with a wide range of water management aspects, such as water quality, flood, and water scarcity problems. The founding motivation of the Wupperverband was mainly linked to the early industrial use of water in this area. Resulting water pollution had eliminated formerly abundant fish, such as the salmon, as early as in 1830. For the population living alongside the river, its bad water quality and smell had become a problem. Today, the Wupperverband is a public corporation with a staff of about 370 employees, mainly with technical and administrative expertise.

The HDSR is responsible for water management in a central region of the Netherlands, located in the Provinces of Utrecht and Zuid-Holland. The total governance area comprises about 834 km², with approximately 750.000 inhabitants (HDSR 2003). The HDSR is a public authority with a staff of approximately 280 technical and administrative employees. The HDSR manages quantitative and qualitative aspects of regional surface water and is responsible for regional protection against floods and maintenance of surface water levels by actively managing dikes, canals, locks, weirs, and pumping stations. For ensuring water quality, wastewater purification stations are managed. Water boards are also responsible for issuing permits for discharge into the water system and constructing drainage systems. Although originally established to protect people from flooding by means of dunes, dikes, and canals, the governance scale and responsibilities of water boards have been extended in the course of history. In depth analysis of the longstanding history of water boards in the Netherlands and their institutional adaptations goes beyond the scope of this paper and can be derived elsewhere in the literature (Huisman 2002; Kuks 2002; Raadgever and Mostert 2006; Van Steen and Pellenbarg 2004).

With the European integration, the background conditions for water management in both basins become increasingly similar, especially since the European Water Framework Directive (WFD) came into force in the year 2000. Overall management goals are aligned on European and on river basin level, but the national and regional implementation of the directive differs. While water management in the Wupper basin aims at achieving a good ecological status (Art. 4 WFD) for many of the water bodies, the management goals for the Kromme Rijn, a river basin within the HDSR governance area, are less rigorous. Since it was entirely classified as heavily modified only a good ecological potential has to be achieved. Despite these differences in goal setting, the implementation of the WFD can currently be seen as a major challenge in both basins and both water agencies work within this new frame.

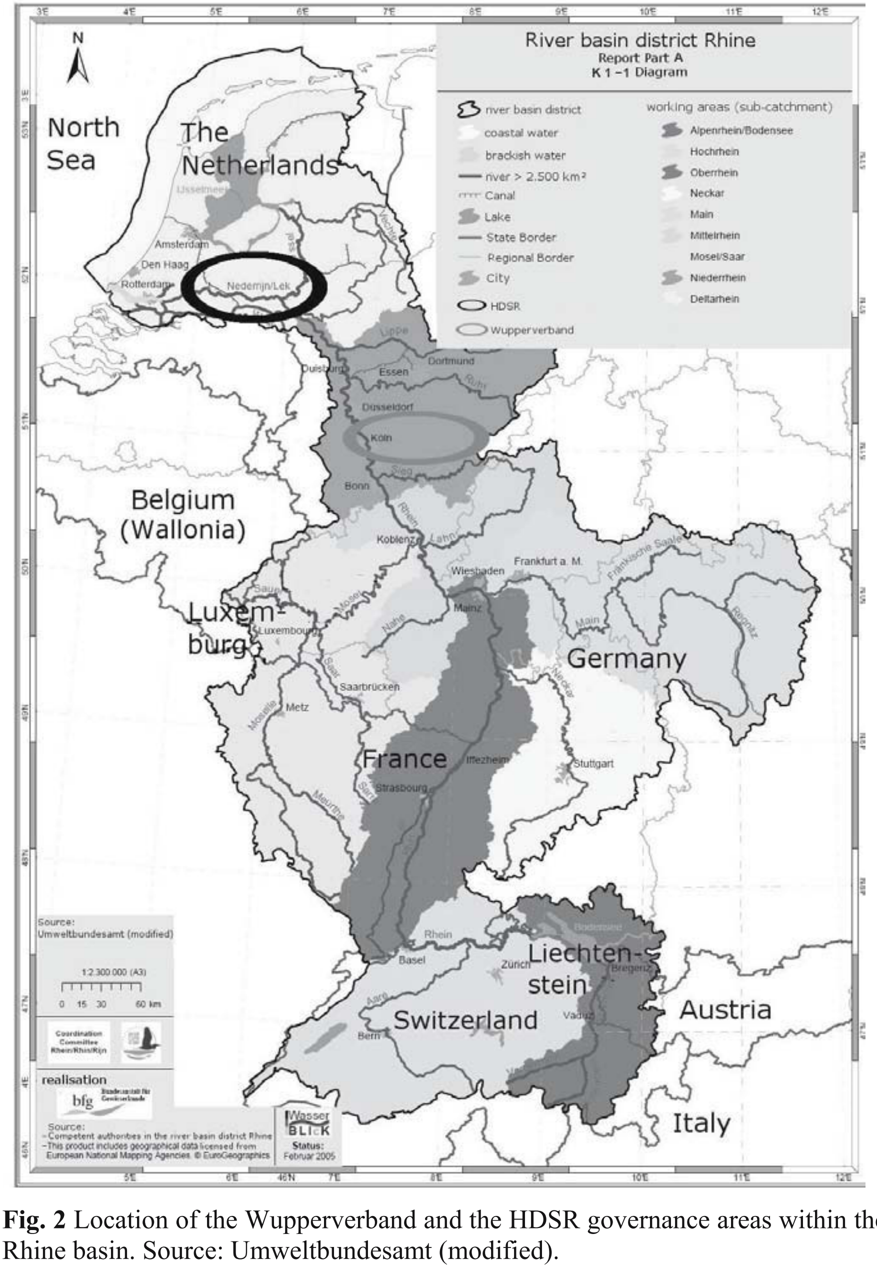

Fig. 2 Location of the Wupperverband and the HDSR governance areas within the Rhine basin. Source: Umweltbundesamt (modified).

4 Investigating relevant prerequisites for adaptive management

The capacity to adapt to new challenges differs within the formal framework of historically grown organizational structures and different institutional settings. This section will discuss different positions taken in the planning and decision-making processes of both water agencies and their relation to the issue of adaptive management. In this framework adaptive management is linked to the capacity of regime participants to recognize the changing conditions at different levels and to their capacity to respond effectively and appropriately to those changes (also see Ostrom 2005). We will focus on the roles different groups in regional water management agencies play in these processes of recognition and response to changes. Before we will embark on this discussion, an overview of the main differences and similarities between the two water management regimes is provided.

4.1 The main differences and similarities in institutional settings

The institutional settings of both water agencies and their positions in the larger water management regime were identified and compared on a range of different criteria. Major differences between the two water agencies include the types of membership categories, the legal framing, the boundary rules for determining membership, democratic legitimisation, payment schemes, and decision making processes. Whereas the Wupperverband is a public corporation with compulsory membership and fixed payment schemes, the HDSR is a public authority with democratically elected representatives and its own taxation system. The main similarities between both organisations relate to their main tasks, their management approach, and their size. The most important results of the comparative analysis are presented in Table 1a and 1b[3].

[3] A more comprehensive comparison was presented to the Amsterdam Conference, 24-26 May 2007 on the Human Dimensions of Global Environmental Change, and can be obtained from the authors.

Table 1a Comparative aspects of the water management agencies' general setting.

Comparative Aspects			
		German Wupperverband	Dutch Water Board HDSR
Positions	Members	Municipalities Districts Drinking water producers Industries	Inhabitants Land owners (e.g. farmers) Building owners Industries (paying pollution tax)
	Daily management	Managing Director	Dike-Reeve and Executive Council members
	Expert body	About 350 technical and administrative employees, management of day-to-day questions, preparation of strategies of the association, led by managing director	About 280 technical and administrative civil servants led by the head of the expert body, the secretary director
Boundary Rules	Non-members affected by decisions or measures	Different interest groups are positively or negatively affected but not a member: fishery, recreation, nature protection (general population is represented by municipalities)	In principle all user-groups that are affected by the water board decisions have the possibility to be directly represented in the water board
	Democratic legitimization	Indirectly through the representatives of the municipalities and districts Previously: legal discussion if democratic legitimization is needed, as the obligations to act within provisions of law are very tight.	Citizens of the water board governance area elect the members of the General Council through democratic elections. Members of the Executive Council are elected among and by General Council members.
	Membership setting	Fixed membership groups. Membership compulsory and fixed by law	Fixed membership groups according to different user groups defined above

Table 1b Comparative aspects of the water management agencies' general setting.

Comparative Aspects			
Choice Rules (Obligations)	Main Tasks	Waste water treatment, sludge disposal Flood protection, low water management Drinking water provision Ecological development of the water courses	Waste water treatment Flood protection Discharge permits Surface water quantity management Ecological development of the water courses
	Payment scheme	Members pay a fee according to their pollution or use of water (citizens pay indirectly through their municipalities)	User-groups pay taxes according to their interest (use and pollution), including citizens
	Decision making process	Decisions prepared by expert personnel and managing director. Informal meetings of members and experts and or managing director outside the formal organisational structures. Mostly formal feedback from members, unanimous decisions on strategic orientation. Much power with the position of the managing director.	Decisions prepared by expert personnel and the Executive Council. In many cases stakeholder groups are invited in the planning phase. Decisions are made by the General Council based on consensus. Both Councils are chaired by the Dike-Reeve.

To gain a more dynamic view of the differences between the two water agencies, the interactions between different groups inside and outside of the two regimes were analysed. Based on the collected material, the organisational structures of the water agencies were identified and represented in two graphs (see Figs. 3 and 4)[4]. The graphs were elaborated based on information from the conducted expert interviews and then partly returned to the water agencies for discussion. Both, the graphs and the comparative analysis table will be referred to in the following discussion of a number of

[4] In the graphs organisational bodies are represented by a square box, whereas plans are presented in oval boxes. In the Dutch graph WMPs stands for Water Management Plans.

important prerequisites for the adaptive capacity of the participants inside the two regional water institutions.

The graphs illustrate the internal organisational structures of the water agencies in different boxes. It shows the influence of the general public on the regimes by different kinds of elections, the position of different groups within the two regimes (e.g. members, experts, etc.), and highlights the relationship of the water agencies to higher level authorities.

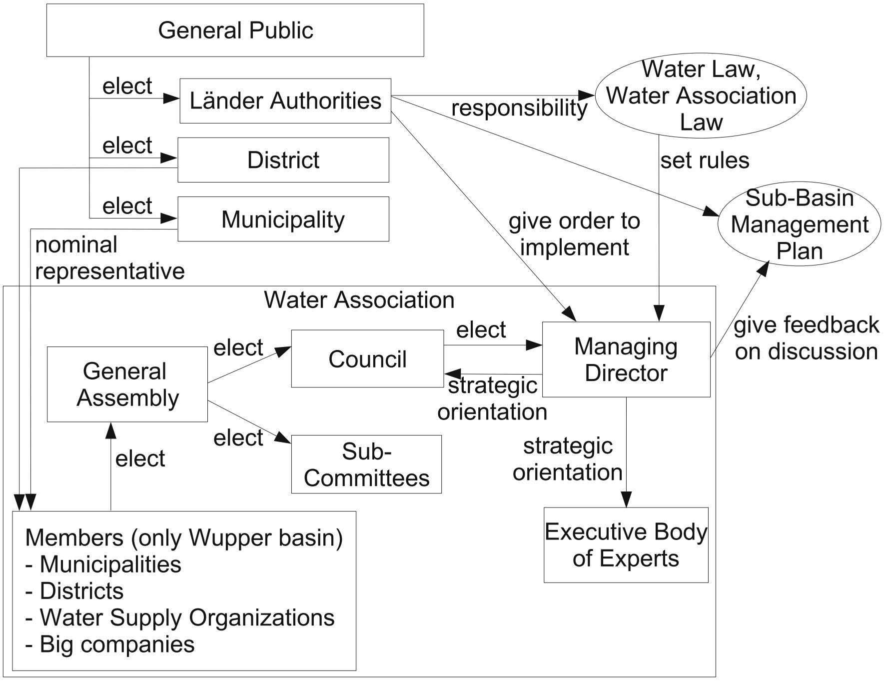

Fig. 3 The Wupper management. Source: own presentation.

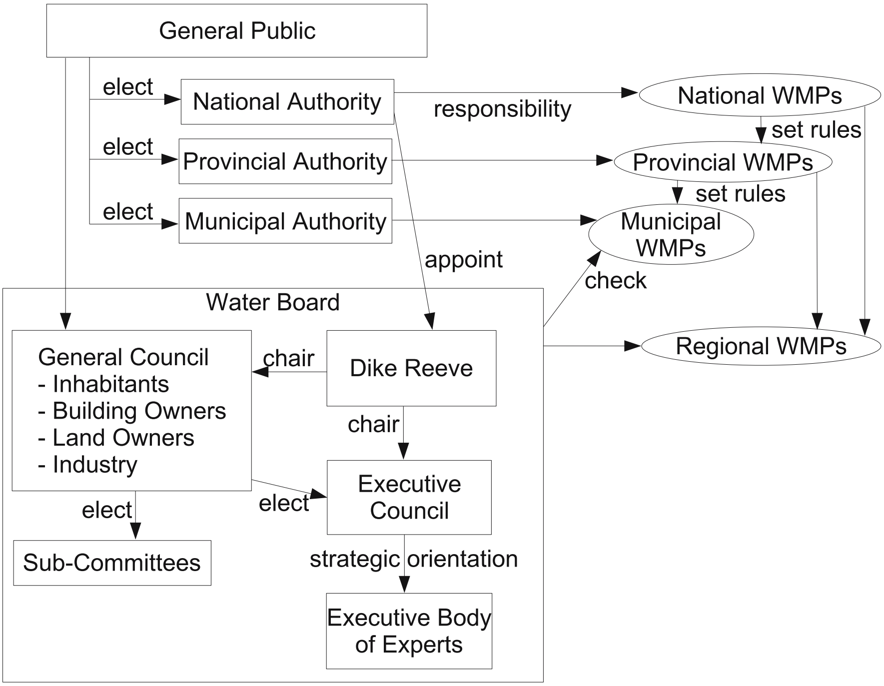

Fig. 4 The Kromme Rijn management regime. Source: own presentation

4.2 Democratic legitimacy and effectiveness of decision making

When comparing the two cases it becomes clear that compared to the German situation the general public in the Netherlands has more opportunities to directly influence water management decisions at different levels, including the direct possibility to elect representatives in the General Council of the Water Board. This allows a wider range of groups to be directly involved in water board decision making, whereas in the Wupper case the wider public is only indirectly represented by municipalities and district representatives. Table 1a and 1b show how the members of both decision-making councils are determined by two different systems and boundary rules. In the Wupperverband, membership is forced by law for fixed user groups, whereas in the Dutch Water Board system members of the General Council are elected through direct elections. For both systems the level of representation and payment of user groups is based on the level of water use and pollution.

Although the Dutch system seems to be more directly democratic and accountable for making decisions on water management, it is generally recognized by the interviewees that this comes at a cost. First of all, despite the historically grown democratic character of the Dutch water board system, elections typically attract only a small electorate and the low attendance levels (25% on average) reduce the legitimacy of the water board to take decisions. Second, according to HDSR policy makers, large differences in experience and capabilities of the Council members prevail, and direct personal interests in the issue slow down the decision making process (Interviews with two HDSR policy makers on 5-3-2007 and 22-3-2007). The Water Board currently tries to improve effectiveness in decision-making by inviting stakeholder groups to participate in early stages of the planning process. We will come to the question of informal stakeholder participation in paragraph 4.4. An upcoming shift in the Dutch national water management laws, aimed at changing the boundary rules during water board elections from personal election to a system of political parties, is planned to lead to better developed policy plans, greater outreach to the public, and more effective decision making.

With respect to adaptive governance it seems that a balance needs to be found between representativeness and democratic legitimacy of regional water agencies and effectiveness of decision making processes. While the inclusion of a higher number and broader range of participants in regional water management agencies increases the probability that changing conditions are recognized, it is important to assure the effectiveness of processes in order to be able to allow for changes in the system. If formal institutional procedures fail in successfully balancing both criteria informal processes - such as public participatory processes - if efficiently organized, can provide an alternative to enlarge the adaptive capacity.

4.3 Emergent leadership and the position of management

Strongly related to the discussion above is the role of leadership in the water agencies studied. It has been argued that leadership is a key element for enabling adaptive management in complex social-ecological systems (Folke et al. 2003). In addition to providing a vision and building and keeping trust, leaders can deal with conflicts, combine different sources of knowledge, and mobilize support for change (Folke et al. 2005). Olsson et al. (2006) illustrated that successful leaders are able to understand and communicate a wide set of technical, social, and political perspectives regarding the particular resource issues at hand. They play a key role in integrating, understanding, and communicating in multiple arenas. Usually, that integration involves networking with key groups, including shadow or epistemic groups (Olsson et al. 2006).

For the present analysis it is necessary to emphasize the distinction between the formal position labelled “Daily management” in a and 1b 1 and leadership as emergent in decision making processes. People in management positions have opportunities for action that others do not have, for instance the possibility to add issues to an agenda. However, whether or not these leading persons emerge in a planning or decision making process, depends on the other participants’ perceptions of their contributions. In accordance to Hosking (1988), we define leaders as those that emerge in a process as “those who make especially salient contributions,” which take the form of leadership acts only if the influence exerted through them is acceptable to others.

In the Wupperverband, the managing director structurally holds a central position in the planning and decision making process. The position is strategically located between the expert body and the members (see Fig. 3). Interviews conducted with Wupperverband representatives show that in general the recommendations of the managing director are taken up by the responsible decision-making bodies of the members. This is linked to several reasons, among others the stable membership fees, good information policy between experts and members as well as trust between the concerned parties (direct information from an expert of the Wupperverband on 04-05-2007). Apparently, in the Wupperverband, a strong management position is combined with skilful and acceptable leadership.

The position of the Dike-reeve in the Dutch water board system is also central (see Fig 4). Unlike to the managing director in the Wupperverband, the position of the Dike-reeve is appointed by the Dutch Crown. As the chair of both member councils and the main spokesman, the Dike–reeve has important process coordinating and representative tasks. The responsibility for internal planning and the outcome of decision making processes, however, is shared between the Dike Reeve, the Executive Council members and the senior policy makers. This approach allows for emergent leadership from representatives of the last two categories.

Concerning the Wupper regime, many interviewees in the Wupperverband perceived the current leadership of one person – the managing director – as being positive. Strong leadership can make institutions more effective as, for example, long discussions can be avoided. These findings go along with those from Olsson et al. (2004) whose investigation of successful adaptive co-management processes showed that a key person, able to transport a clear and convincing vision and trusted by other stakeholders, was central to the success of the management process.

However, we have to realize that the adaptiveness of the institutions largely depends on the personal and strategic abilities of that one person. In other words, while it is quite effective, strong leadership also comes at a risk, for example, in the case of a future managing director who might not head for progressive water management or who does not have the experience or knowledge of its predecessor. In the long term a new managing director might have to undergo a long learning process, if experience and institutional knowledge were not shared by several persons, or not effectively transmitted to others. Such learning processes can be seen in light of the social learning concept (for example Mostert et al. 2007). Therefore, we argue that sharing responsibility for process and outcome and stimulating institutional learning is more adaptive in the long run.

4.4 Participation of relevant non-members and nested institutions

In the Wupperverband membership is fixed by law and thus rather stable, whereas at the HDSR membership seems more adaptive when it comes to including new members representing emerging issues and interests (see Table 1a and 1b). This is due to the fact that the inhabitants of the area are entitled to elect members of the Water Board providing a direct feedback loop between the public opinion and the representation in the Board. Despite the public's prevailing lack of interest in these elections, the flexibility of the Dutch membership structure is higher, meaning that the resulting planning and decision making processes target the problems of various groups more easily and directly.

Besides including new members in the existing decision making structures, another way of recognizing and responding to emerging issues or changes allows new ways of stakeholder participation in planning processes initially not foreseen in the organizational structures. These can also be seen in line with the shadow networks considered as successful ingredients for transformation processes (Olsson et al. 2006). Olsson et al. state that successful transformations towards adaptive governance seem to be preceded by the emergence of informal networks that help to facilitate information flows, identify knowledge gaps, and create nodes of expertise of significance for ecosystem management that can be drawn upon at critical times. In our case this means that the interests of non-member groups which are not considered within the formalized decision making structures, can be fed into the processes from informal structures outside the established system.

In fact, at the HDSR participation of relevant stakeholder groups in the early planning phase is increasingly recognized as an effective way to smoothen the decision making process. As the interests of different user-groups are adequately addressed in policy planning, the General Council members will more easily reach consensus. The extent to which stakeholder participation is allowed in HDSR planning processes is decided on a case by case basis. According to a water board policy maker, the problem is that many aspects of water management do not allow for participation. It is stated that it has to be very clear from the start on which issues stakeholders can participate and what aspects are non-negotiable (Interview HDSR policy maker 5-3-2007). Stakeholder processes can also open the way for new discussion rounds with perceived less effective decision making on the short term. However, allowing stakeholder participation and bridging perspectives and interests of a wider group of stakeholders may be more effective in the longer term. Clearly, here the tension between accountability, legitimacy, and effectiveness recurs.

Adapting to changing conditions, by including new user-groups or stakeholders in the organisational structure of the Wupperverband, is more difficult in the German case and would entail changing the law. Evidence from a number of interviews held with Wupperverband representatives suggests that this intervention is considered not necessary at this stage. In line with the development towards new strategic goals under the WFD, the Wupperverband aims at opening up for new and informal co-operation with additional user groups instead. This is currently realized by inviting representatives of interest groups to participate in workshops and public information meetings. Doing this can partly overcome the non-inclusion of new stakeholder groups or any group that is not included in the initial law, such as fishery, into the formal procedures. It also allows for discussing interest shifts away from the stakes of initial members that can otherwise not be taken into account. Thus informal co-operation which takes place outside of the formal structure is one way to include new groups and views of stakeholders into the discussion.

For adaptive management, participation of a broad stakeholder community facilitates the adaptation to emerging issues by recognizing new challenges and also possible needs for institutional change. Effective decision making requires leadership to some extend, while maintaining adaptive and responsive to new challenges. This requires either inherent flexibility in the decision making structures, or the ability to create new and at first informal structures that enable new groups to take part.

The adaptive capacity of the water agency can also be increased by co-operating closely with authorities and other water institutions at different levels. Such nested institutions (also see Ostrom 2005: 269) facilitate coherence and consistency in policy, while other authorities and institutions can help recognizing emerging issues and changes from different governance levels.

As Figures 3 and 4 illustrate, both the Wupperverband and the HDSR are part of a broader governance system but are nested in different ways. Representatives of District and Municipal governments are formal members of the general assembly of the Wupperverband and can assure the consistency of the water agency's policy with the public authorities (see Fig. 3). The Wupperverband has further to act within the obligations set by the Land level in difficult legal prescriptions. Being a public authority itself, consistency of policy of the HDSR with higher level authorities and the Municipalities is guaranteed by the obligation to stay within the scope of higher level Water Management Plans (WMPs) and various monitoring functions (see Figure 4). In addition, policy makers of Provincial and Municipal governments responsible for water management are increasingly involved in informal participatory planning sessions.

5 Conclusion

This paper analyzed some major differences and similarities between two regional water agencies in the Rhine basin. While the basic frame of the organizational setting of the water management regimes still differs, the common frame of the WFD seems to drive an evolution towards increasing equivalence in function. Both water agencies have set new aims towards a more ecologically sound management and are open for addressing issues of new user-groups – either formally or informally. While a strict frame of general organizational structures prevails, both systems are able to adapt within this frame, but in different ways.

Using the IAD framework we have compared important positions and actions of participants in the planning and decision making processes of both water agencies. Compared to the Wupperverband, the HDSR proves to be more flexible in adapting to the changing needs of inhabitants and users in the region, and to changing management goals. The HDSR system has a democratic feedback loop that legitimizes decisions and anticipates to changing conditions. In the case of the Wupperverband changing the membership structure to better represent the interests of other users and inhabitants would entail changing the law, which is currently not regarded necessary by the actors interviewed. However, the Wupperverband is able to engage additional stakeholder groups by opening up informally by means of workshops on water management questions.

The previous section has shown that a balance is struck in adaptive water management institutions between taking legitimate and accountable decisions (addressing issues and stakes of all those involved) and the effectiveness with which these decisions are taken. With regard to effectiveness, the Wupperverband seems to be performing better in the current management situation. It has become clear that the leadership position of the managing director of the Wupperverband stimulates effective decision making processes and determines the strategic direction of the water agency to a large extent. On the other hand the democratic structure of the HDSR, despite being an adaptive element, can hamper effective decision making due to not finding a compromise. In the long run though, the transmission of social capital and institutional learning is easier between groups that share responsibility than between two leading persons in case of a management shift.

Remarkably, stakeholder and public participation is considered in both agencies as a possible way to face new challenges. At the HDSR, both public and stakeholder participation in the planning process is currently employed to anticipate difficult decisions at a later stage. At the Wupperverband relevant stakeholder groups that are non-members are increasingly often invited for workshops and informal meetings. This way, planning and decision making processes are conducted in a legitimate and effective way.

Acknowledgements

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Intellectual history and current status of Integrated Water Resources Management: A global perspective

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Abstract

As a conceptual solution to the complex problems of water management the concept of Integrated Water Resources Management [IWRM] has recently come to prominence. Though institutional transfer of IWRM from international to domestic arena has been widespread, this process is arguably under-researched. This paper attempts to address this problem by looking at the area of history and theory of IWRM, in particular focusing on how deeper analysis of the conceptual framework of IWRM can enhance the current understanding of the institutional transfer of IWRM. The paper consists of three parts. The first part deals with the history of the IWRM concept and its relations with other theories [e.g. integrated resource management, strategic planning]; the second part is devoted to globalization of IWRM and introduces the notion of policy transfer networks as applied to water governance; and the third part analyzes the on-going process of institutional transfer of IWRM to Guney-Dogu Anadolu Projesi [GAP] project in Turkey.

Key words: IWRM, policy transfer networks, strategic planning, GAP, Turkey

1 Introduction

It has been nowadays widely accepted that the essence of the current water crisis is not as much in resource scarcity and poor infrastructure, as in power, poverty and inequality [UNDP 2006]. To put it more specifically, the central problem of water resources often has been seen in the *fragmentation* of water management by sectors and media [Agenda 21, Article 18; GWP TAC 2000, GWP 2006 etc.]. In response to this recognition the plea for a more holistic vision and management embodied in the concept of Integrated Water Resources Management [IWRM] came to prominence starting from the 1992 Dublin Conference on Water and Environment and the 1992 United Nations Rio Summit on Environment and Development. The most cited definition of IWRM is:

> …a process which promotes the coordination of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems”
>
> (GWP TAC 2000)

The IWRM concept is undoubtedly the most popular concept for water management existent in the global rhetoric at the moment [UNDP 2006, GWP 2005 etc]. The WEB issue analysis of the IWRM concept conducted in 2005 [Thelwall et al. 2006] showed considerable representation of the IWRM literature on the web with 41,381 hypertext markup language [HTML] pages and 28,735 PDF documents mentioning the issue available to download. Such prominence is not limited to the WEB only, but is revealed in a number of reports of the high-profile organizations and initiatives launched to support IWRM planning. Examples include Agenda 21 [Article 18] 1992, where the aim to have the National IWRM Plans by the year 2000 was explicitly stated; and the WSSD summit of 2002 which extended this deadline to 2005. IWRM was embraced by such organizations as the United Nations Development Programme [UNDP, 2006], the United Nations Environmental Programme [UCC-IWRM], the World Bank [WB], the Asian Development Bank [ADB 2006], the World Water Council [WWC], the European Union Water Framework Directive[EU WFD], and most famously by the Global Water Partnership [GWP 2006] etc.

Why should the IWRM concept be important to research? There are three main reasons. First of all, it is defined quite in general terms and proved difficult to interpret for practical purposes. There is still much debate about the practical value of IWRM and additional inquiry into history and intellectual foundations of the concept is desirable. Secondly, due to intensified globalization, the IWRM concept contemporarily readily travels across nations and has turned into a truly global discourse. This transfer of IWRM occurs at multiple levels and constitutes high complexity, which is crucial to be understood. Moreover, creation of a global discourse around IWRM policy adds a discoursive dimension to a previously only normative or prescriptive concept, therefore amplifying its nature. This interplay of IWRM as both a normative and a discoursive concept needs to be researched. And thirdly, it was noticed that many ideas and policies are being transferred across nations long before they have actually proven themselves empirically, taking as such various non-intended forms of transfer [De Yong 2002, Lodge and James 2003, Rogers 2003 etc.]. There is a danger that this is happening with IWRM and this is issue has to be studied too. These three main reasons constitute the rationale for research in this field and thereby justify importance and timeliness of this paper.

First of all the paper discusses the intellectual history and conceptual basis of the IWRM concept and attempts to throw light on possible reasons of why IWRM implementation has been somewhat problematic; the second part focuses on global institutionalization of IWRM and offers valuable notion of policy transfer networks in the global water governance; and the final third part briefly illustrates the value of policy transfer and networks approach to IWRM to study water reform at national level employing an example of the GAP project in Turkey.

2 Intellectual history and the conceptual basis of IWRM

2.1 History of IWRM

There seems to be a tacit agreement that the IWRM is something principally new that emerged after the 1992 Dublin Conference on Water and Environment and the 1992 United Nations Rio Summit on Environment and Development [Wolsink 2005, Bellamy 1999 etc]. I hereby argue that labeling of IWRM as new or old can be made only after specifying the exact meaning of the word "integrated". Let us illustrate our point by taking an example of categorization of IWRM by Mitchell [1990]. In his first definition IWRM means *"systematic consideration of the various dimensions of water: surface and groundwater, quantity and quality"*. This approach is fed by the theory of *ecosystem* management, but does not include social systems. It was broadly used with the Progressive Era in the USA in the beginning of the 20th century. As White [1969] puts it: "…the idea of multiple-purpose water construction within entire drainage basins had its roots in technological advances of the early twentieth century, which permitted low-cost construction of large dams through use of concrete and of earth moving equipment, generation of hydroelectric power, and electric energy transmission over long distances". So, there is nothing new about IWRM in this sense. Secondly, IWRM can encompass *"water system… in interactions with other systems [land, ecosystems]. Knowledge of both terrestrial and aquatic systems, erosion control, diffuse pollution control, wetlands is necessary in this approach"*. This approach is closer to Integrated Resource Management theory [or ecosystem-based management]. It also does not take account of the social system in a full manner. The Tennessee Valley Authority in the 1930-s is a good example, that has been extensively studied [Rahaman and Varis 2005, Barkin and King 1986, Tortajada 2004]. And thirdly, *"water can be considered as connected with the broader social and economic development"*. This approach is the most "integrated" taking into consideration biophysical, social and institutional factors, while bringing them together at the higher level of public sector strategic planning. In this view, the IWRM concept is truly new.

To sum up, the principles behind the IWRM are not newly developed in the 1990-s within the Sustainable Development thinking, how it is argued in a number of sources [GWP 2005, Bellamy 1999, DIE 2006] but are rather old, dating back to the multiple purpose river development practices in the USA in the 1930-s, and at the global level to the UN document titled "Integrated River Basin Development: Report by a Panel of Experts" from 1958 which recognized IWRM as the generally advisable practice [New York: UN 1958], [White 1969].

However, if one takes the third definition of the nation wide planning and incorporation of water resources at the highest level, the IWRM appears to be new and has to be given appropriate attention. History, nevertheless, matters and water management experiences, especially those of the 20th century, should be investigated in depth to derive useful policy implications.

2.2 Conceptual basis of the IWRM

2.2.1 Rational comprehensive planning and conservation movement

As was mentioned above, first efforts towards rational comprehensive planning in the water for integration of flood control, pollution control, water supply and conservation took place in the 1930-s in the USA. However, early attempts to *integrate* largely failed because they tried to center on *comprehensive plans.* The concept of *rational comprehensive planning* was deemed as the best during the Theodore Roosevelt's *conservation movement* in the USA in the 1890-1920 years. It was based on the Baconian-type belief in applied science as an omni-potential tool for effective decision-making, while paying little attention to democratic processes. Being in nature centralized, expert-driven management idea, it was against the "democratic" means of decision-making through lobbying and the struggle of different organized interests, called otherwise "politics". The rational comprehensive plans of multi-purpose water developments often failed because they were not always needed, recommendations were often too numerous, and planning studies were expensive and time consuming [Hays 1959, White 1969]. In this discussion it is appropriate to indicate a very relevant discourse of *Strategic Planning and Management* that has been around for some 40 years [Mintzberg 1998, Bryson and Einsweiler 1988]. While Strategic Planning is distinct from comprehensive planning by putting a bigger emphasis on selectivity of goals, priorities and clarity of the means to achieve them, the whole idea of IWRM with integration in the long-run and ambition to control a complex system in a turbulent environment is very similar to the concept of Strategic Planning. More subtle links between IWRM and SP will be established later in this paper.

2.3 Integrated Resource Management [Ecosystem-based management]

According to Mitchell [1990] "Integrated Resource Management is the sharing and coordination of the values and inputs of a broad range of agencies, public and other interests when conceiving, designing and implementing policies, programs or projects." This approach, being conceptually attractive, encountered a number of obstacles on its way to implementation. According to Blomquist [2005] this is because of the *"wicked"* character of the natural resources planning. "Wicked problems and messy situations are typified by multiple and competing goals, little scientific agreement on cause-effect relationships, limited time and resources, lack of information, and structural inequities in access to information and the distribution of political power"[Lachapelle et al. 2003]. Under such circumstances, "normal stage-based planning" with identification of the problem, consideration of alternative solutions, selection of a proper one and policy implementation just would not work! To the contrary, planning in the "messy" situations should be "politics with science advisors" and inclusion of two main steps should be ensured: ***1] public participation*** *to the point when it becomes intrinsic to the process of planning; and* ***2]*** *exploration of the* ***role of*** *science* *in messy situations and the relationship between* ***politics and science****.* [Burchfield 1998].

These three main principles are also envisaged in the recommendations of various organizations give with regard to IWRM. However, I have never seen such categorization advanced specifically for IWRM. Therefore, I would suggest that these three principles of IRM encounter main principles lying in the nutshell of the IWRM concept.

> ***Integrated Resource Management*** has three main principles: **co-ordination**, **stakeholder participation** and existence **of different level of decision-making** at which integrated resource management can be pursued [Mitchell, 1990].

2.4 The Problem with implementation of the IWRM concept

The World Summit on Sustainable Development [WSSD] in 2002 called for all countries to draft IWRM and water efficiency strategies by the end of 2005. At the end of 2005 only 20 of 95 countries surveyed by the Global Water Partnership produced or significantly progressed towards such plans [see Table 1].

Table 1. The Survey on the Page with the IWRM Plans [GWP 2006]

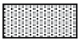
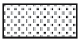
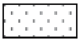
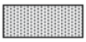
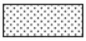
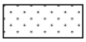
				Total
Number of countries	20	50	25	95
Percentage	21%	53%	26%	100%

Table 2. The Legend for the Table 1 [GWP 2006]

	Countries that have plans/strategies in place, or a process well underway, and that incorporate the main elements of an IWRM approach.
	Countries that are in the process of preparing national strategies or plans but require further work to live up to the requirements of an IWRM approach.
	Countries that have taken only initial steps in the process towards preparing national strategies or plans and have not yet fully embraced the requirements of an IWRM approach.

Nominally integrated water resources management plans, that have been developed [20 by 2006] say little about whose interests are served or whose voice is heard. In many cases integrated water resources management has a technical rather than social focus. Far more attention has gone to increasing the efficiency of water use through transfers into higher value-added areas or through new technologies than to the equity and social justice central to human development [UNDP 2006]. Thus, the primary criticism of IWRM converges at its dubious record of implementation, and not only since 1992 when it got globalized, but since the 1930-s when the multipurpose comprehensive plans could not be realized in practice effectively [White 1969, White 1998, Sabatier et al. 2005]. IWRM was also criticized for negligence to the local conditions and "one size fits all" approach (Moss 2003). It was also suggested that IWRM principles contradict to the democratic principles "carry the seeds of centralization and gigantism, fail to incorporate adequately the elements of decentralized, local, community-led planning and management" (Rahaman 2005).

Although it is beyond the scope of this paper to engage with the debate about the practical value and features of the IWRM concept as it appears in the normative way, I hereby suggest to make a brief endeavor into the field of Strategic Planning in order to illustrate the potential value of a more in-depth inquiry into this field. Like IWRM, Strategic Planning (SP) has an ambition of long-term planning as opposed to short-term problem solving; of identifying direction as opposed to moving in a given direction; of more innovative solutions as opposed to solutions based on the existing ideas; of synthesis as opposed to analysis; and of a greater attention to future possibilities, strengths and opportunities as opposed to attention to present trends, weaknesses and threats [GWP 2005]. SP symbolizes epithets such as "systematic, efficient, coordinated, consistent, and rational" [Mintzberg 1994] and it is of little surprise why Strategic Planning was so popular in both public and private sectors. A guru in the field of SP, Henry Mintzberg, identified the advantages and threats of SP, which in my opinion can be beneficially utilized for IWRM as well.

Table 3. Examples of insights from the Strategic Planning discourse to inform the IWRM discourse [adapted from Mintzberg 1994 and GWP 2005]

IWRM plan (GWP 2005)	Strategic Planning [Mintzberg 1994, 2003]
1] The IWRM sets direction for long-term planning of water resources to reach poverty reduction and other Millennium Development Goals by 2015.	Advantage "The main role of strategy is to chart the course of an organization in order for it to sail cohesively through its environment". Threat There is a danger of setting a course in the unknown and dynamically changing waters called "fallacy of pre-determination". "While direction is important, sometimes it is better to move slowly, a little bit at a time…"
2] IWRM is seen as a policy cycle that starts with a vision, proceeds with the situation analysis and strategic choices for drafting an initial IWRM plan, which is then put in practice, monitored and the feedback is linked to the vision again. Stakeholder participation is recognized as crucial in this process.	Advantage "Strategy is needed to reduce ambiguity and provide order. In this sense it is like a theory: a cognitive structure to simplify and explain the world, and thereby facilitate action." Threat There is a danger in viewing preparation of plans and their following implementation in separation, called "the fallacy of detachment" [Mintzberg 2004]. It says "effective strategy making connects acting to thinking which in turn connects implementation to formulation…either the formulators [of plans] have to implement or else the implementers must formulate".

Adapted from Strategic Orientation [SOR], MDF Training and Consultancy, Ede, The Netherlands. Source: GWP [2005].

To sum up, it has been argued that IWRM is conceptually based on the theories of planning, especially SP ideas and is guided by three principles of IRM: coordination, participation and consideration of multiple levels of governance. Implementation of IWRM has been briefly discussed and while no clear answers to the question of why it is hard to put IWRM plans in practice are provided, it is suggested that deeper research should be made into the field of SP to inform the current IWRM discourse and practices.

3 Global discourse of IWRM and policy transfer

If IWRM has proven difficult to implement and is arguably controversial, how can one explain its proliferation at the global scale? One could speculate about the motives, about the interests and the function of the concept globally, but it would be impossible to make a valid claim or even a testable hypothesis if I do not first try to understand the process of how the IWRM concept was disseminated all over the globe, who were the actors and what mechanisms were at work. For these purposes I utilize the concept of Policy Transfer and Global Networks that are methodologically combined to offer an approach called *Global Policy Transfer Networks*. "…refers to the process by which knowledge of policies, administrative arrangements, institutions and ideas in one political system (past or present) is used in the development of policies, administrative arrangements, institutions and ideas in another political system" (Dolowitz 2000; Dolowitz and Marsh 2000). Policy Networks theories focus on the dynamics of interaction of actors, and the patterns of their interaction over time. A combination of these two approaches helps to illuminate the current global water governance in the mode of transnational networks, rather than in the mode of static organizations.

Building on the valuable theories and models suggested by Walt et al. [2003], DiMaggio and Powell [1983], Haas [1992], Stone and Maxwell [2005], and Saleth and Dinar [2005] I offer a model to depict current global water governance. Based on the Walt et al. [2003] model, I argue that evolution of the IWRM discourse proceeded in three loops: 1] Knowledge-generation from "bottom-up; 2] Policy standardization and formulation at the international level; 3] "Marketing" and promoting policy transfer from "top-down". Different kind of networks participated at different stages.

Figure 1 provides description of the network/partnership-based understanding of water governance as it has been evolving from the 1970-s onto a global scale nowadays. In the first loop experts trained within different disciplines came together since the 1970-s to form a global "epistemic community"[1]. Epistemic communities were comprised of professional consultants and researchers who share common ideas for policy and seek

[1] An epistemic community is a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area [Haas 1992].

privileged access to decision-making for a on the basis of their expertise and scholarly knowledge. Due to ambiguity and uncertainty associated to water problems in the 1980-s and 1990-s many politicians turned to epistemic communities for advice, but generally, they require political patronage to legitimize and apply their knowledge. Examples of epistemic communities include International Water Resources Association (IWRA) created in 1972, International Hydropower Association created in 1995, International Water Management Institute created in 1984, International Commission on Irrigation and Drainage created in 1954.

The second loop involved the so-called "Global Knowledge Networks" [KNETs]. According to Stone [2005] KNETs "…incorporate professional bodies, academic research groups and scientific communities that organize around a special subject matter or issue. Individual or institutional inclusion in such networks is based upon professional and/or official recognition of expertise, as well as more subtle and informal processes of validating scholarly and scientific credibility. The primary motivation of such networks is to share, spread, and, in some cases, use that knowledge to inform policy and apply to practice". This Network has involved NGO-s and Think Tanks as well as IFI-s and the research carried out by them. However, Stone warns that "KNETs also might fall in the same pitfalls: lack of democracy, accountability and transparency. They can be biased by framing of the agenda by dominant institutions and individuals; legitimize or challenge power" [like the Evian Group]. Examples of the KNETs are the World Water Council created in 1994, and the Tokyo Club created in 2000.

The third loop started in 1996 when the World Bank, the United Nations Development Program [UNDP] and the Swedish International Development Agency [Sida] created the Global Water Partnership [GWP] in 1996. Reinicke and Deng (2000) recognize the GWP as the Global Public Policy Networks (GPPN). These networks enter the realm of politics and does the twofold job: 1] simplify the work of the epistemic communities and the KNETs in an effective and most commonly usable way; 2] communicate and disseminate the simplified strategy. Usually dropping of complexities and over-simplifications achieved at this loop leads to some conflicts among scientists. They often are defined as "the quasi-corporatist alliance of governments, agencies and civil society working together to deliver health care or a similar public good. [Reinicke and Deng 2000]". Actors engage to pursue material interests, but have in common a shared problem. GPPNs also act as advocates but are more institutionalized, performing with a greater degree of "delegated authority" as opposed to advocacy groups. The GPPN basically start to apply their standardized guidelines and the expertise at the national levels, as currently is taking place with the

IWRM concept. The framework of Saleth and Dinar [2005] is presented to depict the water institutions at the national level. These linkages can be of particular interest to a researcher, especially if the emphasis is made on the linkages between the global and national level water policies.

To sum up, Figure 1 presents water governance from a new angle of policy transfer networks. Networks are convenient research units, as well as a welcomed development in the governance field thanks to many advantages they have. For example, according to Stone [2005] networks may involve dissidents or subaltern players and in the meantime stay stable; networks provide possibilities for southern based organizations to influence policy, and networks attract more attention of donors and more research than organizations. Nevertheless, Stone [2005] also warns that networks might fall short to have lack of democracy, accountability and transparency. They might be biased by unequal power relations, for example. These challenges need to be understood and mechanisms to foster network governance developed by the world water community if the ambition to improve global water governance is pursued. The mechanisms through which the policy transfer networks operate still need to be better understood, as well the factors which influence their success and failure. A methodology to study such networks needs to be put forth and applied to the field of global water governance.

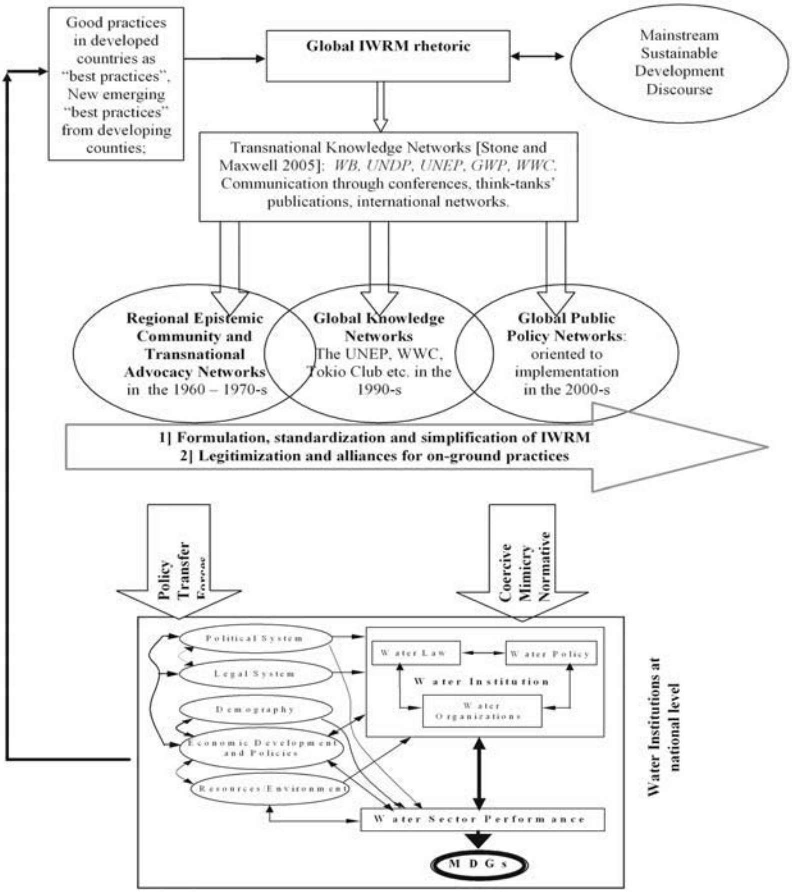


Fig. 1 The Global Networks in Water Governance at work. Adapted from Walter 2003, Haas [1992], Powell and Di-Maggio [1983], Stone [2005], and Saleth and Dinar [2005]

4 Application of policy transfer networks to study national level water governance

In this section I are interested in the engagement of Global Public Policy Networks with the national water policies through policy transfer mechanisms. The case on IWRM in GAP [Southeastern Anatolia Project in Turkey] is presented to illustrate the value of the *policy transfer networks* approach to study IWRM at national level.

The GAP [Southeastern Anatolia Project in Turkey] is a 32 USD billion, multisectoral, integrated regional development programme, encompassing construction of 22 dams and 19 hydro-plants for irrigation and electricity production [Unver and Rajiv 2004]. The main distinguishing feature of this large-scale project from others in Turkey and in the region is its explicit ambition to achieve a "water-based sustainable regional human development" [GAP-RDA 1995, GAP-RDA 2002, Unver 2001, pers. comm.]. GAP has a long history that started in the 1930-s with an idea to harness the Tigris and Euphrates rivers for electricity production and agricultural development. The inspiration for the GAP project came from the Tennessee Valley Authority in the 1930-s and the main plans for GAP were drawn in the 1950-s by the State Hydraulic Works of Turkey (established in 1954). In the 1970-s, when the major construction works within the project started, it was first conceived as "a package of water and land resources development project", which then developed into "a multi-sectoral, socio-economic regional development programme in the early 1980-s, and a "sustainable human development project" later in the 1990-s [Unver and Rajiv 2004]. This evolution of development approach obviously reflects evolution of water management paradigms at the global level culminating with the concept of IWRM n the 1990s, which is very close to what the GAP-RDA calls "water-based sustainable regional human development" (only with regional overtones).

In 1989 the government with the help of a Japanese consultant company formalized the GAP Master Plan, which established the general framework for integrated regional development. Many approaches that were used in the TVA and American experiences with "unified river basin development" were offered including creation of a separate administration fully responsible for the project. However, those proposals had to be adjusted to the national and local conditions and as a result there was a separate entity created, the GAP Regional Development Administration [GAP-RDA]. GAP-RDA which was given a task of multi-sectoral planning, the ability to integrate water and land use planning and development, independence from the existing government hierarchy, and the flexibility to collaborate with the private sector, local governments, NGOs, international organizations, and professional societies. However, it lacked the real authority to do so (pers. comm.). Therefore, the case of "TVA policy transfer" did not take place as another "hybrid" administrative model was chosen for the project due to political reasons.

The GAP project is managed by three governmental agencies: the State Planning Organization (SPO), the State Hydraulic Works (SHY) and the GAP-RDA. The SPO is responsible for approving all the plans and allocates state investments; the State Hydraulic Works is responsible for the whole water sector in Turkey and is the actual implementing agency that builds the dams, irrigation infrastructure and is responsible for their maintenance and operation. The primary mandate of the GAP-RDA is planning, monitoring, reporting and coordination of stakeholders with the purpose to achieve "sustainable human development".

GAP-RDA was instrumental in engineering links with the IWRM networks. A crucial role in this networking was played by the president of the GAP-RDA, a progressive American-educated policy entrepreneur who has managed to engineer strong links between the GAP-RDA and international organizations. Thus, technical and capacity-oriented partnerships were established with EU (47 million USD grant for the GIDEM[2] project), with UNDP (5.9 million USD for SDP); with FAO, UNICEF, WB, UNIDO etc. GAP-RDA was especially close with IWRM networks, for example with the IWRA (an epistemic community). In 2000 GAP project received the IWRA Millennium Award for "Sustainable Water Resources Management Project". Also GAP-RDA kept close contacts with the WWC – (a KNET). These linkages and resulting policy innovations and transfers still need to be better understood, but identification and classification of those contacts already provide a convenient framework for such an inquiry.

It is suggested that strong international linkages and networking by GAP-RDA were stimulated by two factors: lack of resources available for GAP-RDA at the national level; and personal contacts and initiative of a policy entrepreneur acting at that time as a president of GAP-RDA. Indeed, many ideas were advanced through the networks to the national level, but only few got implemented. IWRM concept has been institutionalized within the GAP-RDA but failed to spread beyond this organization

[2] Entrepreneurial Support Centers were established in the GAP region to facilitate business developments.

to have a real impact on the project. Therefore success of policy transfer was limited.

As for the mechanisms of policy transfer in GAP all three pathways illustrated in Figure 1 were used by the networks. The coercive forces were both “subtle” (GAP-RDA had greater propensity to adopt the IWRM concept and advocate for it due to the need to improve reputation of GAP as having grave transboundary impacts on Syria and Iraq downstream) and based on the resource-dependency model (GAP-RDA was limited in resources and could easier access international funds having the IWRM concept on board). The normative forces were based on personal contacts and beliefs of GAP-RDA managing staff, many of whom were educated in the West and had innovative visions about GAP. Mimicry forces played probably less a role, being limited to emulating rhetoric and policies of the TVA and suchlike project (GAP-RDA 1995, 1999, 2001).

To sum up, this section showed value of the policy transfer networks to study projects with IWRM planning and implementation at national and regional level. It was preliminarily suggested that policy transfer of IWRM occurred only to the GAP-RDA and not the GAP project (operated by SPO and SHW) and therefore policy transfer was limited. However all three pathways of policy transfer took place in the GAP-RDA case. Linkages between GAP-RDA and an epistemic community (IWRA), and a KNETs (WWC) were identified and a deeper analysis of these linkages suggested to be studied in the future.[3]

5 Conclusions

This paper brought up a number of points and suggestions for further research. To conclude, I argued that the IWRM concept is not a new phenomenon as most sources suggest, but has at least 60 years of history. Therefore, useful lessons can de drawn from looking into historical evolution of IWRM, especially in the 20th century. However, the concept of IWRM acts as a truly novel concept if *“... considered as connected with the broader social and economic development”*. Furthermore, it was identified that there are strong conceptual links between IWRM and Strategic Planning, and because SP discourse was developed earlier, the IWRM

[3] This is expected to be addressed at later stages of my PhD research

planners could potentially benefit by learning lessons from it. The view of currently complex global water governance through the lenses of policy transfer networks that were divided into Epistemic Communities, Transnational Advocacy Coalitions, Knowledge Networks and the Global Public Policy Networks was suggested. The three loops theory was incorporated into Figure 1 and showed that IWRM evolved in a consistent way from formulization of the concept in the 1970-s to its standardization in the 1980-s and 1990-s and subsequent simplification and application to the national levels in the 2000-s. I suggest that network management should be at the center of attention in the future research and action if the ambition of improved global water governance is pursued. Finally, the case of the GAP project was presented to illustrate the value of the global policy transfer networks and some preliminary observations have been presented. Many suggestions in the paper will be further developed and tested at the later stages of my currently on-going PhD research.

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A broadened view on the role for models in natural resource management: Implications for model development

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Abstract

Models play a central tool in the development and implementation of management strategies. In this paper we identify four major modeling purposes that are important for understanding and managing complex socio-environmental systems: prediction, exploratory analysis, communication and learning. Each of these purposes highlights different system characteristics, role of uncertainty, the properties of the model and its validation. We argue that uncertainty has no meaning in isolation, but only relative to a particular modeling activity and the purpose for which a model is developed (e.g., when a model is developed for predictive purposes uncertainty needs to be eliminated as much as possible, while when a model is developed for exploration uncertainty can be considered a source of creative thoughts). Here, we specifically investigate the implications different purposes have in dealing with uncertainties. We present a set of strategies modelers can use to guide their developments. In light of these concepts, the modeling activity is re-contextualized, from being a process that aims at representing objectively an external reality, to one that can only be defined according to the characteristics of the problem at hand: its level of complexity, the knowledge available, the purpose of the model and the modeling tools. We present an example from the adaptive management field.

1 Introduction

During the last decade the complexity and uncertainty associated with managing natural resource systems became apparent. Managers have been challenged to make decisions under fast changing socio-economic conditions, far-reaching technological innovations and climate change that affected the global, regional and local scales. This promoted the development and application of processes such as adaptive management, which are based on the premise that to deal with complexity and uncertainties solutions have to be flexible and capable to adapt to unknown and changing conditions. It has been suggested by several authors (Pahl-Wostl, 2007A; Gleick, 2003) that to be able to carry on such managing processes, a combination of hard and soft systems approaches is needed. In so doing, the use of models –conceptual ones or implemented in a computer- play a central role, since they provide a general framework where a diversity of managing solutions can be explored.

A model constitutes a simplifying abstraction of a real system and is built for a particular purpose. In natural resource management, it is a common practice to build models to predict, in space or time, the states of the system to be managed. These models are based on scientific knowledge and the information derived from them is used to aid decision making. Several examples can be found in the field of hydrological modeling; for instance, prediction of evapotranspiration to help managers developing water budgets to improve irrigation scheduling (Hart et al. in review; Mardikis, 2005; Kite, 1999); or, real time flood forecasting to help decision makers in the design of protective measures against floods (Chen and Yu, 2007; Toth et al., 2000). However, these models often fall short in fully supporting a decision making process (Gunderson et al., 1995). Generally, managers and decision makers have to deal with what has been defined as messy problems (Vennix, 1996); that is, controversial situations with conflicting interests in the problem domain, where the different opinions and perspectives have to be integrated in a solution. In particular, but not only in the presence of a contested knowledge base, more than one legitimate and plausible interpretation of a situation and potential future developments may exist (Dewulf et al., 2005). In such cases, models require incorporating subjective interpretations to capture the processes of learning and change (i.e., soft solutions, Pahl-Wostl, 2007A).

In this context, we think models should focus on the whole process of negotiation, learning, and communication, which constitutes the basis for decision making (Pahl-Wostl, 2007A). Using models for other purpose than prediction, not only changes the way in which models are built and conclusion derived, but also how uncertainties are considered and the meaning they have for modeling and the decision making processes. When a model is used for prediction uncertainties should be eliminated as much as possible, while when a model is built for exploration, uncertainty can be used as a source of innovative thought (Brugnach et al., in press). Despite increasing awareness about the different capabilities models offer, the goal of looking at a single best, simple and objective explanation, brought by models in their role of prediction, still permeates the modeling exercise.

What we believe is necessary is to broaden the scope of models use and to implement approaches that tailor the development of a model more closely to its envisaged use. To this end, we identify four major modeling purposes that are important for understanding and managing complex environmental systems: prediction, exploratory analysis, communication and learning. Here, we specifically focus on the role uncertainties play in models, and investigate the implications of the different purposes in dealing with this matter. Using these concepts, we present a set of strategies modelers can use to guide their developments.

We first present an overview of four different modeling purposes which set the context of modeling that we identify as being of major importance in natural resource management: prediction, exploratory analysis, communication and learning. For each of the different modeling purposes we then investigate how uncertainty should be addressed and included in the overall process of model development and application. We highlight where we see the major priorities to address uncertainties depending on model purpose. Finally, we present an example from the adaptive management arena.

2 Modeling purposes

2.1 Prediction

Even for complex environmental problems models may be used to predict dynamic characteristics of a system. In such cases, prediction is typically not focused on the forecast of the development of a single variable in a specific system over time and space. Prediction refers rather to understanding overall system properties such as the effect of increasing diversity on the adaptive capacity of a system or the influence of network structure on the spread of innovation in a social system (review by e.g., Levin, 1998). Hence, such modeling exercises can generate general insights and support the development of guidelines for integrated system design to achieve certain system properties (e.g. the role of centralized versus decentralized control in resource management regimes and implications for the ability of a regime to adapt to change (Pahl-Wostl, 2007B)).

2.2 Exploratory analysis

Models may be used to map the space of possible development trajectories of a system to find out more about unexpected behavior or thresholds leading to abrupt change. In general it may not be possible to determine the exact location of a threshold (Andries et al. 2006) or attach a number to the probability of certain development pathways, but simply providing evidence for its existence may be sufficient to trigger implications for intervention strategies. The development of possible and plausible scenarios should take part in participatory settings to include the wealth of tacit knowledge and creativity of human beings (Pahl-Wostl, in press; van der Heijden, 1996, 2000).

2.3 Communication

Models may serve the purpose to communicate insights into the specific factors and system structures that influence complex dynamics to decision makers, stakeholder groups and the public at large. Hence the educational potential of models to raise awareness and change deeply entrenched beliefs on the nature of system response can focus on the key subsets of complexity that need to be managed. An example is given by difficulties to understand implications of positive feedback cycles or the danger of responding in a reactive way to observed macroscopic change when threshold effects may lead to abrupt system change and the system may already be at a point of no return (Carpenter et al., 1999; Schlumpf et al., 2001).

2.4 Learning

Learning about complex systems requires communication that clarifies and deepens understanding. However, the learning referred to here refers goes beyond the individual. The model, and in particular the whole model building process, supports a process of social learning (Pahl-Wostl and Hare, 2004; Pahl-Wostl, 2002) and reflection in stakeholder groups. Those who are represented in the model actively participate in its design. Hence, the model becomes part of the system it is supposed to represent (Pahl-Wostl, 2002). This implies an extreme shift in the role of the model and the role of those who guide the process of model building. Scientists adopt the role of facilitators participating in a process of co-production of knowledge rather than being "external observers" who reveal objective, scientific truths (Vennix, 1996; Checkland, 1999; Sterman, 2000; Pahl-Wostl, 2007A).

Table 1. summarizes the implications of different modeling purposes on the system characteristics represented in a model, the role of uncertainties, important model properties and the type of model validation to be chosen.

Purpose	System characteristics	Role of uncertainties	Model properties	Model validation
Prediction	Stylized facts available, central elements of overall structure known, abstract representation possible	Uncertainties must be constrained within manageable bounds	Clear structural dimension with rules how to explore relationships systematically	Agreement of model results with observed system behavior
Exploratory analysis	Evolutionary, trajectories may explore large development space	Uncertainties as source for innovative processes	Evolutionary components	Plausibility of results based on expert and stakeholder judgment. Completeness of mapped space.
Communication	Complex dynamics leading to counterintuitive behavior. Robust knowledge on system complexity available	Uncertainties must be clearly captured	Simple and transparent	Adoption of new insights
Learning	Reflexive system Model internal to the system	Role of uncertainties in social interactions must be addressed	Focus on modeling process Highly interactive	Facilitation of social learning in group, plausibility assessment by stakeholders

3 Uncertainty as an intrinsic and irreducible property of models

When addressing complexity it is of limited use to talk about uncertainty as a single and distinctive concept. Uncertainty is a multidimensional concept; that originates from many different causes (Zimmermann, 2000). While uncertainty has been commonly viewed as an attribute associated with the quality of the information used to build a model, recent developments have expanded this notion to also include more subjective aspects in its definition (Patt, 2007; Brugnach et al., 2007; Refsgaard et al., 2005; Klauer and Brown, 2004; Walker 2003; Van Asselt and Rotmans, 2002; Pahl-Wostl et al., 1998). Following this line of thought, we refer to uncertainty as the situation in which there is not a unique and objective understanding of the problem to be modeled.

Here, uncertainty is considered from the point of view of the modeler, or those participating in the modeling exercise, who have to develop a model based on their understanding about the system to be modeled. Even though uncertainty can be due to deficiencies in the information used, it can also arise from the way in which the problem is interpreted and framed (Dewulf et al., 2005). Thus, a model conveys information that is filtered through the values, beliefs and experience of the modeling participants, who are the ones that ultimately conceptualize the problem and set the modeling objectives. This makes uncertainty a complex problem in itself, which cannot be considered external to the modeling process, its analysis and evaluation.

4 Treatment of uncertainty depending on model purpose

Uncertainties are an intrinsic and, for the most part, irreducible component of complex system understanding. The process of modeling can clarify these uncertainties to some extent by transparently and openly bringing them into the model representation, affecting the data, structure and framing of the model. In this context, the modeling process involves the creation of a meaningful representation, using not only what it is known, but also having to assume what it is *not known* about the system to be modeled. Uncertainties cannot be understood in isolation, but only in the context of a particular modeling activity and their importance is relative to the purpose the model is designed for. The combination of the model, or family of models produced, and the modeling process itself captures most of what participants negotiate and agree on as known and not known.

The previous section states that the uncertainty inherent in the empirical knowledge base and knowledge about system properties cannot be seen in isolation from the issue framing into which the whole modeling process is embedded. What is important and what is not important, and to whom is it important? Why do we choose to model what we model? These are questions that define the modeling activity as much as the information available as inputs (experience, data and opinions) or outputs (analysis, models, conclusions). Hence any knowledge about complex adaptive systems and in particular knowledge generated in a modeling process, which is an even higher level of interpretation, is context dependent. This context dependence is of overriding importance when the knowledge is to be used for system intervention.

5 Linking modeling purposes with uncertainty management

5.1 Prediction

When models are used for prediction, they are expected to capture the essential characteristics of the system to be modeled and to generate behavior that transparently and reliably mimics it. Thus, predictive models become devices that can be used as a surrogate of a real system. To this end, models should be closely matched to the system modeled, requiring the consideration of all the uncertainties that can prevent attaining this goal, either by reducing, eliminating or explicitly considering their effect(s) in the model. In models used for prediction, uncertainties in data stemming from measurement errors and the possibility of having a diversity of equally plausible model structures are of key importance. Key steps in improving and validating a model involve reducing and then communicating the residual, irreducible, effects of uncertainty in model predictions to derive the boundaries within which model results are valid.

5.2 Exploratory analysis

Models used for exploratory analysis focus less on mimicking reality and more on learning about general patterns of system behavior. These models are expected to convey alternative views of the system and to be used to explore the diversity of behavior different options can trigger. Thus, these models do not aim at predicting as accurately as possible a system's future states, but at uncovering in particular unexpected properties of the modeled system. Such exploratory models are especially useful when the knowledge base is very weak. Here, uncertainties do not necessarily need to be eliminated, but used for identifying different alternative scenarios that can be explored. Ignorance can be a source for creative thought when intelligently and skillfully exploited in an adaptive learning process. Beliefs and values shape worldviews, which can be the base for the development of coherent, internally consistent scenarios for the future.

5.3 Communication

Models are useful communication tools when they reduce complexity to the few salient characteristics of the system modeled which are most important to the actors for whom the model was constructed (e.g., Walker et al. 2006). However, communicating insight about systems dynamics means also to communicate about the uncertainties associated with these dynamics. This implies that these models must convey and illustrate the characteristics of the real system as well as the deficiencies in knowledge, interpretation and diversity of opinions about it. One the one hand, uncertainties play an important role in highlighting where the gaps in knowledge and understanding reside. On the other hand, it is even more important to convey the inherent limitations in the predictability of complex systems where non-linearity and feedback effects or the emergence of novelty may lead to unexpected behavior.

5.4 Learning

When used for participatory learning purposes, the differences between model and modeling process dissolve. Model and modeling are used in a group of actors to compare their different view points and opinions about a particular problem and perhaps derive a synthetic overview. Thus, the model becomes the vehicle to engage individuals in a dialogue with the aim of developing a solution. During this process, uncertainties become central in identifying the commonalities and differences in views, especially where differences become obstructive points of conflict. Knowledge elicitation techniques and participatory model building approaches can be used to make explicit mental models and frames (Hare and Pahl-Wostl, 2002; Vennix, 1996) which is of major importance for social learning processes (Bouwen and Taillieu, 2004; Pahl-Wostl and Hare, 2004).

The different purposes are not mutually exclusive when models are used in dealing with understanding and managing environmental problems. However, it is a real challenge and a responsible task of the modeler to make explicit and eventually combine different purposes in a scientifically credible and transparent way. Next, we illustrate these concepts with an example in the adaptive management arena.

6 Example from the adaptive management arena

Adaptive resource management is chosen as example of a management approach which is explicitly based on the insight that uncertainties and surprises are unavoidable in complex adaptive systems, making modeling a key tool for management. Adaptive management has been applied in ecosystem management for quite some time (Holling, 1978; Walters, 1986; Pahl-Wostl, 1995; Lee, 1999). The initial impetus for AM grew from the realization that the ability to predict future key drivers influencing an ecosystem, as well as system behaviour and responses, is inherently limited. Increasingly it became also evident that one cannot deal with environmental and/or social systems in isolation but has to adopt the perspective of tightly coupled social-ecological systems and shift management goals towards properties of these coupled systems (good overview in Berkes et al., 2003). Hence, management must be adaptive and should include the ability to change management practices based on new experiences and insights. For example, changes can be brought by improved understanding of the response of ecological and social systems to management interventions, or by a change in the socio-economic boundary conditions.

Adaptive management refers thus to a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies and taking into account new developments influencing the success of management practices (Pahl-Wostl et al., in press). In the first phase of such a process, participatory assessment, the often ill-defined and controversial problem situation in the current management system is structured as an integrated process. The second phase, participatory policy formulation, identifies the possible and desirable future states and barriers for change together with a plan for individual and collective action and accompanying measures. The following phases, management actions, policy implementation and monitoring and evaluation, consist of carefully designed monitoring and evaluation programs, based on a sound understanding of the total system and the most important causes for uncertainty. The whole process is not linear but is more appropriately characterized as iterative cycle (or spiral in time) where one may for example go back to the assessment phase if one realizes that basic assumptions are flawed. From this characterization one can conclude that all the modelling purposes discussed in the previous section are of importance albeit to a varying degree during the different phases.

Models are used in this adaptive management process for different and sometimes overlapping purposes embracing the whole range from prediction, exploratory analysis, and communication to learning. In the initial phase of participatory assessment of the current problem situation, models are mainly used in the communication and learning mode and constitute essential tools for depicting a family of alternative explanations emerging from multiple stakeholders perspectives. An appropriate method for this is participatory model development where simulation models are developed based on combining scientific analyses and cognitive maps elicited from stakeholders participating in the model building process (Pahl-Wostl and Hare, 2004; Sendzimir et al., in press). The model development process supports the framing and reframing of the problem and facilitates thus a process of social learning (Dewulf et al., 2005). Collective action and the resolution of conflicts require that actors recognize their interdependence and their differences, and learn to deal with them constructively. This initial phase of a process is crucial to build up the trust and social capital needed to implement and sustain adaptive management strategies (Folke et al., 2005). The learning process can be supported by models used in both predictive and learning mode, which can be applied in sequence or parallel. Models may provide graphic or mathematical evidence of assumptions and so can document the world views of participants based on their beliefs in certain cause and effect relationships (e.g., the role of fertilizing practices on nutrient leaching into the groundwater and uncertainties in the underlying knowledge base). Embedding such a modelling approach in a stakeholder process is supposed to increase the likelihood that model results are accepted by the participants, and eventually, the stakeholder groups that participants represent in society, and that the quality of the deliberations is improved (Pahl-Wostl, 2007A). This implies for example, that in an open and transparent modelling process the uncertainties are exploited by conflicting interest groups. That is to say, they are not used by different groups to promote their individual interests and to dismiss results contradicting their point of view. This is the transparency that reinforces trust and sustains participation in such processes over time periods relevant to policy making and other long-term (for example ecological) processes.
Regarding the goal of managing for resilience, it is even more important to derive an understanding for general system properties such as the influence of system structure and diversity of sub-system functions on the resilience

and adaptive capacity of socio-ecological systems. Here, prediction, exploration and learning may be closely intertwined. Take the example of alternative stable states in lacustrine ecosystems as a consequence of the amount of nutrient loading. Whereas the response of the ecosystem to different nutrient loadings can now be reasonably well predicted (see for example Carpenter and Brock 2006) the response of human beings and the appropriateness of different institutional settings to find a balance between exploitation and precaution to avoid catastrophic shifts is much more at an exploratory stage (e.g. Carpenter,1999). At much larger scales the whole discussion about the impacts of climate change reflects similar arguments. It has become increasingly evident that slow accumulation of nutrients at large scales make it likely that positive feedbacks, even very small and rapid ones, can push the system across critical thresholds precipitating a collapse to a degraded state (eutrophy). Despite a century of experimentally building a vast knowledge base, efforts to manage a reversal still fail (Scheffer 1998, Scheffer et al. 2001). Such potential irreversibility makes the need to manage for resilience and to increase adaptive capacity increasingly important. Innovative management strategies could include using analytical insight to exploit or modify the structure of social and communication networks or the spatio-temporal heterogeneity of habitats. Diversity in functional groups and response characteristics embracing a wide range of temporal and spatial scales increases the ability of a system to deal with external and internal stress (Levin, 1998; Pahl-Wostl, 1995; 2000; 2004). Such knowledge, reinforced with iterative monitoring of results that informs renewed modelling and analysis, can guide the setting of priorities and determine the overall direction for measures to be taken to increase the adaptive capacity of the overall management regime.

In the second phase of the management cycle, participatory policy formulation, during the analysis of possible and desirable future states, models are mainly used for exploratory analysis, communication and learning (Van der Heijden, 1996; 2000; Pahl-Wostl, in press). In an initial creative phase, uncertainties and ignorance should be seen as a resource to explore a wide range of scenarios for the future. In a second phase the space of scenarios should be constrained by what it is deemed to be possible (Pahl-Wostl, 2002). Here the predictive capacity of models plays again a more important role. However, “stylized” models that do not precisely predict outcomes but give credible qualitative output can also illustrate the dynamic implications of stakeholder assumptions. High uncertainties are in general associated with the possibility of evaluating the characteristics of future states, and in particular, in understanding the nature of processes of change. As a system metaphor one can state that adaptive management favors the paradigm of complex adaptive systems, which implies that adaptation to change is an evolutionary process in a shifting fitness landscape, rather than an optimization to achieve a well defined goal. Models help experts and stakeholders to navigate this fitness landscape, to analyze first barriers for change and then define and guide paths and stepwise decision making and learning processes (Kaufmann, 1995; Pahl-Wostl, 1995, 2007A).

Further on the participatory policy formulation phase, during the analysis of barriers for change, models are used in both for their predictive and learning capability. Models may help to analyze causes for lock-in situations where change is blocked due to the fact that a number of different factors stabilize the current system (Pahl-Wostl, 2002). Such factors may be mutual expectations stabilizing conflict and lack of trust in a group of stakeholders. For example, in river water management the current system of flood protection is often in competition with attempts of river restoration practices. Large scale technical infrastructure for flood protection, habits of citizens to settle in flood plains and expect complete protection, rules of good practice of engineers on how to design dams, attitudes towards risks, and fragmentation of responsibilities have all co-evolved over decades. In such situations, it is very difficult to change to the currently advocated integrated flood and landscape management approach. The development of conceptual models in a group can support a process of learning so that various stakeholders understand the complex relationships and the need for collective change (Vennix 1996).

Analyzing barriers of change is the first step to identify a portfolio of individual and collective action to implement change, leading to the next phases of the adaptive managing cycle. In this process models are used in exploratory analysis and learning. Here, models are important tools to reduce and clarify major uncertainties by identifying factors and structural features that influence the success or failure of implemented actions:

- the response of ecosystems is predictable to a limited extent only,
- actors may change their attitudes, plans and behavior,
- environmental and socio-economic boundary conditions may change.

Finally, results from participatory modeling exercises can guide the design of evaluation and monitoring programs. By identifying key structural elements that influence system dynamics, models can also support the development of performance indicators to monitor progress (e.g., Magnuszewski et al. 2005).

It would be ideal to design and implement a learning process that follows that overall principle of a complex adaptive system – seeking its path in an evolutionary landscape without being constrained by central control but being kept within bounds by a complex web of interactions. This principle is in the spirit of Bormann et al. (1994) when they point out that "Adaptive management is learning to manage by managing to learn". Modes, in their different capabilities, can allow the design of such systems.

7 Conclusions

In this paper we have identified prediction, exploratory analysis, learning and communication as four modeling purposes that are relevant for natural resource management. Each of these purposes highlights different uncertainty sources and ways in which these uncertainties become manifested in the data, structure and framing of the model. We have argued that uncertainties can only be understood in the context of the modeling exercise in which they are immersed. When models are used for prediction purposes, uncertainties ought to be explicitly recognized and their effect evaluated. Sometimes models cannot be used for prediction, but as a device to highlight, communicate and resolve the known and unknown about the reality modeled.

These characteristics have changed the way in which we understand modeling, switching its goals from creating a valid representation of a single, unique and objective reality to being a means to build consensus about a socially constructed reality. This new view facilitated the emergence of participatory modeling approaches, whose focus is not so much on prediction, but on using the model as a device to gain social consensus about a real problem that needs solution. Such a changed perspective poses a major challenge to modelers. In such processes models may be used for different purposes and this entails the danger that models may be used for purposes they have not been designed for. A model designed for prediction may perform very poorly when used for communication. And a model designed for learning should not be used as a predictive device.

However, this needs to be explicitly taken into account in model design. As our analyses have shown some requirements may be incompatible and rather than using a single multi-purpose model the combination of different tools during a process may be more appropriate. The example clearly illustrates how exploiting the different capabilities of models can facilitate the design and implementation of adaptive management processes. It highlights the importance of models as a support of a learning process that allow to collectively deal with problems in a constructive manner allowing a better integration of the modeling and decision making activities. We hope that our paper raises the awareness of the modeling community for the broadened scope of models and the need to be more explicit about model purpose and design as applied in the iterative learning processes for the adaptive management of natural resources.

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Deliberation, negotiation and scale in the governance of water resources in the Mekong region

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Abstract

Deliberating, negotiating, designing, and implementing water management policies are often disconnected activities. Different actors come together in separate arenas at different times, places and levels to gain support for their policies, programs and projects. Scale represents a class of key choices, commitments and constraints that actors contest or are forced to accept. In the Mekong region water governance is multi-level and multi-scale with issues and actors that surge and ebb as they move from deliberation, negotiation and allocation of water and related services and back out again. The attributes and outcomes of multi-level governance – like fairness, equity and sustainability – depends not only on the interplay of institutions, but also the fortuitous and staged cross-level interactions among less rigid and formalized social networks and deliberative platforms. While attributing impacts to deliberative engagement is not a straight-forward exercise, our hypothesis remains that cross-level interactions in deliberations initially produce and later help influence negotiations and the robustness of structure of rules, agreements, policies and institutions.

1 Introduction

Deliberating, negotiating, designing and implementing water management policies are often disconnected activities. Different actors come together in separate arenas at different times and places to gain support for their plans, policies, programs and projects. The politics of scale can help explain some of these disconnects.

The scales and levels *in use* are a joint product of social and biophysical processes; they are not unambiguously defined by the physics of flows, the dynamics of ecosystems or the rules of water use (Lebel et al. 2005, Lebel 2006b). Actors contest scales and levels, overtly through debates, media releases, lobbying and protests, and more subtly, through use and control of technologies, indicators, measurements and controlling the channels of contestation (Hirsch 2001, Sneddon 2002, Hirsch and Wyatt 2004, Lebel et al. 2005).

The reputation of water management organizations has a lot do with their success in managing spatial relationships. But, not all spatial politics involving water are about scale. Issues of position and place, for instance upstream-downstream and left-right bank conflicts, are common too (Lebel et al. 2005). Nor are all forms of scale politics are primarily about space whether administrative areas, hydrological units or ecological processes. Rule form, time, knowledge and groups are other important scales (Cash et al. 2006, Lebel and Imamura 2006).

Institutions map to, and actors attempt to influence, different levels on multiple scales (Fig. 1) creating opportunities for cross-scale interactions. If these are strong they may even confound analyses based on assumptions of interactions occurring within levels on a single scale and produce diagonal interplay among institutions (Lebel and Imamura 2006). The presence of cross-scale and -level interactions introduces additional uncertainties for the emergence and evolution of water management institutions.

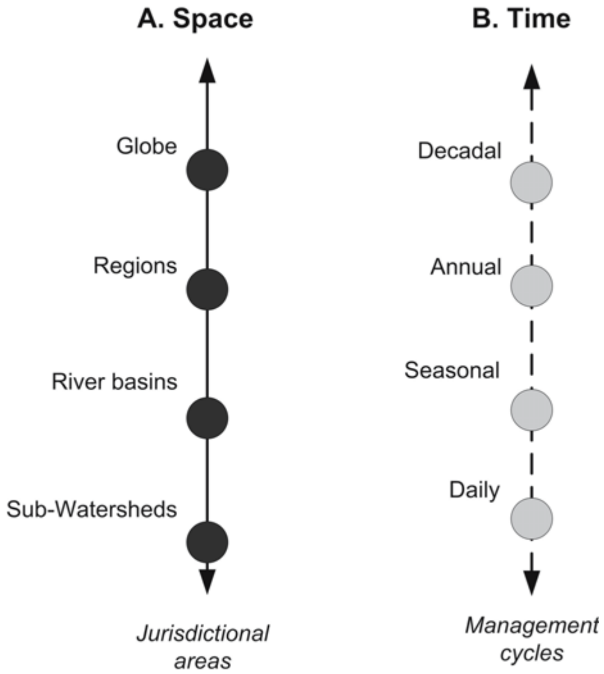

Fig. 1 Levels (e.g. watershed, basin, region) and scales (e.g space, time) should be distinguished in water governance.

Deliberative engagement in this paper refers to structured and informed conversations involving multiple-stakeholders or the general public. These include formats like: multi-stakeholder dialogues; joint fact-finding or assessment procedures; public forums, reviews and consultations; and citizen panels or juries. Engagement activities may be convened by state, multilateral, private or community organizations.

Deliberation takes place at different levels and may involve debating choices about appropriate scales and levels for water management and consequently who should be involved in negotiations and decision-making. Facilitators of dialogues and other deliberative processes need to be skeptical about *a priori* claims of different stakeholders regarding levels and scales.

Many actors have strong preconceptions about the importance of their own or other levels. Some actors are free to select their vantage points, whereas others are restricted by mandates to viewing water resources and management from a particular level. For example, irrigators may wish the scope of discussions around water management to focus at the level of water user groups or local irrigation districts where they are familiar and powerful. A basin authority or urban-based conservation group, on the other hand, may both argue for a higher level view, with less detail about allocations, but which includes municipal areas downstream and upstream forested catchments.

Conducted well, deliberations can help people learn about others' problems, interests and shared resource constraints, including those which are level-dependent (Warner 2006). Inclusive, open and accountable conversations may, in turn, help shape formal negotiations over trans-boundary water resources, the design of national water policies, and basin management practices (Dore 2007, Molle 2007).

In this paper we extend our earlier work on the politics of scale in water resources development and management in the Mekong region from a focus on a few formal institutions and key management organizations to the interactions between deliberations and negotiations with emerging and evolving resource regimes. Our working hypothesis is that multi-level governance depends not only on interplay of institutions (Young 2002), but also the fortuitous and staged cross-level interactions in deliberative processes. Specifically, we predict that deliberations which enable cross-level and cross-scale interactions through the actors they bring together are more likely to influence negotiations and institutional form than those which do not.

Our exploration of the politics of scale in water negotiations and deliberations is organized in two sections. The first focuses on regional, that is multi-national, cooperation. The second explores integrated and basin management ideas both sub-nationally and regionally.

2 Regional cooperation

There are several competing and evolving frameworks for regional cooperation on economic development and environmental management in the Mekong region (Dore 2003). Each of these initiatives represents an effort at rescaling how development is imagined and organized to a spatial level and country grouping beyond the sovereign territory of individual states. Most prominent of the multi-lateral efforts are the activities framed under the Greater Mekong Sub-region (GMS) initiatives, the Mekong River Commission (MRC) and the Association for Southeast Asian Nations (ASEAN). We will encounter each as we explore the formation of river agreements and related energy and transport initiatives.

2.1 Negotiating River Agreements

The negotiations of the 1995 Mekong Agreement and subsequent activities of the Mekong River Commission underline the importance of interactions between formal and informing processes of governance at several levels. Agreements on other major international rivers like the Nu-Salween in the Mekong region are less advanced.

Negotiations about the use of waters in the Lancang-Mekong river basin have a long history tied up with security concerns of states (Jacobs 2002). Regime formation and maturation was complicated by the presence of a very powerful non-member upstream state, China, and its relationships with the US throughout the Cold War (Makim 2002, Dosch & Hensengerth 2005). The US had ensured that China was kept away from the first charter for the "Committee for Coordination of Investigations of the Lower Mekong" signed in 1957 bringing the Mekong Committee into legal existence. Subsequenlty, in 1975, a Joint Declaration on Principles was signed; but during 1978-1991 Cambodia was excluded because of lacking a representative government and a 3-member country Interim Mekong Committee was formed in 1978.

After Cambodia's return in 1991, lengthy negotiations eventually resulted in the 1995 Mekong "*Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin*" that established the current Mekong River Commission (MRC) with a council, joint committee and secretariat (Radosevich 2000). The negotiations were difficult because the incentives to cooperate for Thailand were relatively smaller than for the other three downstream riparian countries (Lao PDR, Cambodia and Vietnam). Given the legacy of mistrust between Thailand and its Indochina neighbors, the interventions of UNDP were critical as initial maneuvering by Thailand and Vietnam threatened to prematurely end negotiations (Browder 2000). It took a series of meetings, first agreeing on the terms and procedures, and then moving through multiple rounds of revisions of a single negotiating text drafted and revised by the UNDP employed mediator George Radosevich (Browder 2000). Throughout, events outside the meetings, including infamous interviews given by government officials not directly involved in negotiations, and events organized by civil society groups, kept the pressure on various parties (Browder 2000, Hirsch 2006). The most difficult negotiation was on Article 5 on "*Reasonable and Equitable Utilization*". Thai and the other teams had very different initial opinions; not surprisingly the final wording is complex, vague and inconsistent. A good example is the mainstream versus tributary distinction despite major tributaries in the basin flowing through multiple countries (Browder 2000): a good example of politics of place and scale (Lebel et al. 2005).

The negotiations reflected the broader economic and political context of the riparian states. In the end the 1995 agreement is much less constraining for Thailand than the earlier ones of 1957 and 1975 such as the veto on Mekong River mainstream development given to members (Browder 2000). Key objectives of the 1995 Mekong Agreement include maintaining dry season minimum flows, sustaining the wet season pulse which drives the reverse flow into Tonle Sap, and restricting activities in the narrowly-defined *main-stem* of the river to those which do not adversely affect navigation (Browder 2000).

The framework agreement continues to be slowly refined in programs on water utilization (WUP), basin planning (BDP) and environment (Jacobs 2002, Myint 2003). Under WUP member countries, and China, have so far agreed on little other than sharing of river data. Progress on the BDP has also been slow with just a first phase on strategies and planning processes completed. Both the WUP and BDP processes have been driven by funders, the Global Environmental Facility, and ultimately, the World Bank. Public participation was introduced to the BDP process late (IUCN et al. 2007) and arguably never happened in the WUP. Instead civil society organizations have tried to shape agendas and negotiations through independent forums and mass media (Dore 2007). There are still few references to the 1995 Mekong Agreement in national legislation (Hirsch et al. 2006).

The MRC continues to have much less influence and relevance than might be expected for a river basin organization. China and Myanmar are not members and the current agreement and structure does not give MRC a basin-wide mandate. Also, MRC continues its reliance on foreign funding where donors determine the MRC work program (Bakker 1999). Another reason is that the National Committees which are supposed to link across levels from the international to national vary greatly in influence and effectiveness among countries (Hirsch 2006, Sokhem & Sunanda 2006). Thus, in 2002 the four countries of the upper Mekong—namely China, Burma, Laos and Thailand—signed an agreement to implement a navigation improvement project that involved blasting of several rapids in an almost 900km stretch of the river between Jinghong in China to Luang Prabang in Lao PDR. Throughout the negotiations the MRC was completely sidelined.

Public participation in decision-making activities of the MRC has been very limited for several reasons, including lack of confidence and capacity (Dore 2003). In Thailand there is a history of events being run outside the formal process by academics and non-governmental actors (Hirsch 2001, Dore 2003). In November 2002, for example, a meeting on "*Dialogue on*

River Basin Development and Civil Society in the Mekong Region" held in Ubon Ratchathani, Thailand, concluded with calls for much greater advocacy and civil society involvement in Mekong region (Dore 2003). In November 2005 the Mekong People's Council met with the participation of over 150 civil society organizations. One of the challenges to transnational coalitions challenging current patterns of development is that the needs and interests across places in the region are huge (Hirsch 2001); a united "campaign" voice is hard to keep-up and justify unless the focus is on representation and process. Deliberative processes that are intentionally engage a broad cross-section of stakeholders and level-dependent interests may be more influential. At the same we recognize the functional value of oppositional approaches and need for advocacy when other avenues are closed or stuck (Young 2001).

Avenues for direct public challenge and dissent on government decisions and involvement in regional initiatives, however, are often much more restricted in the other countries of the basin (Ratner 2003). Mass media is monitored and controlled, and under pressure, self-censors, but there is an increasingly diverse set of alternative media options through which views can be expressed (Garden & Nance 2007). Here the everyday *politics of environment* are more prominent by default (Hirsch 2001).

The 1995 Mekong Agreement can still be read as a dead letter. The important observation here for understanding water governance is not the futility of multilateralism, but rather the purposes of negotiations and agreements undertaken by various actors.

2.2 Transport, energy and regional development

Roads, optic cables and transmission lines, like waterways, link people and places. The discourse of region has been used to re-scale plans for how resources should be managed upwards through arguments about the benefits of integration and economies of scale. The top-down, behind closed-door decision-making on transport and energy infrastructure in the Mekong region, however, raises several questions: *Will investments in large-scale infrastructure projects improve the well-being of those most in need? Who will bear the involuntary risks and share in the benefits? Is 'regional' the most appropriate or only level at which development should be imagined and decided?*

The Greater Mekong Subregional Economic Cooperation Program (GMS) established in 1992 with financial support from the Asian Development Bank has focused on transport and energy. Progress was initially slow but in the past few years enthusiasm in key ministries across the region has grown. The first summit of all Ministerial-level leaders was in 2002 and the second held in Kunming, China, was in 2005. Leaders jointly stated "*we pledge ourselves to a closer and stronger GMS partnership for common prosperity*" and "*our most important achievement has been the growing trust and confidence among our countries*" (Asian Development Bank 2007). The discourse of dialogue and region is not unlike that promoted by civil society actors but among a different subset of stakeholders.

The economic corridor programs have received strong support from China and Thailand as they fit national economic and development strategies (Masviriyakul 2004). The GMS Cross-Border Transport Agreement (CBTA), for example, ratified by six member countries in December 2003, aims to facilitate more detailed bilateral agreements on border crossings of people and vehicles as well as road and bridge design standards. Actual coordination of policy with respect to energy remains modest and has not yet dealt adequately with equity issues such as rural electrification or the distribution of environmental risks (Yu 2003).

Cooperation within, but not necessarily because of, the GMS is reflected by trade statistics. For Myanmar, Laos and Cambodia the dependencies in terms of imports with other GMS members is high. In 2002, for example, more than 20% of Yunnan's exports were to Myanmar (Poncet 2006). Economic growth of China, both within the remote province of Yunnan and even more so outside it, is driving a further re-scaling of investment, transport and energy flows. In recognition of this expanded linkages in December 2004 Guangxi Zhuang Autonomous Region was included in the GMS (Asian Development Bank 2007).

Dealing with the environmental and social consequences of meeting rising energy demand in the GMS through hydropower and alternatives will take substantial cooperation (Yu 2003, Dore et al. 2007). China began a cascade of planned dams on the mainstream of the Lancang-Mekong with the construction of the Manwan Dam in 1986-1993 and a second dam at Dachaoshan completed more recently. Thailand already has an initial agreement to purchase electricity from the yet to be completed Jinghong dam (Dore 2003). Dams are also being built in other countries, once again with little reference to multilateral frameworks like the MRC, for example in the central highlands of Vietnam (Hirsch & Wyatt 2004) and other locations in Laos (Hirsch 2002).

Many actors are concerned about the local social and environmental impacts of dams as well as their aggregate downstream impacts on natural flood regimes and sediment transport (Sokhem & Sunada 2006). The greatest concern is usually reserved for the seasonal *flood pulse* in Tonle Sap Lake which supports a fishery crucial to the diet and livelihoods of the population of Cambodia and the extent of sea-water intrusions in the Mekong Delta of Vietnam.

Public consultation regionally and nationally with GMS initiatives has historically been very limited. Most forums of consequence are between government officials and key individuals from the private sector. In these settings it is impossible to ensure that the interests and rights of less economically important actors are even considered. Not surprisingly anti-globalization and other groups concerned with development or the environment frequently target ADB and GMS meetings in the region with public protests (Hirsch 2001, Dore 2003). The GMS Strategic Environmental Framework now includes provisions for public involvement which actors now frequently demand (Dore 2003). Nevertheless, such actors may continue to exercise power through controlling where, when and how deliberative engagement takes place.

In November 2005, IUCN organized a roundtable in which the Chinese delegation participated with officials from lower Mekong countries to discuss environmental cooperation. Again in July 2006, IUCN with other partners including TEI, IWMI and the water governance network known as M-POWER, hosted the "*Mekong Region Waters Dialogue: exploring water futures together*". The large event was held in Vientiane and covered governance issues in several sectors and at several levels (IUCN et al. 2007). The dialogue was "*a regional multi-stakeholder platform organized to provide an opportunity for high-quality, multi-faceted debate and learning that will contribute to improving water governance inthe Mekong Region*" (p7). One part of the meeting and report specifically asked participants to evaluate the role and governance performance of the World Bank, Asian Development Bank and Mekong River Commission. Other parts reviewed their strategic plans for the region providing commentaries and suggestions. The dialogue event was followed up by exchange of correspondence between conveners and these agencies which were included in the final report (IUCN et al. 2007).

A set of follow-up national level and language dialogues were planned. At the time of writing two had been completed by May 2007, in Lao PDR and Cambodia. The activities in Cambodia, for example, are organized through the Cambodian Water Working Group which represents more than 30 non-governmental, international and other organizations. The working group is facilitated by the Cambodian Center for Study and Development in Agriculture (CEDAC) and places a strong emphasis on irrigation and its interaction with other water uses and users. Between November 2005 and February 2007 the working group held 12 meetings and two study tours.

A two-day dialogue event was also held in October 2006 to specifically follow-up discussions at the Vientiane event on the North-South Economic

Corridor. This meeting was notable diverse participation from Myanmar and ADB representatives. The event focused on exploring development assumptions through building scenarios at local, regional and global scales.

The need for such engagement to monitor and inform the scaling-up strategies of the multilateral banks has increased with prospects of greater cooperation between them on water. In 2004 the World Bank launched it's Mekong Water Resources Assistance Strategy (MWRAS). The first major report produced jointly with the MRC uses a suite of hydrological models from their Decision Support Framework to justify further investments in dams based on the argument that they have acceptably low impacts on hydrology at larger spatial levels (World Bank 2004). The second report was produced jointly with the ADB (World Bank and Asian Development Bank 2006). It reaffirms the conclusions of the first report regarding potential for development of Mekong water resources and claims the "*basin has flexibility and tolerance*. It calls for abandonment of the "*precautionary approach of the past decade that tended to avoid any risk associated with development, at the expense of stifling investments*"(World Bank and Asian Development Bank 2006). The solution, it is now claimed, is "*balanced development*". Needless to say such assertions were contested and debated at the Mekong Region Waters Dialogue (IUCN et al. 2007).

3 Integrated and basin management

3.1 Water resources and services

Integrated water resources management, or IWRM, in the Mekong region is a managerial discourse. It is about coordination across government departments. Integration makes for an ambiguous, more glamorous, wrapping of water management practices than the vocabulary of projects. Its effect has been to make it more difficult to see what is really inside, to assign responsibilities, and to evaluate responsibilities (Molle 2007). This may explain its overwhelming popularity. IWRM ideas have been promoted through dialogue events.

The Global Water Partnership, for example, convened a Southeast Asia Regional Dialogue on Water Governance on 28-29 November 2002 focused on IWRM practices that brought together findings from a series of national level dialogues (including Thailand and Vietnam) to explore their regional implications (Dore 2003). It was a mixed forum with both state and civil society engagement. Other key sponsors were the Asian Development Bank, the Mekong River Commission and the International Water Management Institute.

The IWRM discourse is also deployed to rescale deliberations and interventions upwards and centrally (see Lebel & Imamura 2006). The Asian Development Bank and Japan Bank for International Cooperation (JBIC), for example, as part of the integration exercise, required the creation of a central apex regulatory authority in the Thai Government as a condition for their loans to the agricultural sector following the 1992 Asian financial crisis (Abonyi 2005). As of mid-2007, however, there was still no water law in Thailand, in part, because of history public criticism of earlier drafting attempts. In other Mekong countries water laws were introduced more quickly (Hirsch 2006).

Most non-governmental organizations criticize what is seen as a Trojan horse tactic with water pricing lurking inside the integration package (Hirsch 2006). Economic arguments figure strongly in bureaucratic discussions about water allocation, but moves towards water markets are resisted in many quarters, and in any case, constrained by existing institutional capacities (Molle 2002a). Instead the allocation of river water within countries and among sectors has been largely left to the domestic water supply, irrigation and dam managers with urban-industrial users implicitly getting priority over agriculture and fisheries.

At larger spatial and group levels of the Mekong basin, regional integration has strong economic connotations. It is to be achieved, as discussed above, through river "improvements" to aid navigation, road and bridge construction projects, transport agreements, inter-basin transfers and economic geometries -- growth *quadrangles* and *corridors*, water and energy *grids*.

Explicit attention to levels and scales, however, is necessary for turning noble but vague objectives of integrated water resources management into meaningful practices (Hirsch 2006). The ecosystem goods and services provided by upper tributary watersheds, for example, are not only used downstream but also by different stakeholders at multiple levels (Lebel et al. 2007). The challenges both technical: of up-scaling water budgets and modeling, and social: of public consultation procedures and accountability mechanisms, have been regularly over-looked. Deliberative engagement has been constrained and level-bound with the result that a coherent national water policy has not emerged in Thailand or elsewhere in the Mekong region.

3.2 Basin organizations

A key component of the IWRM model, but also some other management regimes, is the idea of giving some powers of management over water resources to hydrologically-defined areas even where these cut across the conventional administrative boundaries within or among states (Hirsch 2006). Such a move has widespread support among conservation activists as well as international relations scholars. River Basin Organizations (RBO) are usually imagined as having a strong planning role with a committee like structure and a supporting secretariat. As a re-organization of responsibilities and decisions along basin boundaries attempts to shift power it is resisted by those who would lose out from such arrangements. This can include actors associated with both higher and lower levels in spatial hierarchies depending on the relative size of the hydrological unit given basin status. Starved of budget and real authority the outcome, unfortunately, is paper organizations.

The MRC is an amputated river basin organization with its tributaries pruned and its' headwaters lopped. Despite these shortcomings it has pursued "basin"-level assessment, planning and monitoring exercises. The MRC has now accumulated several useful and standard-setting studies especially on the environment and fisheries. The MRC Secretariat has also produced accessible publications on a broader set of issues such as the *Social Atlas of the Lower Mekong Region*. It has even produced distinctly educational and user-friendly educational materials including visual materials such as *River Awareness Kit* and *Environment Training Kit*. But after a decade of gravitating towards knowledge-broker and technical support functions through the work of consultants in the Secretariat the MRC took a sharp turn to being touted for a larger role as investment facilitator under its new CEO Olivier Cogels since 2004. This inconsistency is of concern to the MRC's foreign donors and would bring it more directly into competition with GMS and ASEAN frameworks like the ASEAN-Mekong Basin Development Cooperation (to which China has belonged since 1996) and the Working Group on Water Resource Management. A knowledge-brokering and negotiation-consensus building role still appears more plausible (Hirsch et al. 2006). One way to strengthen the basin organization would be to fill it: a Mekong River basin authority involving full membership of the six riparian states (Sokhem and Sunada 2006).

In the Upper Ping River Basin of northern Thailand deliberations have occurred at multiple levels. At the river sub-basin level a lot of early progress has been made, in part, due to a willingness to experiment with organizational models and adapt them with time (Thomas 2005). Such experiences could be helpful in designing procedures at the higher river basin organization levels and even in shaping wider principles and norms for public participation in the yet to be enacted water law (Thomas 2005). The range of stakeholders involved in discussions has been expanded, but public involvement in water resources management remains carefully circumscribed by the bureaucracy to exploring local decisions and proposing small projects (Lebel and Garden 2006). The planning processes, partly public, partly expert-led and driven, have begun to emerge as a modest experiment in multi-level, multi-stakeholder dialogue.

A third illustration of disconnects and challenges with the river basin organization model is the management regime for the ecologically and socially critical Tonle Sap Lake in Cambodia. The emerging Tonle Sap Basin Organization initially established with funding support of ADB while being set up closely with the Cambodian National Mekong Committee is not clearly well connected or supported by other key agencies in the Cambodian Government (Sokhem and Sunada 2006). The connections, however, matter greatly as processes triggered at the larger scale could easily have consequences that overwhelm its nascent management capacity and authority. The basin organization is designed to act as a dialogue forum among line agencies and local government (Wright et al. 2004). The extent of opportunities for public participation in its operations and future planning roles appear modest with representation on committees by "*selected*" NGOs. Limited financial resources, technical skills and inadequate representation of diversity of stakeholder interests are likely to constrain the effectiveness of the basin organization (Sokhem and Sunada 2006). Institutional limitations could conceivably be overcome through better cross-level linkages, both institutionalized (finances), and through dialogue processes (technical, representation), that link to conversations at the larger Mekong region level. Of course, if each of the components is doing little in practice their combination, however complementary the components, cannot be expected to achieve much either.

Either way we concur that international and sub-national river basin organizations of different sizes need to be embedded in and linked more with local and national institutions—such as educational and research institutions—for more lasting and mutual engagement with a wider range of riparian societies (Hirsch 2006, Sokhem and Sunada 2006). River basin organizations will need to be given more authority and downward accountability. Strengthening deliberative processes around basin management will help shape more adaptive institutional and organizational forms. In the end, integration and basin management policies may turn out to be more important for whom they bring together than what actions they specify.

4 Multi-scale governance

Water governance is multi-scale and multi-level. Institutions, issues and actors shift the loci of their attention among levels in response to and as part of wider governance processes (Fig. 2). A particular dialogue process may appeal to international water norms, involve participants and domain of relevant water resource management problems that cut across borders, but administratively be bound to laws and regulations made at the national level (Fig. 2). Decision-making processes can be scale complex.

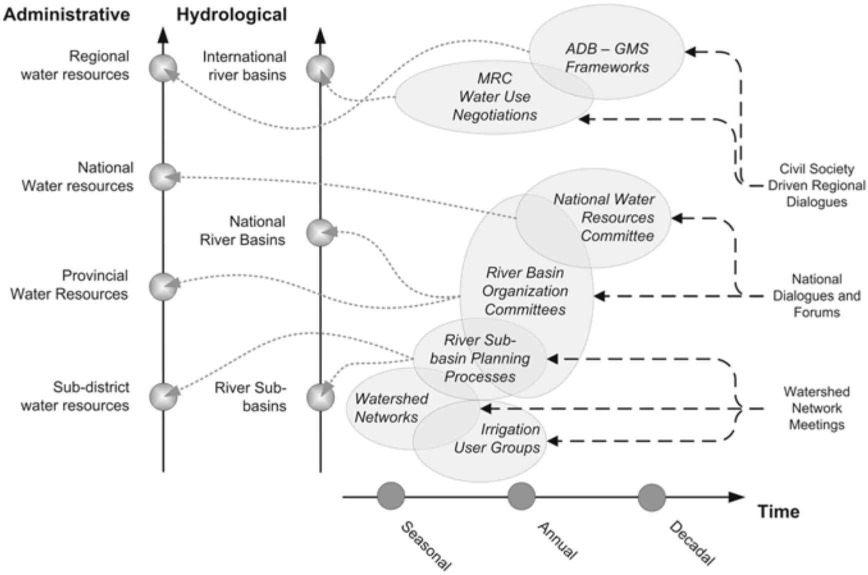

Fig. 2 Multi-scale complexity in water governance in Thailand. Planning and management institutions mapped onto two spatial scales (administrative, hydrological) and a time scale. Dark dashed lines indicate examples of deliberative engagement influencing decision-making and institutional forms at different levels.

4.1 Complex scale contests

Across the range of issues explored in this chapter we extract four examples to illustrate more complex scale politics.

The first is the contest of regional *groupings* that pits the ASEAN, GMS and MRC frameworks against each other and as alternatives to Chinese and Thai unilateralism. Actors across countries both within and outside formal government agencies use, ignore and resist these frameworks in furthering their interests. Closed forums and more open dialogues are convened to stitch together groups which would otherwise not meet, but are also sites of persuasion and recruitment.

The second is the contest among *banks* for the hearts and minds of finance ministers. A battle waged in corridors as regional and private alliances for investment tackle the limited means of small nations and resistance from civil society groups with diverse agendas working more independently. Dialogue processes may be succeeding in pushing multilateral agencies to be more transparent about projects and increasing opportunities for public consultation even against the wishes of some national agencies.

The third is the contest of *technologies* which pits proponents of small against big, in many different sectors, from upland sprinkler integration and the proliferation of small pumps in the plains, through to massive inter-basin transfer and "water grid" schemes. It is a battle of ideologies with the merits of size, or *mega-logics*, substituting for reasoned argument and the possibility of alternative or diverse outcomes. It is also a contest over rights to access and control water infrastructure with the unexplored assumption and dominant rhetoric being that big and expensive means state control and little and cheap means *possible* community control where the real effect may something else entirely: control by private sector.

The fourth and last is the contest of *livelihoods and lifestyles.* Water governance, it turns out, is not as easily confined to the "water sector" as integrationists would have it. Water issues invariably spill-over into transport, energy and agriculture, and vice-versa, demanding consideration of broader development objectives and assumptions. This is reflected in the rural-urban livelihood tensions, such as between hydropower versus irrigation or fishing. But issues of energy for rural households, and employment opportunities for fishers, on the one hand, and for environmental quality on the other are often forgotten. As interventions expand the livelihood-lifestyle contest also raises questions about the resilience of freshwater socio-ecological systems (Folke 2003) and losses of biodiversity (Dudgeon 2000). Scale contests arise in dialogues and assessments because different sectors privilege particular temporal, spatial and administrative levels in their analysis and arguments. Energy, for example, is often framed in national-level benefits but individual project-level impacts, whereas fishery livelihood implications may be framed at level of local jurisdictions or more broadly through aggregate and cumulative project impacts.

4.2 Scale and deliberation

The existence of politics at multiple levels and institutions that can be mapped to different levels and scales does not on its own imply that the governance problem is finding *the* right multi-level systems of governance (Cash et al. 2006, Lebel et al. 2006). Nesting may be very hard in some situations. Being nested or embedded may mean a loss of power for local level watershed management groups and individuals in key positions. Nesting may do little to help solve upstream-downstream conflicts (Lebel et al. 2005). A multiplicity of non-coincident institutional frameworks on various scales is not itself a problem, *if* interplay among them provides adequate coordination. The uncertainties inherent in cross-scale dynamics of modified rivers, changing water resources and uses, means that flexibility, bungling and tinkering – occasionally adaptive – may better characterize multi-level governance than the logic of finding the *perfect design* (Lebel et al. 2006).

In this messier version of water governance, deliberative processes that foster social learning become much more important, in helping shape, refine, and reinterpret directives, guidelines and decisions. Not only does deliberation possibly inform negotiations and policy design, but also makes sense of them after they have been declared. Policies often appear more coherent then observations of practices in particular places would suggest (Mosse 2004).

More inclusive, but still good quality, dialogues that are sensitive to level-dependencies and cross-level issues are likely to produce more debate and contest (Dore 2007). This takes time and coordination effort or innovative structures (Pingree 2006). The costs of engagement are high for some stakeholders making it essential that deliberation is deployed when it matters most. There are many issues related to water management that don't require in-depth public discussion but rather should be dealt with by a responsible bureaucracy. Moreover, scale issues are not the only or necessarily the most important issues needing deliberative engagement in the Mekong region,

Deliberation does not necessarily *take care* of scale politics or diffuse other water-related conflicts. The avoidance of overt politics itself is perhaps the most fundamental water governance problem in the Mekong region. Some actor resist notions of level meaning nesting and others promote it to further claims or assumptions of authority associated with particular levels and scales. It may take other actions, like dissent or advocacy (Fig. 1) to shift levels, or monitoring and exposure of practices, to bridge the disconnect between multilateral talk and bilateral or unilateral action. The challenges in the Mekong region with its history of centralized or authoritarian regimes are considerable. States are still seen by many as *the* actors who need to be convinced or changed to solve water governance problems in the region. Practices suggest something else entirely: an array of firms and banks, and to a lesser but non-trivial extent, local water user groups, environmental and social development advocates, each skillful at deploying the institutions of the state.

Incorporating scale- and level-sensitive issues into design and conduct of deliberative engagements seems likely to be most important when: (1) administrative hierarchies relevant to water resources development and management are present; (2) actors outside such hierarchies are arguing for or representing interests, issues or water-related services that are at clearly distinct spatial or temporal levels; (3) management of trans-boundary regional water resources.

In some non-democratic and "sensitive" situations deliberative engagement may be dangerous for the participants or have little influence on formal negotiations and policy decisions. When there is a possibility to inform and influence, careful consideration of levels and scales is often worthwhile for water resource management issues, but because of the costs of engagement may not always be pursuable. Attributing impacts to, or attempting to measure, the deliberative engagement on policy-making processes, negotiation outcomes, and institutional forms is not a straightforward exercise and making strong claims about level-sensitive variations is even more difficult. This initial survey of the evolution of several water resources development and management issues in the Mekong region underlines the need for more experiments with, and reflections upon, the content, process and outcomes of deliberative engagement. Our initial working hypothesis needs some refinement as noted above in that scale and level issues are likely to be more important in some situations than others. When these situations pertain our working hypothesis remains that cross-level interactions in deliberations initially produce and later help influence negotiations and the robustness of rules, agreements, policies and institutions.

5 Conclusions

In the Mekong region water governance is multi-level and multi-scale. Issues surge and ebb from deliberation to allocation and back again. Actors, in turn, push and pull the same issues up and down levels to where they have more influence and power. This is underlined by the contested meanings of even the notion of a *Mekong region.*

The outcomes of multi-level governance – like fairness, equity and sustainability – depend not only on the detailed designs or interplay of institutions, but also on the fortuitous and staged cross-level interactions in deliberation. Deliberations at several levels and among levels give actors opportunities to compare the merits of alternative governance arrangements and understandings of interests, causes and effects. Deliberations, however, vary hugely in inclusiveness, structure, and how they are facilitated. As a result the quality of conversations and argument also varies tremendously. Who convenes and who engages in these conversations, of course, matters as well. Good and bad, broad and narrow, dialogues can all influence negotiations that help shape allocation rules central to water governance.

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Enhancing the Potential for Integrated Water Management in New Zealand Throughthrough Adaptive Governance

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Abstract

The mandate for making decisions on allocation of freshwater resources in New Zealand has been devolved to regional councils by the Resource Management Act (RMA) enacted in 1991. The RMA promotes a *sustainable management* approach to integrated management of air, water and land. Growing demand for an increasingly scarce supply of sustainably allocatable water under a relatively buoyant market-led export economy based on primary production has increased competition and conflicts between different stakeholders. Regional councils have found it difficult to satisfactorily address such conflicts under the current RMA institutional framework and conflicts have escalated in regions such as Central Canterbury. As discussed in this paper, the objective of the *Sustainable Groundwater Allocation Research* project is to identify and address the underlying causes of these conflicts with the aim of enhancing the potential for integrated water management in New Zealand through adaptive governance. Progress to date suggests that institutional arrangements for water governance that facilitate strategic planning based on collaborative multi-stakeholder processes with cognitive and social learning are key ingredients in this quest.

1 Introduction

The explicit purpose of New Zealand's (NZ's) groundbreaking devolved environmental planning legislation, the Resource Management Act 1991 (RMA), is to promote a *sustainable management* approach to integrated management of air, water and land (Memon 1993; Ericksen et al. 2004). The more recently enacted Local Government Act 2002 creates a long-term, strategic planning process to enable regional councils to identify local sustainability priorities and implement long-term action plans within a participatory *sustainable development* governance framework (Borrie et al. 2005; Thomas and Memon 2007).

Despite these and related significant natural resource governance policy initiatives in NZ, public critics have raised numerous concerns about NZ's lack of progress in addressing long standing and newly emergent water conflicts within a sustainable development framework. In comparison with near neighbor Australia, NZ is not a water short country. For years the NZ Government has promoted the harnessing of multiple hydro-power, tourism and recreational potential of an apparently water-plentiful country while also encouraging other economically beneficial water uses such as irrigated agriculture. However, the continued promotion of this 'clean green' image is increasingly under threat as many of NZ's rivers and aquifers are considered to be reaching full allocation potential and ecosystems are showing signs of stress (e.g., PCE 2002). Resolution of water management conflicts has been hindered by a number of constraints stemming from the lack of a strategic planning perspective on the part of central and local government, coupled with limited opportunities for stakeholders to collaborate on crafting water management solutions in a deliberative and communicative manner.

The ramifications of these shortcomings for water allocation decision-making are particularly evident in the Central Canterbury region in the South Island of NZ (Figure 1). Central Canterbury sits on sloping alluvial plains bounded to the north and south by large braided rivers which recharge high quality water into the underlying aquifers. Rivers on the upper plains also recharge into the underlying aquifers, becoming intermittent across the center of the plains. In the lower plains, groundwater is discharged via springs to streams and rivers, into Lake Ellesmere/Te Waihora and finally the Pacific Ocean.

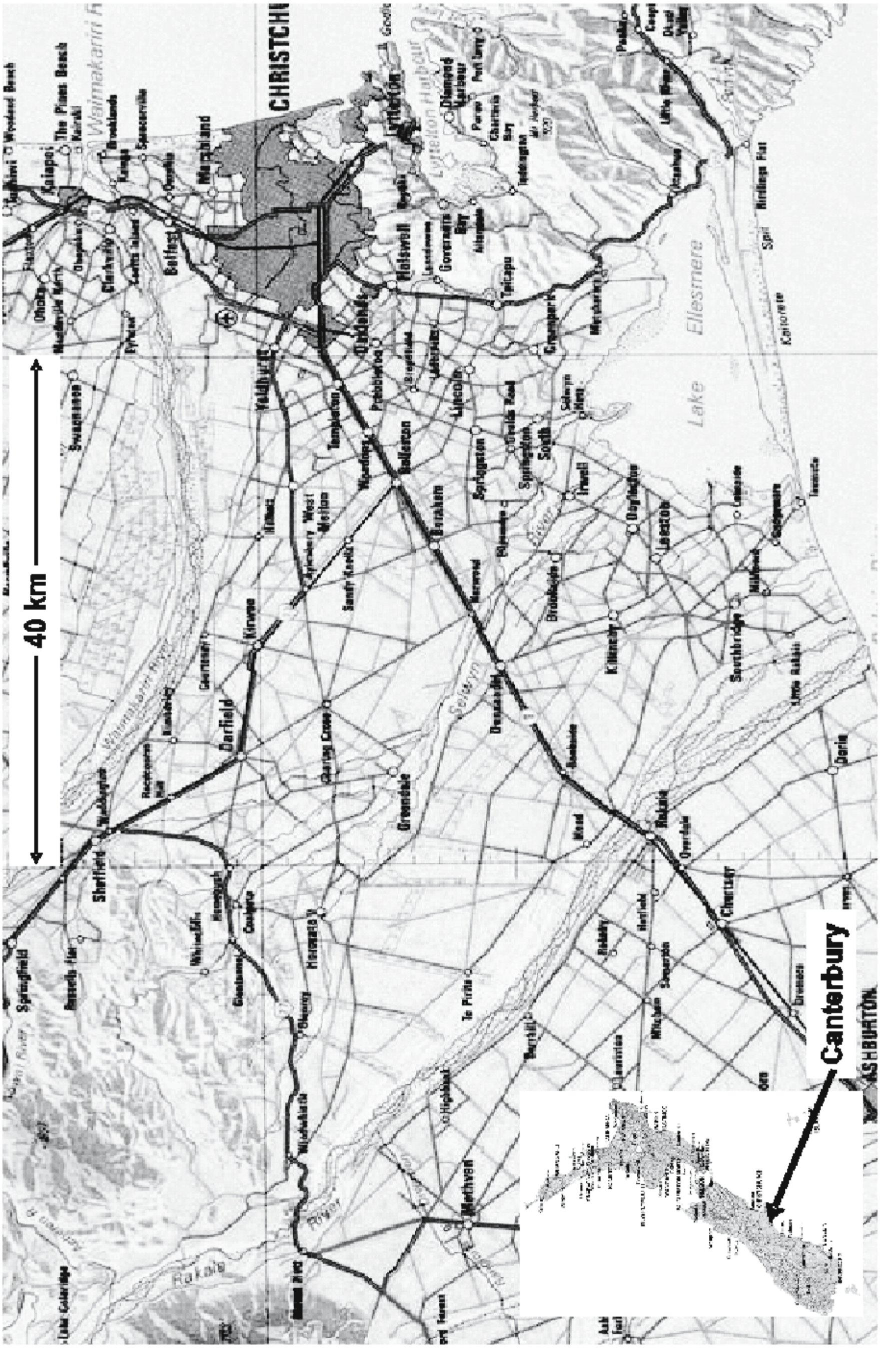

Fig. 1 Central Canterbury in New Zealand

Canterbury is a relatively dry region due to the sheltering effect of the Southern Alps to the west. It covers approximately 17% of the country's land area but currently contains 70% of NZ's irrigated land and uses 60% of all water allocated for consumptive use in NZ. Farming has existed on the Canterbury Plains since European colonization in the mid 1800s, with water races created for stock water and then cropping requirements. The most significant irrigation development has occurred since the 1980s, driven primarily by conversion of dry-land farms to irrigated dairy farms. High global returns on NZ dairy products are maintaining the pressure on further dairy farm conversions and intensification. With surface and water resources in Central Canterbury now considered by the Canterbury Regional Council to be at or near full allocation limits, water quality, water use efficiency, re-allocation and augmentation have become important current issues. Each future pathway includes a complex blend of associated benefits and costs (Lincoln Environmental 2002).

The multi-disciplinary *Sustainable Groundwater Allocation Research* (*SuGAR*) project, funded by the NZ Government, commenced in 2004 to address these challenges. The research project has three objectives: firstly, to develop and test an approach for quantifying the relationships between water level change and the environmental, economic, social, and cultural effects; then deciding how much groundwater can sustainably be abstracted; and finally, developing institutional arrangements and decision-making processes to efficiently, effectively, and equitably allocate this water between competing groundwater users. The project is based in the territorial jurisdiction of Selwyn District, which covers most of Central Canterbury.

The objective of this paper is to discuss the research findings for the most recent eighteen months of the *SuGAR* project, with particular emphasis on three related facets of designing and undertaking research on integrated water management based on adaptive governance: collaborative processes, systems research and reflexive institutional arrangements. The significance of these three research facets as conceptual underpinnings for integrated water management based on adaptive governance, how these concepts were operationalized in our research and the preliminary research outcomes will be discussed sequentially in the following sections.

2 Research Methodology

The chosen research methodology for the *SuGAR* project draws on the principles of participatory action research (e.g., Whyte et al. 1991), integrated management and adaptive governance (e.g., Susskind 2004), and institutional design (e.g., Ostrom 1990; Agrawal 2001; Weber 2003; Connor and Dovers 2004; Folke et al. 2005; Verma 2007). Participatory action research advocates meaningful collaborations in the research programme by all parties affected by research outcomes. Integrated water management requires identification and inclusion of all relevant systems and system interactions (environmental, economic, cultural and social). The breadth and complexity of these systems and their interactions requires pro-actively adaptive governance processes that can inform decision-makers with a continually improving understanding of the effects of management decisions. Implementing integrated management through adaptive governance processes under the RMA and Local Government Act is contingent on networked institutional arrangements for water governance. It is imperative for these institutions to possess strategic political and technical capability to anticipate and respond to environmental change from a holistic, longer term perspective within a 'whole-of-government' setting.

2.1 Collaborative Processes

The Resource Management Act and Local Government Act both advocate community involvement in plan making. In regions such as Canterbury the regional council has successfully collaborated with stakeholders on localized resource management issues, for example water quality in a particular reach of a stream (Environment Canterbury 2007a). However, stakeholder interactions to address regional issues such as water allocation have primarily occurred within adversarial judicial water management decision-making processes (The Press 2007).

A collaborative approach to addressing these issues in the Selwyn District commenced with the formation of the *Selwyn Water Allocation Liaison Group* (*SWALG*) in August, 2004. This group includes the research team, representatives from the Canterbury Regional Council (as the regulatory authority), and water stakeholder representatives of place and interest. Participation in *SWALG* is not closed and has steadily increased over the course of the project. A Terms of Reference document and Participation Agreement have been collaboratively created as part of a research strategy to design and test alternative institutional configurations most appropriate to promote integrated water management in NZ based on adaptive governance processes.

Individual stakeholder meetings were held during 2005 to encourage buy-in to the process and discuss research objectives and stakeholder issues in more depth. *SWALG* meeting discussions were initially just minuted but moved to full recording and transcription of discussion sessions in 2006. This change was made to encourage accountability and enable more effective participation from stakeholders not able to attend the meetings. Wide dissemination of information through the represented stakeholder groups was encouraged through electronic distribution of documents. Stakeholder feedback after the first year of *SWALG* also resulted in the introduction of the following further initiatives in 2006:

- A streamlined research personnel structure to co-ordinate interaction between the research team and *SWALG*.
- Additional meetings as requested by *SWALG* members to discuss relevant issues and research with specific researchers.
- Creation of a historical information project to collate and present relevant historical data from the Selwyn District to stakeholders. This was considered an important first step in defining current issues, values and a future vision for water allocation in the Selwyn District.
- Two additional written research updates per year sent to stakeholders.
- Copies of meeting presentations sent to stakeholders prior to research meetings.

2.2 Systems Research

Key underlying drivers to current local water allocation conflicts are considered to be different competing understandings of relevant systems and conflicting value sets among stakeholders, which lead to different interpretations of what is sustainable water allocation (e.g., Environment Canterbury 2005). Identifying and filling information gaps was considered an essential first step in addressing this issue. A historical information collection and collation project was therefore designed by *SWALG* and is now well advanced. The project's aim is facilitated community learning, enabling stakeholders to consider future visions for their district in the light of a fuller understanding of its history. The key aspects of this project are:

- Information collection is to be managed by the support team and is to include a variety of sources (e.g., meteorological, hydrological, biological, photographic, individual resident records, historical, and cultural writing).
- Initial presentation of collated data is not to include cause-and-effect relationships.
- Stakeholder groups are to be given time and support to digest collated historical data.

- Presentations and facilitated discussion are then to be held on generalized cause-and-effect relationships in the relevant systems, including the degree of current understanding in the relationships.

The next stage of this process involves consideration of a vision for Selwyn Catchment water allocation, a set of goals to describe this vision, and a comprehensive set of indicators for forecasting and tracking progress in an integrated and pro-actively adaptive manner.

2.3 Institutional Arrangements for Water Governance

Integrating environmental, economic, social and cultural policy objectives for a common pool resource such as water poses considerable challenges, including those outlined in the 'tragedy of the commons' scenario (Hardin 1968). Socially inclusive participation by empowered stakeholders representing the diversity of civic sector stakeholders in a plural society as well as central government, local government, Maori tribal authorities and the science community is imperative if a sustainable water allocation strategy is to be successfully negotiated and implemented. Appropriate institutional arrangements to facilitate this encompass formal rules (such as statutory prescriptions) and also informal norms, roles and operating practices that are so stable, structured and accepted that they can said to be 'institutionalized'.

In addition to the adaptive development of *SWALG* as an institutional innovation to promote polycentric water governance, wider research into historical and potential innovative institutional and policy approaches to allocate freshwater resources in NZ has been undertaken in four sections:

- An international literature survey on designing appropriate institutional arrangements to achieve desired policy outcomes for sustainable management of water resources.
- An analysis of the antecedents to the RMA water planning regime for allocation of freshwater resources in NZ.
- A performance appraisal of the current freshwater allocation planning regime based on the RMA.
- Generation of alternative innovative proposals describing ways in which water allocation practices can be improved in NZ within the context of the RMA institutional framework.

3 Results and Discussion

In this section, we will discuss the research outcomes relating to research on each of the themes: collaborative processes, systems research and institutional arrangements, respectively.

3.1 Collaborative Processes

Initial meetings with the Selwyn Water Allocation Liaison Group and with individual stakeholder groups identified that the current lack of collaboration across the board on water issues was not considered to be in the best interests of the community. Research providers had been in competition for research funding and stakeholders had been competing for an increasingly scarce supply of unallocated water through an adversarial judicial process not designed for a resource nearing its allocatable limit. Researchers were also involved as consultants in the adversarial consenting processes due to the small pool of relevant expertise and the small size of the research market.

The resulting climate of mistrust and misunderstanding was amplified by the complex and interdisciplinary nature of systems and system interactions relevant to water allocation (environmental, economic, cultural and social). The busy schedules of the research team and stakeholders also meant that the process of collaboration had to be managed efficiently. A way forward was therefore proposed, based on transparent processes and objective, peer-reviewed, non-adversarial, collaborative science. Progress has been measured through:

- Thorough documentation of all research, including full transcription of research discussions and dissemination of research presentations and outputs.
- The collaborative efforts and outputs of four research programs funded by the Foundation for Research, Science and Technology (Groundwater Allocation, Surface Water Allocation, Integrated Research for Aquifer Protection and Groundwater Ecosystems) involving a large number of research providers. These collaborations provide an opportunity to progress integration possibilities in addition to the individually contracted research objectives.
- Providing a variety of opportunities for participation and peer-review; including research reports, research meetings, conference workshops and presentations, meetings with regulatory authority representatives,

journal articles, popular press, public meetings and symposia, and a website.

Research to date has focused on providing an international and national perspective on future water governance potential, the development of an adaptive planning framework and the fundamental science needed to support such a framework. The chosen adaptive planning framework (see Figure 2) is based on that used by the *Cooperative Research Center for Coastal Zone, Estuary and Waterway Management* in Australia (Bennet et al. 2005). Key 'adaptive management' aspects of this framework are its cyclic design and continuous improvement focus.

Identifying and clarifying beneficial terminology has been an important part of the adaptive learning process. Painter and Bright (2006) reported on the first eighteen months of this process, describing the following terminology:

- 'stakeholder-driven collaborative research';
- 'integrated, participatory, pro-active, and adaptive planning framework'; and
- 'consensus-seeking processes' involving 'mutual gain solutions'.

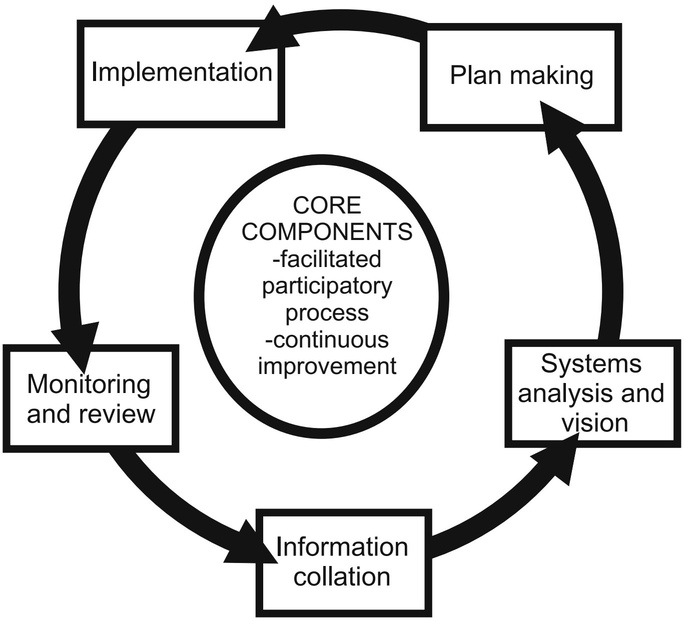

Fig. 2 Adaptive Planning Framework

A key term currently being debated is how ‘sustainability’ can be defined and applied to water resource management in Canterbury. Resolution of this issue has been hindered by the lack of a national sustainability policy framework and the use of different terminology in two key and interrelated pieces of legislation. As noted earlier, *sustainable managemen*t was chosen for the Resource Management Act (1991) while the Brundtland Report (United Nations 1987) definition of *sustainable development* was chosen for the Local Government Act (2002). There have been a variety of conflicting opinions since this time as to the similarities and differences between the two terms.

Many consider the RMA concept of *sustainable management* to be a narrower concept than the Brundtland Report definition of *sustainable development* in that it does not explicitly seek to achieve social or economic outcomes (e.g., MfE 1997; Upton et al. 2002). This view has resulted in a number of regional councils limiting their planning focus to the management of adverse environmental effects through their regional plans rather than a more integrated holistic perspective that is inclusive of environmental, economic, cultural and social considerations. This approach has put water allocation processes at odds with evolving case law based on the Environment Court judicial decisions. The Court’s decisions have been informed by an integrated perspective more congruent with the Brundtland Report definition of *sustainable development* (Memon and Skelton 2002). The Canterbury Regional Council has recently responded to this challenge by stating that they are “adding the role of facilitator of sustainable development to our role of sustainable management regulator under the RMA” (The Press 2007).

The absence of an overriding national sustainability policy framework developed by central government has also motivated the formation of organizations with a sustainability focus. A common thread in the output from these organizations is the proposition that consideration of environmental, economic, social and cultural effects as separate ‘pillars of sustainability’ does not adequately promote system interrelationships and can encourage ‘silo’ thinking. The *Strong Sustainability* model (e.g., PCE 2002; SANZ 2006) with the addition of temporal effects has been proposed to address this challenge (Figure 3). The temporal effects are one way of representing the RMA concept that future generations are also water stakeholders.

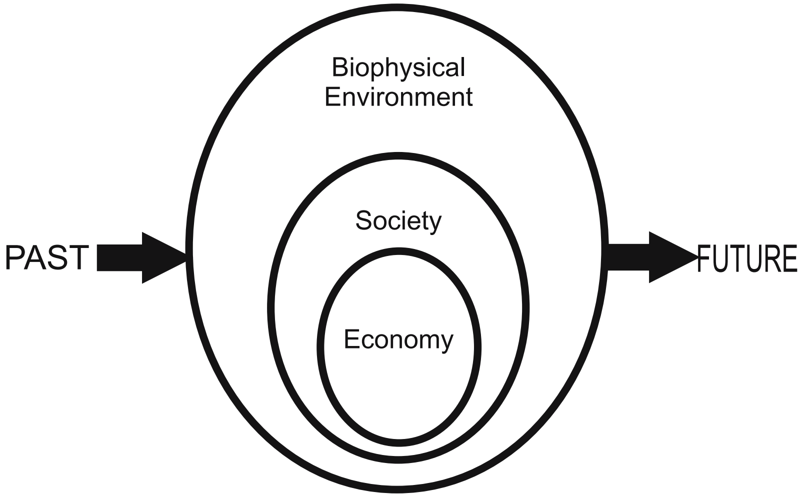

Fig. 3 Integrated Strong Sustainability Model

This particular *Strong Sustainability* model is inclusive of social, cultural, spiritual and institutional imperatives under the general heading of “Society”, despite there being clear areas of distinction as well as overlap. The model recognizes that the economy is a sub-set of society, and that many important aspects of society do not involve economic activity. Similarly, human society and the economic activity within it are totally constrained by the natural systems of our planet. The economy may expand or contract, and society’s expectations and values may change over time, but to function in a sustainable way we must not exceed the capacity of the biosphere to absorb the effects of human activities. All spheres are reliant on the past and affect the future. The Integrated *Strong Sustainability* model is closely comparable in its stance to the holistic Maori perspective on the environment in terms of its implications for integrated management (e.g., Te Runanga o Ngai Tahu 1999).

This model has been proposed as a guiding ethos for driving current collaborative efforts, articulation of community values for water resource management and choosing indicators to measure these values. A recent Environment Court decision (Lynton Dairy Ltd 2005) and an interim planning consent decision (Environment Canterbury 2007b) have highlighted the need for a balanced and defensible set of community values to inform water allocation in Canterbury. A clearly understandable guiding ethos is important, as the volume and complexity of information relevant to these efforts can be daunting. Progress toward development of this guiding ethos will be discussed in the following section.

3.2 Systems Research

Information collation and analysis are necessary for developing evidence based policy. The historical information project and core ecological research projects in the Selwyn District are making significant contributions in this respect.

Collated historical information is presented at research meetings and stored on a website (*SWALG* 2007). Information is presented on the website in a variety of forms and detail to encourage the interest and participation of a wide range of water stakeholders. An important consideration for many rural stakeholders is their relatively slow internet connection speed, which affects the presentation of web pages and the size of documents they can realistically download.

The first step in the historical information project has involved the collection and presentation of information that will inform discussion on the history, current status and future potential of water resources in the Selwyn District. Information is currently presented under six subject headings: General Historical and Social, Climate, Water, Land, Culture, and Wildlife/Ecology. Collation of this breadth of information is a challenging first for the Selwyn District, but stakeholder groups have enthusiastically grasped the opportunity to provide information and be part of facilitated debate on system behavior and system interactions.

There are significant gaps in data sets and whole subject areas, as the priority given to data collection and analysis has been inconsistent over time and across the relevant sectors. Fundamental ecological research under current research contracts is seeking to rectify significant gaps in understanding of relevant ecological processes. A recent research output details some of the remarkable complexities of the Selwyn River (on the Central Canterbury Plains), with pervasive surface water-groundwater exchange, and contiguous ephemeral, intermittent, perennial-losing and perennial-gaining reaches (Larned et al. 2007).

Certain aspects of hydro system behavior (e.g., inputs to groundwater systems from rivers and outputs from groundwater systems to lakes and the sea) cannot be measured accurately and require appropriately calibrated computer models for their estimation. These models are also required to forecast the future effects of potential water allocation scenarios, ensuring adaptive governance arrangements are pro-active and not reactive. A variety of computer models are currently at various stages of development (e.g., Bidwell 2005; Good and Bright 2005; and Weir 2005) to model water quality and quantity at local and regional scales. These models have been developed collaboratively to encourage trust, transparency and uptake. Attention has also been given to their appropriateness for purpose through explicit consideration of system complexity and uncertainty, both due to the system being modeled and the way the computer model is characterized (e.g., Moore and Doherty 2005). The importance of peer-review of the computer modelling and underlying research has been a recurring theme in relevant discussions with stakeholders.

The process of seeking to understand the history and potential of Selwyn hydrosystems has led to consideration of a vision for sustainable water allocation in the Selwyn District that relates to wider relevant visions for the region from regulatory and community agencies. Development of such a vision is now well advanced for the Selwyn District, involving collation and analysis of all stakeholder group objectives with relevance to water allocation and/or quality. Measuring progress toward a vision requires appropriate indicators. A recent appraisal of local authority community indicator programmes (Johnston and Memon 2007) has identified cultural indicators as one of the most critical areas for further indicator development. A research subcontractor has produced indicators for recognizing and expressing Maori values (Tipa and Tierney 2006) as well as other tools to enable Maori to participate as themselves in current resource management processes. These tools are currently undergoing further testing.

Development of other indicators to support adaptive water governance within an Integrated Catchment Management framework is underway or timed to begin later in the research programme. Current ecological research is leading toward better quantification of ecological indicators relevant to water allocation. A new research subcontract will start in late 2007 to develop relationships between groundwater supply reliability and socio-economic indicators. By this time, testing of the Choice Modelling methodology for supporting individual determination of aesthetic and recreational values should be complete. Choice Modelling uses images and diagrams of different attributes of streams and stream corridors, which are presented to stakeholders as a set of choices. Analysis of the choices people make identifies the relative significance of the different attributes most affected by different management regimes.

The principal output from this area of research will be means of measuring certain economic, environmental, cultural and social valuations of management decisions. These valuations are measured in different ways and on different scales. The relative importance of these valuations will differ throughout a community. The Choice Modelling methodology is also contracted to undergo testing for its potential in enabling comparison and integration of output valuations. Choice Modelling enables statistical analysis of preferences and trade-offs in decision-making, enabling decision-making pathways to be constructed and compared until agreement and commitment are reached.

3.3 Institutional Arrangements for Water Governance

Institutional arrangements for water governance research has helped to clarify the scope for a range of innovative water allocation arrangements that are feasible under NZ's current political and constitutional setting as well as provide specific input into the Plan Making and Implementation sections of the proposed Adaptive Planning Framework (Figure 2).

This research has confirmed that institutional inertia, in terms of formal and informal institutional constraints on water governance, is a major barrier to realizing the innovative potential of the RMA's planning provisions for integrated water management in NZ (Memon and Skelton 2007). Sustainability in water allocation demands radical changes in mainstream political, economic and social institutions in order to modify socio-economic and organizational behaviors to take account of the four sustainability well-beings in an integrated manner. This is not easy to achieve because business, consumers and governments generally accept only those institutional changes that mobilize shallow or short-term conceptions of sustainability (Owen and Cowell, 2002). Too much has been expected of water sector reforms that are limited to fine-tuning administrative and technical approaches to water allocation when the real issues are those of institutional inertia, power and advantage.

The institutional constraints need to be partly addressed through formal policy interventions that extend strictly beyond the RMA. The wide ranging neo-liberal policy reforms in NZ since 1984 have *hollowed-out* the strategic planning capacities of central and local government agencies. While the RMA has devolved the water management mandate to an inadequately resourced local government sector, central government has essentially taken a hands-off role in providing national policy direction.

Strong *government* and strong *governance* are not mutually exclusive or necessarily competing imperatives for promoting water sustainability. Equally as important as the strategic planning role of the central and local state in promoting an integrated approach to water governance is the collaborative involvement of relevant experts and stakeholder groups. Research findings demonstrate that too much reliance has been accorded by regional councils to formal hierarchical approaches to managing water allocation based on statutory RMA plans. However, because of a restrictive interpretation of the *sustainable management* purpose of the Act by regional councils and central government, first generation regional plans are devoid of adequate strategic policy guidance for water allocation. Water allocation processes have tended to be dominated by legal jurisprudence with the relevant expertise in other disciplines split between opposing sides during public hearings on statutory plans, water allocation and discharge applications. Furthermore, important issues such as future cumulative effects and system interrelationships have not yet been adequately addressed by these adversarial planning and decision-making processes.

The potential for wide-ranging stakeholder inclusion in shaping water allocation policies and adoption of markets as water allocation mechanisms was not widely appreciated prior to this research. Likewise, Maori communities have felt their values have been marginalized in water allocation decision-making because they lack adequate political representation in local government.

In a recent research output, Memon and Skelton (2007) provide four key challenges requiring further research and consideration by policy makers. The current NZ government policy initiatives, the *Sustainable Water Programme of Action* and a proposal for a National Policy Statement on the management of freshwater are potential opportunities to address these issues.

The first key challenge relates to the clarification of Maori customary ownership and management rights to water under the Treaty of Waitangi. Some believe that vesting the sole right to 'use' water in the Crown through the Water and Soil Conservation Act (1967) and RMA was a breach of Treaty rights. Numerous claims over the years have failed to resolve the scope of Maori property rights in freshwater. The issue is of particular interest when considering adoption of market-based economic instruments to allocate water resources.

A second challenge is the empowering of robust institutions that can promote water sustainability, either by administrative allocation processes (*hierarchies*), by using market-based approaches, via community based participatory management or by a mix of these approaches based on network governance. The Selwyn Water Allocation Liaison Group is currently testing the potential for adaptive water governance approaches, as presented in the Collaborative Processes section.

A further challenge for the RMA is to clarify how it can deliver better integrated water resource decision making that is aligned with the Local Government Act's long term strategic planning perspective. This issue is related to the need for a national sustainable development policy framework with guidance and support for statutory and non-statutory approaches to natural resource allocation and management. Amendments to the RMA in 2005 were a step in the right direction by clarifying the regional council mandate to prepare strategic water allocation plans. Recent comments by the Canterbury Regional Council chief executive (The Press 2007) and the inclusion of environmental, social, cultural and economic benefits as well as costs in the water allocation plan of a nearby catchment (Waitaki Catchment Water Allocation Board 2006) show further progress in this area.

The fourth key challenge involves increasing the scope for reallocation of water resources according to their market value in alternative uses. In comparison with other potential frameworks, the ‘prior appropriation’ or ‘first in, first served’ water allocation framework in the RMA performs poorly in this area, although RMA amendments in 2005 specifically providing for transfer of water permits are a positive step. A related policy issue is clarification of the status of water permits as a property right. Lessons can be learned from the apparent success of recent Australian water sector reforms to develop water markets (ACIL Tasman 2004). However, these markets are currently focused on regulated catchments. Application to unregulated NZ catchments such as Selwyn will create additional challenges due to system complexity and uncertainties.

Other related potential initiatives suggested for further consideration include resource rental charging for water permits, water allocation auctions and a water allocation tendering system. Local researchers have created an online water auction framework which is currently being tested in the Tasman District north of Canterbury (Raffensperger and Milke 2006).

Recent progress on addressing these challenges has been reviewed in a study commissioned by the New Zealand Business Council for Sustainable Development (Aqualinc 2007). The aim of this study is to further investigate and develop an improved water allocation management model for the New Zealand situation. With further consultation, this model has the potential to provide a basis for developing future Integrated Catchment Management Plans in areas such as Central Canterbury.

4 Conclusions

Widespread perception of New Zealand as a clean, green and water plentiful nation has hindered the adoption of a strategic planning perspective required to adequately prepare for inevitable conflicts as the sustainable water allocation limit is reached in many regions. Regional councils have found it difficult to satisfactorily address such conflicts within the framework of recent approaches towards implementation of the Resource Management Act and conflicts have escalated in regions such as Canterbury. A recent report by the Parliamentary Commissioner for the Environment

(PCE 2002), the country's environmental ombudsman directly accountable to the Parliament, identified five key barriers to adoption of a strategically informed sustainable development policy stance in natural resource governance:

- understanding of the sustainable development concept;
- knowledge and capacity to support sustainable development implementation;
- relevant indicators;
- leadership in all sectors; and
- education.

A large number of research and policy initiatives are currently underway to progress different aspects of these challenges. One such initiative, the *Sustainable Groundwater Allocation Research* project, has enjoyed productive collaborations with regulatory and stakeholder representatives as well as related research projects. Transparent processes, a high level of documentation, and peer-review have enabled constructive and measurable steps to be taken down an adaptive and integrated path to future sustainable water allocation arrangements for the Selwyn District in Canterbury.

The sustainable development concept has been researched and discussed within a wider sustainability discourse. Concepts of collaboration, adaptive governance and consensus-seeking processes have also been researched, discussed and documented. Knowledge and capacity gaps in certain fundamental aspects of ecological, hydrological and institutional systems are continuing to be addressed.

Promising progress has been made in developing a set of objectives to define integrated water management in the Selwyn Catchment, with indicators and data to measure progress toward these objectives. Education through social and cognitive learning is ongoing through a wide variety of opportunities for participation and peer-review; including research reports, research meetings, conference workshops and presentations, meetings with regulatory authority representatives, journal articles, popular press, public meetings and symposia, and a website. Leadership is being shown through the constructive actions of *SWALG* participants, despite other historical and current relationships which may place these participants in competition or conflict.

However, there is still a lot more work required in all areas. System processes, interactions, monitoring, indicator development and modelling require further resourcing before the future integrated effects of potential water allocation management options can be forecast with confidence. New Zealand requires leadership from their government through a national sustainable development strategy and proposal for a National Policy Statement that clarifies how resources such as water can be allocated in a manner that is integrated, participatory, and adaptive. At a regional level, implementation of sustainable resource management processes requires closer integration of relevant RMA processes with Local Government Act arrangements as defined in each region's Long Term Council Community Plan. Further integration is required with catchment-level initiatives such as catchment plans and sub-catchment initiatives such as stream care groups and iwi management plans. Principles of collaboration, commitment, trust, continuous improvement, efficiency, transparency, consensus-orientation and a commitment to peer-review will maximize long term implementation success provided the resourcing of the networking processes is maintained.

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How Social Networks Enable Adaptation to System Complexity and Extreme Weather Events

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Abstract

There are growing accounts of innovative, often collaborative institutional approaches to water management that seem to respond better to new challenges in supply and water quality management. While some describe these new institutional designs as a "third way", as opposed to traditional state-centered or market-based modes, we find that the most salient features of it to characterize even those effective state or market designs. The fundamental ingredient, which is patterned relationships, is one that arises when social networks are built around the formal (state or market) institutions. The necessary plane of description is not on the dimension of structure (state, market, or otherwise) but in the nature and workings of these relational networks. We describe necessary features of these networks. We illustrate these points with a case study: the Environmental Water Account (EWA), a novel market-based program for negotiating water allocations around the San Francisco Bay-Delta (California, U.S.A.). We point out how this institution worked precisely because it was not merely a market-based program but, rather, built in features of an effective social network. In this way, we found a capacity of the EWA to adapt to the dynamic nature of water resources and needs, along with the uncertainties inherent in a complex social-ecological system.

1 Introduction

Increasingly in the environmental literature, accounts of how innovative, collaborative institutions that allow more responsive approaches to complex, intractable issues, such as extreme climatic events and others, are appearing (e.g., Berkes et al. 2003; Pielke et al. 2007). In the field of water, these case study reports discuss how these new forums are creating innovative solutions through watershed organizations (e.g., Lubell et al. 2002), "adroit" agency programs (e.g., Fraser and Ingram 2006), and river basin agreements (e.g., Wolf 1998).

The public administration literature has come to recognize these collaborative forums as a "third-way", intervening between the opposite poles of state and market modes of governance (e.g., see Karkainnen 2003). While in general agreement with this literature, we make an important distinction (which is crucial to understanding new water institutions). That is, the new mode of governance is not something that sits apart from state and market --rather, it is a more fundamental mode of institutional design that exists in effective bureaucratic programs, markets, and hybrid institutions. The relevant plane of description is not in the formal-structural, but in the nature, patterning, and adaptability of the social networks found in all these effective designs. It is the working of these webs of relationships that allow institutions to match the complexity of their context (Lejano 2006).

The most salient descriptor is whether or not an effective and functioning social network undergirds the program. Social networks are patterned relationships that bridge, cross, and blur organizational boundaries. They allow the pooling of multiple knowledges and concerns. They are the mechanism by which adaptability and resilience is built into an institution and, in so doing, allow the program to survive system changes and find new innovative practices. In the following account, we build this relational theory. Further into this paper, we discuss how this helps us understand innovative water institutions, using the case study of a novel water market in California, U.S.A. to illustrate these claims.

2 Relational Institutions

Social networks, a term coined by J.A. Barnes, are defined by these authors as a system of sustained, patterned relationships among actors, which cross and sometimes blur organizational boundaries. These networks can be part of a formal institution, such as a transboundary organization, purely informal (e.g., dog owners who meet in a park each Sunday), or something purely social, such as a coffee klatsch. Such a network can be driven by function, but this is not the essence of the network --whether or not the network has formal objectives and material outcomes, what most characterizes it is the system of lasting relationships. When we study social networks, we emphasize the relationship as the unit of study. As described by one author (Scott 1992):

"Social network analysis has emerged as a set of methods for the analysis of social structures, methods which are specifically geared towards an investigation of the relational aspects of these structures. The use of these methods, therefore, depends on the availability of relational rather than attribute data."

Simply put, a social network is an institution that allows complex and innovative responses to occur. It does this by providing a framework, i.e., a constellation of relationships (which is people knowing other people whom they know will respond when they call), that can be activated when needed, can be perturbed for new information or ways of doing, or simply turned to for an extensive store of knowledge. The network allows for new and complex ways of doing because it crosses organizational boundaries and blurs formal categories. This transcendence allows the conversations that take place within the network to escape narrow rational-purposive logic that Weber said takes place within one organization. By blurring formal boundaries and categories, it frees up the conversation to try new ways of talking or thinking about a problem. By requiring that actors from different organizations talk to each other, it forces them to "translate" their concepts and, in so doing, allow for transformations in how these concepts are understood (since translation allows reinterpretation).

A social network may be created for specific purposes, but an important point for us is that the social networks, over time, attain an existence independent of these original objectives. The network remains because, simply, it has become a network --i.e., because people have grown accustomed to relating with each other, sharing knowledge, seeking advice, in a word, relating. They continue to exist out of habit or for other reasons --e.g., providing a social community that one can turn to for support and company. One sees this in professional associations where the quarterly get-together attains more importance than formal functions of the group.

Other times, the network will last not because it was organized around the specific objective but, rather, is implanted into already existing social institutions. As an example, one cannot understand the civil rights movement in the U.S. in the mid-20th century without understanding the Southern Baptist Church, because the movement was not created en toto but grafted onto the southern church. In this case, the social institution provides continuity, resilience, new members, and elements of structure to the latter movement. We see a good example of this in the field of water in India, where water cooperatives seem to be strongest in communities where there exists an important temple (Meinzen-Dick 2007) --in this case, the temple serves as the hub of a social network that exists for its own sake but, in so existing, supports other programs like water cooperatives.

The link between these social networks and resilience is important. As Pielke et al. (2006) point out, increasing trends in losses from extreme weather events is most readily related not to the pattern of weather events themselves, but from increasing social and economic vulnerability of communities. Take the recent flood in New Orleans, U.S.A., a widely touted case of the failure of Federal and other formal government programs to deal with contingent, emergency events. The day the flooding began to hit the community hardest, locals remember there being no one around to help --the fire department was overwhelmed, many of the police force had left, and the Feds were just nowhere around. In the middle of the chaos, there appeared an army of volunteers in yellow t-shirts armed with vast stores of emergency supplies. This volunteer army came from the Mormon church and seemed to exhibit an uncanny sense of organization where other formal programs had failed. This illustrates the ability of an ongoing social network to provide organization and adaptation in the face of unexpected circumstances. Why is this? For one reason, the network exists regardless of the formal organization and forms of support --it was always there, even in extreme situations when the formal breaks down. When phone lines went dead, the social network was able to communicate with each other through multiple means (knocking on doors, word of mouth, or just reacting out of shared habit). The social network, by virtue of the manifold ways by which members inter-relate with each other, has a built in redundancy of relationships --mechanisms by which people talk, share, and relate. These redundancies came to the rescue when more streamlined, formal systems broke down.

Certain common characteristics of these social networks emerge from our research. First, place is put squarely into the picture. These social networks are not just associations, whether formal or informal, they are associations built around a specific place (whether a temple, a school, a neighborhood). Part of the reason, we conjecture, involves the multiple dimensions of relationship that occurs with face-to-face interactions. First, these interactions are contextual --there is a common place of encounter, and this creates an important commonality between members (of time, place, condition, joy, and suffering). Second, these interactions are multiplex --when people at one place and time talk, it is not just the literal talk that is being exchanged; it is feelings, images, sights, and experiences.

People can talk about a sunset, or they can experience it together. This multiplexity of relationship enables complexity and redundancy in these interactions. This complexity and redundancy, in turn, can be employed to respond to situations which are complex and multiplex. Whether virtual, place-removed networks can find other ways to seek this multiplexity is an open question. Our initial thought is that there is no reason to expect them to.

It is this multiplexity of relationship that allows people to transcend instances of conflict. One will not abandon a water cooperative when talks about water allocations break down because of the multiple dimensions of relationship. "We cannot see eye to eye on this agreement, but he's a good guy. We'll laugh about this years from now." The social dimension has become recognized in the literature on consensus-building (e.g., Susskind et al. 1999; Forester 1999) --specifically, because relationships do not end with disagreement and, in this continued interaction, new directions for action or resolution may emerge.

These networks are also not strictly functional --they exist for other than the narrower, formal functions they are supposed to carry out. People in a water association will call each other not just because they have a question about water allocation. They will talk just to say "hi", to ask about job opportunities, to share new ideas or new recipes, to complain about other members, that is, just to talk. They will attend each other's functions, play golf or bridge, or seek each other out in instances that have no direct link with any program functions. Social networks are strongest when they are not merely teological but constitutional --they become part of how people understand themselves. This link to identity is key for our understanding effective institutions, whether we are studying the Mormons or smallholder farmers or river enthusiasts. Social networks are constitutive of identities of people and groups of people.

Social networks bridge the formal and bring different types of people together. Some successful watershed coalitions involve very different types: engineers, biologists, neighborhood advocates, and teachers. That is, their strictures on membership are either open or democratic or, at least, fuzzy enough to be moveable. This creates conditions for encounters between specific constructions of an issue and, in 'dialectical' fashion, allows new understanding and knowledge to develop. Part of this is the requirement to simply talk one's talk to people outside one's immediate community --this transcendent conversation allows the ideas to evolve beyond the local. The encounter between differing groups also allows the conversation to enter the realm of the ethical and, moreover, into the area where multiple ethical systems are considered. Ethical concerns are so often taken for granted, unspoken, internalized within a single, narrowly constituted group. It is by going outside the group that these ethical considerations become more explicit and, perhaps, better linked to policymaking. For these reasons, we are most interested in social networks that have, built in, a capacity for diversity in membership and democracy in interaction (see Ingram and Schneider 2006).

In the following, we will show how a novel program, the Environmental Water Account, took on these essential characteristics of a social network and, so, transcended its original design.

3 Case Study: Environmental Water Account

This discussion paper deals with water policy changes related in the California Bay-Delta shown in Figure 1. This is the largest estuary on the West Coast, draining some 40 percent of the waters of the state of California including the watersheds of the Sacramento and the San Joachin Rivers. Federal and state projects in the Delta deliver water to both cities and farms. Two-thirds of the state's residents, the majority of whom are in Southern California, receive some or all of their drinking water from the Delta, and it waters over 200 crops that produce 45 percent of the nation's fruits and vegetables annually. The Bay-Delta also supports the state's largest habitat for fish and wildlife, providing a nursery and migration corridor for two-thirds of the state's salmon, and contains Suisun Marsh, the largest contiguous brackish water marsh in the United States.

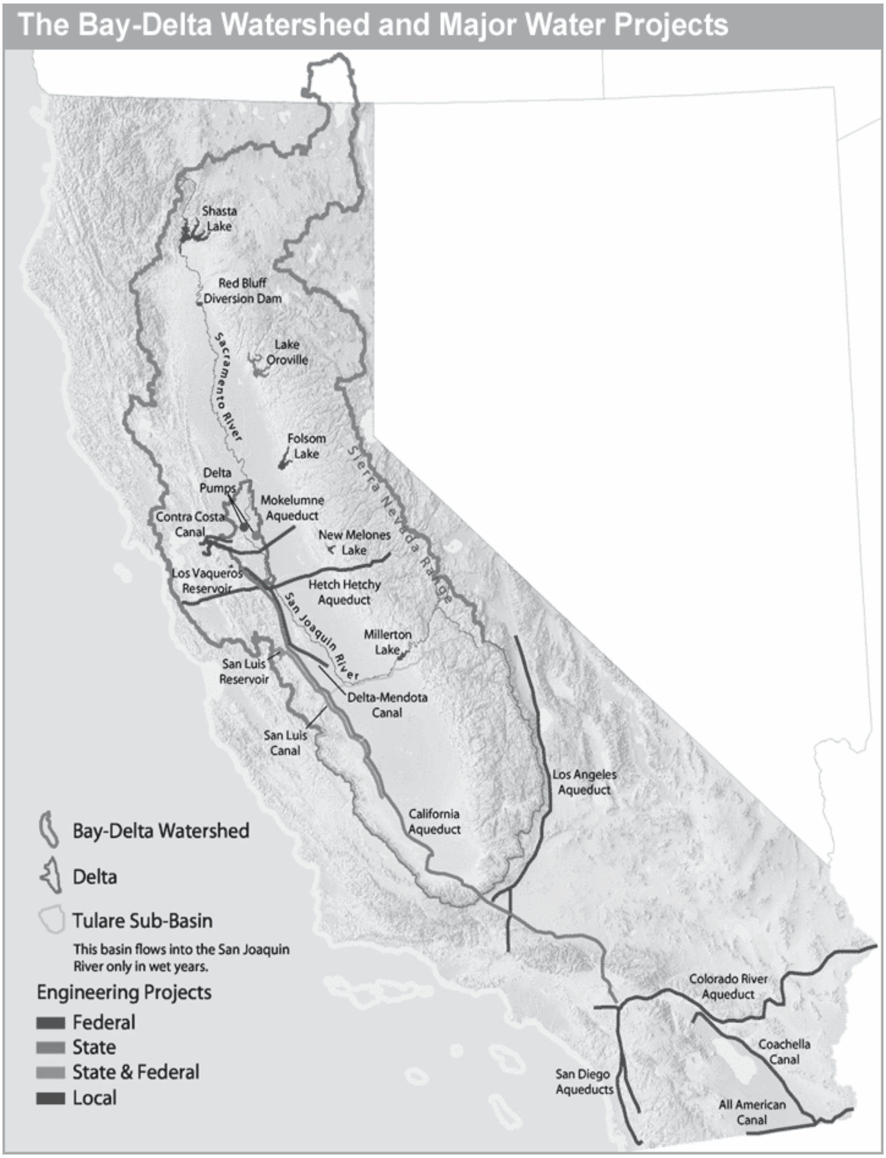

Fig. 1 The environmentally-important California Bay-Delta region is located within the agriculture-dominated Central Valley extending from Northern California nearly to Los Angeles. The Southern California Region is dominated by urban land uses.
(The authors thank the Natural Resources Defense Council for permission to use the figure, downloaded from http://www.nrdc.org/greengate/water/diverted.html, Sept. 4, 2007)

Governance over water in California reached a crisis about a decade ago when the major interests in the region came to virtual gridlock over incompatible aims and conflicting priorities. Agricultural and urban water contractors were very concerned about the reliability of water supply. Supply issues were confounded by water quality concerns as levels of salinity in some municipal systems exceeded U. S. Environmental Protection Agency standards. The stability of the levee system protecting valuable farmlands in the California Bay-Delta was threatened, and neither farmers nor government agencies wanted to shoulder the cost of upgrades. Environmentalists and Northern California residents objected to shipping large quantities of water they deemed essential for Bay-Delta ecological health to satisfy what seemed to them endless thirst resulting from rapid population growth in arid lands. The perspective of Southern Californians, and especially those municipal water utilities, was sharply different. The California Water Project, funded in large part by the growing tax base in the South, failed to live up to promised water deliveries.

According to most accounts, an important change in the Bay-Delta decision process occurred in a cascade of decisions over the past decade[1]. Instead of gridlock and crisis between water contractors and environmentalists, between North and South, and between federal and state governments, an era of peace has been uneasily established. We establish the background for this significant policy and institutional change by describing the longstanding characteristics of water policy that make it so impermeable to abrupt policy change, contributing to path dependency in water policy. The narrative emphasizes the extent to which past policy decisions have locked in the way water problems are framed and the range of alternatives are narrowed to what is "comfortable" and conventional. Spreading the risks of blame for mounting problems among many organizations blunt inclinations toward fundamental change. At length, however, these approaches to policy proved insufficient, allowing dissatisfied participants to hamstring Bay-Delta water policy until institutional change took place. This paper looks at the institutional and policy change that moved water management out of path dependent trails and the management ideas undergirding these new practices. It considers the utility of what has come to be called boundary organizations that bridge the differences between kinds of knowledge and levels of governance. It also considers inclusive and adaptive management supposedly enhanced by new institutions and policies. Most importantly, change hinged upon the development of new, more inclusive networks.

The Environmental Water Account (EWA) is an innovative program developed by the Bay-Delta process, which responds to the growing tension between environmental water uses[1], SWP operation, and water users. The EWA created a system wherein fisheries agencies own and manage water. The EWA reflects a backing away from the regulatory approach that had marked fish protection. Instead of simply mandating water releases and letting water contractors whose expectations of water supplies were disappointed bear the cost, fisheries agencies themselves were to own and manage the water. The EWA involves voluntary water sales and contracts. It guarantees that environmental water will be available for fish with costs compensated to the contracting agencies (cities and farms). It also modifies the role of fish agencies that were to manage the account, and requires a close working relationship with facilities operators not previously sympathetic to fisheries problems. To make the EWA work, a number of organizational boundaries must be spanned, different perspectives consulted, and cooperation gained.

An integral aspect of EWA's innovative design is its dependence on water acquisition through voluntary markets rather than governmental mandate. Water markets encounter considerable resistance even though most water resources academics and many environmental groups favor moving water to higher value uses through markets. There are concerns about the ancillary effects of water sales on agricultural communities. Further, markets make the allocation of water more efficient, but do little to halt urban growth and development that many environmentalists oppose. Consequently, many water sales are quite controversial even though they regularly occur and have been taking place for over thirty years. The sale of water from the Imperial Valley to the City of San Diego that transfers 200,000 acre feet took nearly a decade and enormous political capital to accomplish. That transfer continues to have bitter enemies among some farmers in the Republic of Mexico who will inevitably suffer negative indirect effects. In contrast, the Environmental Water Account, which in some years has moved almost as many acre-feet, was negotiated in months and has a generally favorable public image.

The idea of protecting the environment through markets is an old idea favored by many water resources economists. To some, however, the idea seemed wrongheaded. According to the public trust doctrine, the state was

[1] See for instance David Nawi and Alf Brandt, "CALFED Bay-Delta Program: From Conflict to Collaboration" paper presented to University of Miami Law School Conference on Adaptive Management, December, 2002; Patrick Wright, "Fixing the Delta: The CALFED Bay-Delta Program and Water Policy under the Davis Administration, 31 Golden Gate University Law Review. 331; Elizabeth Anne Rieke, "The Bay-Delta Accord: A Stride Toward Sustainability" 67 The University of Colorado Law Review 341

supposed to guarantee the use of water in the public interest of citizens, and if low flows were endangering fish, then diversions from the streams should be regulated. The citizens should not have to pay to purchase the welfare (adequate flows for fish) already guaranteed. Agricultural interests also had doubts. If problems were solved through markets, there would be less public support for the infrastructure projects farmers believed were essential. Further, many farmers felt that although water sales might make individual farmers better off, the farming communities would suffer as people moved off the land and no longer supported local businesses, schools, and civic enterprises. Further, water sales to city or state governments raises demand and water prices, making water more expensive in local water markets among farmers. As a consequence, water markets were more talked about than actively pursued until recently. The EWA has little of the purity of water markets that economic theorists prefer, but it offers just enough to each important constituent group to attract support. Cities like to see water flow in their direction through markets where relatively well off municipal water utilities can afford to get through purchases what is very difficult to accomplish through ordinary politics. Environmentalists liked that the water purchased was directed at saving fish. Farmers were pleased to escape the risk of having their water sources dry up because of an application of the Endangered Species Act.

Special skills are necessary to succeed in water markets involving knowledge about pricing, investment risks, and debt not usually found in water or fisheries agencies. In its early years the EWA was blessed with skilled staff that could act as boundary spanners. David Fullerton, who was senior scientist at Natural Heritage Institute, and environmental organization, and was hired by CALFED to develop an analytical approach and computer model to make decisions about the types of water assets and quantities of water to acquire each year. Subsequently, he was hired by the state and became the manager reporting to the Scientific Review Panel. Fullerton managed the successful acquisition of water during the first year. When Fullerton moved on to the Metropolitan Water District, Jerry Johns took over. He, too, had a diverse background, and could span boundaries. He had previously worked for the State Water Resources Control Board, the California water quality agency, and was chief of the Bay-Delta unit. Jerry Johns managed to diversify the kinds of water acquired by the EWA, always searching for the cheapest water whether it was located above or below the Delta.

Jerry Johns was cognizant of the criticisms of markets among farmers. He prepared and disseminated information and procedures aimed at prospective water sellers to expedite acquisition of water with a minimum of third party impacts. The intention was to make the state an "enlightened consumer" of water through the EWA and other programs. The aim was to make purchases as environmentally and socially friendly as possible. Three principles guide the EWA:

1. No injury to other legal users of water
2. No unreasonable effects to fish, wildlife or other in stream beneficial uses of water
3. No unreasonable effects on the overall economy or the environment in counties from which the water is transferred.

These rules address the usual complaints about rural to urban water transfers. Their enunciation and enforcement avoids possible difficulties.

The Environmental Water Account also profited by exceptionally able leadership in the science program at CBDA. Sam Luoma, on leave from the U. S. Geological Survey, was the lead scientist during the first three years of operations. His impressive scientific credentials lent prestige to the program. The science program sponsored a large number of workshops and annual meetings, sometimes with hundreds in attendance. A great deal more has been learned about fish behavior through CALFED science studies. Science is moving the management focus away from take at the pumps to the more general conditions existing in the total life cycle of fish. For example, it would seem that the pumps have less influence upon the survival of endangered salmon runs than was previously thought, at least if flows are above some particular thresh hold. Also, predation studies in Clifton Forebay, which is the pool in front of the pumps, and studies of the consequences to fish of the operations of the Delta Cross-Channel may eventually result in means for saving endangered fish that may be as or more effective than the old method of reducing take by shutting down the pumps.

The Environmental Water Account is by far the more successful of the Bay-Delta program's attempts to create new policy instruments that incorporate different perspectives. Fish management agencies, which had always looked at water as fish habitat, were made by the boundary-transcending design to work with project managers which saw water as a product it must deliver to important human constituencies. Regular interactions over issues of when to release from storage what water and where led to changed attitudes and a building of trust among all participants in the networks. Science, which had credibility because it came from an outside interdisciplinary team of experts, not only helped actors to adjust, but conferred legitimacy to the effort. While the program is small, we contend its progress is quite important for water sustainability. In this case, water transfers were made through market-like mechanisms that are endorsed by nearly everyone who writes about needed reforms in water resources. Equally important, changes were made without large political upheaval. What made any of these changes possible was new networks that brought together people who previously had limited interaction: farmers and the state water agency buyers in the EWA; Fish and wildlife professionals and water project operators in the Army Corps of Engineers; and Science advisers and practitioners.

The EWA was not just a market instrument but, in truth, a social network. It did not work simply as a market --i.e., one where buyers' and sellers' actions and preferences are coordinated purely through a price mechanism. In this case, people met regularly and exchange ideas and concerns. Fish advocates would share their druthers with dam operators. Water agencies would talk with public interest groups. Much deliberation, communication, and coordination occurred even before any talk of prices were broached. What was negotiated was not just the purchase of water, but the proper operation of water facilities, timing of usage, and even conservation practices. As evinced in interviews with the participants, the EWA enabled formation of a new community.

4 Conclusions

Water resources management is a field in flux. Old templates such as multipurpose projects and comprehensive, river basin planning have been replaced with new ideas of water markets, watershed councils, adaptive management and inclusive governance. Our contention is that it is not the change in formal structures that are likely to lead to better performance, but instead the construction of new networks that cut across formal and informal boundaries. In building such networks, the geographic focus needs to reflect shared human experience, and it is far less important that boundaries reflect hydrological realities than they reflect institutionalized social interaction. Science finds it way into real world decision not by holding itself apart from other human interactions, but instead by becoming part of networks that are able to enroll in new ways of knowing about water issues. Similarly, markets can become important in water not by offering an alternative nongovernmental arena for action, but instead by embedding market-like structures within governance arrangements including public and private actors.

Our main point is: the EWA worked precisely because it was not just a market, but because it incorporated salient characteristics of a well-functioning social network. Some of these features:

- the network established patterned relationships across organizational boundaries;
- these patterned relationships were sustained, face-to-face interactions;
- the nature of the interactions evolved with the changing demands on the relationship;
- the relationships involved not just translation from one party's language to another but a sharing of ideas and ways of understanding;
- the network did not seek to displace formal institutions but, instead, strengthened them;
- the network was sustained with social relationships which nurtured the network even when formal support (e.g., funding) ran out;
- in other words, the EWA became a social institution.

These institutional innovations are seen to be enacting fundamental changes to water institutions in the U.S.A., a field that has otherwise been characterized as overly tradition-bound and sluggish to respond. Our hope is that the coming years will see increasingly sophisticated analyses of these evolving institutional designs.

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Managing flood risk in the urban environment: linking spatial planning, risk assessment, communication and policy

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Abstract

Over recent years there have been a number of attempts at integrated approaches being taken to water and flood risk management. Recent flooding events in Europe have triggered discussions about giving rivers back their nature (floodplains in stead of dikes). However, the emphasis tends to be on finding space for flood water in rural areas in order to protect the urban areas. The question how to deal with major floods in urban areas has not received much attention, and as yet the delivery of increased system resilience as defined by de Bruijn (2005) is a major challenge. In a resilient approach the focus is on accommodating flood waters, with concurrent impact minimalization and rapid recovery. Spatial solutions (diversification of defense levels for different land uses according to their vulnerability) may provide important opportunities to reduce flood impacts, whereas flood proofing of buildings enhances the recovery capacity of the system. In this paper it is argued that cities play an important role in driving the transition to adaptive flood management approaches across different spatial and temporal scales. Yet, at the moment there are a number of bottlenecks which have so far hampered the adoption and effective implementation of flood risk management into urban planning practices. As such the recent Urban Flood Management (UFM) project, which aims at the development and verification of UFM strategies and methodologies in the cities of Dordrecht, Hamburg and London, may provide relevant practical examples to address these issues. These experiences could contribute to national and European policy making, such as input for the EU Flood Directive. This paper discusses the background and challenges to the UFM project, and also shares the first insights from this international umbrella project.

Key words: urban flood management, resilience, participatory approaches, spatial planning, communication, policies, practical cases

1 Introduction

The European Commission stresses the need for a new approach to flooding; a directive on the Assessment and Management of Floods is being developed [6]. Under the proposed directive, Member States would work together to identify potential flood zones such as river basins, coastal areas and flash-flood paths. Each flood zone will be analyzed concerning existing and future flood damage potential. Result of these analyses are ‘flood risk maps’ supporting the production of local or regional action plans based on prevention, protection and preparedness. Creation of these flood risk management plans will help to prevent and limit the damaging effects of floods. The management plans will include measures ‘to reduce the probability of flooding and its consequences and address all phases of the flood risk management cycle, focusing particularly on preventing damages by avoiding construction of houses and industries in present and future flood-prone areas or by adapting future developments to the risk of flooding’. Currently there is hardly any practical experience with the development of long term integrated (urban) flood risk management plans at local level, whilst there is a growing need and concern amongst stakeholders.

Many public authorities are facing the challenge of how to manage the risks of urban floods in their redevelopment projects and expansions in at-risk areas, which may be situated outside the main line of defense or in low-lying polders. For example, plans have been made for 12,000 new waterfront habitants in Hamburg Hafencity, Germany in 2010 [12], for over 150,000 homes in the Thames Gateway, England by 2016 [4] and 550.000 new houses are planned in the Randstad (Netherlands) by 2020 [15]. For the future, increases in sea level, peak rainfall intensities, and river flows, due to climate change, will challenge efforts to create a safe living environment. Therefore new approaches need to be developed to adapt the urban environment to climate change by enhancing the resilience to floods and thus reducing its vulnerability. The recently started Urban Flood Management (UMF) project [8, 7] is an important step towards the use flood risk as a design parameter for spatial planning, towards the increase flood risk awareness and towards the development of practical strategies to cope with and communicate the (residual) risk.

The UFM project aims to draw up such an (urban) flood risk management plan for pilot areas in the Thames Gateway, and for the floodplains of Hamburg and Dordrecht, to apply necessary tools, and to share its experiences with the EC and other stakeholders. This paper discusses structure and methodology of this innovative umbrella project, and captures insights from the initial phases, with a particular focus on the Dutch part of the umbrella.

2 Targets and bottlenecks of flood risk management, background for the UFM project

A number of aspects of an integrated approach to urban flood management are relatively new to the world of urban planning. Adoption and effective implementation of flood risk management into urban planning practices have so far been hampered by the following main bottlenecks (International Expert Meeting UFM, 2004) [13]:

- Lack of understanding current and future risks and implications: flood frequency is likely to increase during lifetime buildings
- Lack of long-term planning, and poor integrated and comprehensive planning
- Inadequate steering role local and regional authorities, and conservative nature of the building sector

In a special session of the International Symposium on Flood Defence (Nijmegen, May 2005), an initiative was launched for a joint action between London (Thames Gateway), Hamburg and Dordrecht. These cities share in part similar challenges such as (re)development activities and expansions in flood-prone outskirts and they recognize the need for new planning approaches to manage actual and future (residual) flood risks in these areas. The initiative that consists of various national chapters (Dutch, German and English) aims to develop sound urban flood management strategies. It sets out a combination of efforts that include:

- An innovative practical project, drawing up an UFM plan for specific sites facing residual flood risk in Stadswerven (Dordrecht), Hafencity/Wilhelmsburg (Hamburg) and the Thames Gateway (London).
- Applied research on models, methodologies and concepts (such as flood risk and vulnerability assessment, flood risk maps), technologies (such

as flood proofing buildings), planning and building regulations, requirements and specifications, to be used for the pilot projects.
- Experience and knowledge exchange and dissemination between the partner cities and other professional and scientific networks.

3 Challenges and building blocks for UFM

The incorporation of resilient flood risk management strategies, which focus on reducing the impact of floods by "living with floods" instead of "fighting floods", poses considerable challenges to the planning, design and management process. These challenges, around which the UFM project is structured, are related to the following building blocks: flood risk assessment, resilient planning and building, pilot creation of an integrated UFM plan, communication and emergency response, and policy and governance.

3.1 Flood risk assessment

In order to comply with policies on climate-proofing urban areas in relation to flooding, actors in the design/decision making process will need to adopt a more integrated approach to spatial planning, flood risk and its various consequences. Key to improving flood risk management is to better understand the risks. The risk of flood is defined as the multiplication of probability and consequence, where probability is the chance of a particular event occurring and consequence is the potential damage of that event. Risk assessment is rapidly becoming more important for decision-making – although the risk concept is relatively new for water management in the Netherlands. Effective risk assessment approaches will have to consider the following aspects:
- Performance of whole systems, rather then merely considering single measures in isolation [11];
- Consequences of certain measures for various flood events, in stead of for a specific probability or return period. This includes flood events that would exceed the design standard [16];
- Natural variability and uncertainty about external pressures, specifically climate change.

It is arguable that the overall performance of the flood risk management system can be improved by adopting a resilient approach [3]. At the same time, this leads to less sensitivity for uncertainties in the flood probabilities. While a resistant approach is directed to maintain the structure and functions of the system (c.q. to preserve status quo), a resilient approach enhance the capacity of the system to recover from non-structural changes in dynamics. The resilience of a system relates to three aspects that determine the reaction of a system to flood waves: (1) the amplitude of the reaction, (2) the graduality of the increase of reaction with increasing disturbances and (3) the recovery rate. The resilience of a system is larger when the amplitudes (i.e. amount of damage) are smaller, the graduality is larger or the recovery rate is higher. This means that the resilience can only be assessed by considering the whole set of indicators, and that indicators are neither to be aggregated nor prioritized. In other words, design strategies with a larger magnitude of the reaction, but with a more gradual slope of the damage-frequency curve, could enhance system resilience. The relation between the reaction amplitude (loss) and the probability of the flood conditions is illustrated in Fig 1.

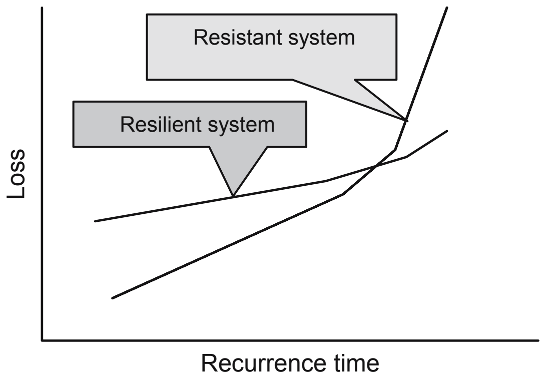

Fig. 1 Enhancement of system resilience by increasing the graduality

3.2 Resilient planning and building

Where new developments are planned in at-risk areas, new strategies of damage reduction are necessary to take account of the residual flood risk (flood above design level). Frequently this challenge will involve multiple scales, and therefore effective damage reduction requires the ability to take advantage of different initiatives over differing spatial scales, from the region or river catchment to the local planning level and street level. Greater engagement of main stakeholders, public awareness and a sense of personal responsibility could enhance sources of resilience in the flood system. Particularly important are measures that could be carried out by local authorities, building companies or house owners, and which could be appropriate for grant assisted schemes. They comprise individual flood proofing of buildings and municipal infrastructure and adapting the building activities to the risk. This kind of measures has a significant potential to safeguard buildings and contents from flooding [17].

Flood proofing can be accomplished by five defense or accommodation strategies, using (1) elevated configuration, (2) dry proofing or (3) wet proofing the building, (4) construction of permanent or mobile water barriers, and (5) using floating or amphibious solutions. In the first strategy, the entire structure is elevated to prevent the entrance of flood water, e.g. by building on columns, walls, or embankments. Dry proofing involves sealing with impervious barriers built into the structure. This strategy can be used for floods of up to one meter depth, but should not be used above this depth of water. Wet proofing is based on the acceptance that some water will enter the building, so the intention is to use materials that will help minimize the impact of water on fabric and fixtures. Permanent or mobile water barriers can be used to try to keep flood water out of individual buildings or whole communities. The fifth strategy entails floating or amphibious buildings that can move with a fluctuating water level.

Flood adapted building use means that endangered stories are not used cost-intensively and no expensive upgrading is undertaken. As an example, designing dwellings with a non-habitable ground floor will be considered as alternatives for the pilot site. The ground floor could be used for flood compatible uses such as car parking, flood resilient storage, public open space, etc (Fig. 2). However, this measure can sometimes have adverse consequences for the appearance of the streetscape and for perceptions of safety and security. Solutions such as mixed-use development with commercial uses on the ground floor can provide active frontages, but may be limited by the market for such property.

Fig. 2 Example of adapted building use

Although considerable progress has been made in the development of flood-proofing technologies and concept world-wide, they have been rarely implemented or tested on full scale. The latter implies that information on its performance (e.g. marketability, costs and effects of such measures) are limited. This specifically holds true for the Dutch context. Consequently, the economic efficiency of different technologies is as yet unclear.

3.3 Creation of an integrated urban flood risk management plan

In urban areas with high social and economic values, more focus on the reduction of the effects of floods may provide important opportunities in flood risk reduction. Moreover, new urban planning approaches, which embrace (high) water management as an important guiding principle, could provide simultaneous short-term social and economic benefits, e.g. in terms of high amenity values of attractive waterscapes.

Urban areas are complex systems in terms of the physical, institutional and scale dimensions. Successful delivery of UFM policy can only be achieved when all actors agree that there is a shared added value, and also whether they will work together to maximize opportunities and overcome constraints provided by the institutional settings e.g. public/private [1]. A move to more integrated solutions, and achieving inter-institutional/stakeholder working will be key to improving UFM overall. In the process, the local scale will be especially important as a platform to work towards an approach that 'cultivates' resilience, i.e. encourages it to grow [2]. This requires combining technical means with participatory planning and design approaches. Such an approach provides the mechanism to help stakeholders to learn about future changes and from interacting with other participants, and the mechanism to encourage stakeholders to take a holistic view, so that plans and designs achieve benefits of synergetic effects.

3.4 Communication and emergency response

It has long been recognized that resilient systems must be capable to perform to acceptable levels when subject to disturbances such as floods. In order to minimize impacts of floods and ensure that recovery can take place rapidly, creating and using dry refuges (like hubs), for example high public buildings, within the development area will in many cases be a more sensible solution than evacuating; from a safety perspective, but also from social and economic perspectives. This solution is specifically desirable to cope with frequent floods, but may also provide important opportunities in reducing the flood risk to people if there is limited time before the flood water arrives. Moreover, accepting for some degree of flooding may send out a signal to communicate the potential flood risk of the site. In this way, experiences with smaller flood events may create a ‘flood awareness’ among residents and increase their eagerness to learn more about it and take precautionary actions. However, the main issue with hubs is that containment at higher levels for long periods of time is unlikely to be feasible without essential public services (medical services, operational sanitation, power, law enforcement, etc.); therefore this solution involves having adequate in-life support systems when subject to less disruptive flooding. Nonetheless, in times of emergency due to extreme flooding, evacuation is still necessary because failure of such services is possible. Hence, safe evacuation routes to higher land are requisite to successful urban flood management through this measure. One option that can be employed for safe access and egress is to raise these routes. This will also guarantee access to emergency services when there is a flood.

Next to the possibilities to evacuate (safe evacuation routes), the time to evacuate can also be influenced through UFM approaches. For example, the knowledge of policy makers and emergency services could be enhanced by practicing emergency responses. Sustained communication (of warning signals and emergency plans) to residents is another effective means to reduce the warning and response times. It should be noted that here communication also entails making the public more aware of the flood risk and broadening the responsibility for floods.

3.5 Policy and governance

The encroachment of flood plains and low-lying areas (e.g. polders) to facilitate socio-economic needs of communities is posing a major challenge as how to deal with long-term flood risks in these areas. It was realized that complete safety cannot be guaranteed; furthermore, one cannot raise dikes indefinitely. This insight has given rise to intense debate on strategies for coping with floods. The idea is that instead of keeping water out, it is about safety with water. This tension between safety and liveability urges policy makers to review the roles, tasks, responsibilities and liabilities of the various actors. The tendency is now to look for new ways to distribute responsibilities between different types of public authorities and for public-private partnerships. The point of departure for the analysis should be the insight whether there is a necessity to regulate this, whether there is an ambition to do this and lastly how this could be done. The analysis should be based on the prevention of casualties, social disruption and large (environmental) damage. These elements are seen as a public responsibility taken up by national or local government. The remaining part of the flood risk is the responsibility of the private sector. Here, private citizens could take control over the level of risk they are willing to accept.

4 Insights from initial phases of the pilot creation of an integrated UFM plan for Dordrecht

The UFM project has provided the opportunity to develop new methodologies for the assessment and management of (residual) flood risk in the urban environment. The chosen integrated approach of the UFM project aims at combining technical means with participatory approaches and carefully designed communication strategies. Therefore the project has gathered various public and private stakeholders able to implement the solutions over differing spatial areas, from the national level to the local planning and street level. There are local, regional, and national authorities, a waterboard, a developer and a housing corporation. A pilot has been conducted using the existing context of an urban regeneration project in Dordrecht to engage the stakeholders in this new process. Taking these stakeholders 'on board' in the design/decision making process has revealed a number of themes for successful implementation of UFM approaches. The first insights that emerge from this learning environment are discussed below.

- It is not possible to impose an integrated UFM plan for resilience on an area, it is only possible to create the conditions in which such resilience can emerge [14]. Therefore it is important to tailor the participatory design process to the local context, taking account of the needs and interests of the participants. The process benefits from a diversification of the type of organizations and backgrounds, which facilitates learning from each other and from different perspectives raised. The goal of this collective striving should be (i) on awareness raising that decisions often lead to solutions which are less optimal in the long run for all stakeholders involved and (ii) on fostering a culture in which integration and enhanced resilience through dual-use options will emerge.

- At the process level, it was felt helpful that some main stakeholders already were familiar with a broad scope and participatory approach through their experience in making urban water management plans. In this document various departments of the municipality and the water board started to cooperate on issues of water management and spatial planning. Nurturing and sustaining such networks, with different interests and a shared responsibility, is seen as valuable for the quality of the process, whilst also providing opportunities for innovation and the growth of ideas which would otherwise not have been included.

- It is difficult to find an appropriate problem owner for water safety issues in areas outside the primary defenses, although the responsibility seems to be with the local authority and developer. An important argument is that integration of water issues with spatial planning takes place at the local level. On the other hand, water (safety) is just one aspect in the local decision making process among many others, such as urban development.

- There seems to be an increasing awareness of the need to use water and floods as a design parameter for spatial planning. However, present day spatial plans do not usually take a longer term perspective, where the future is rather uncertain. Yet, the recognition that the future is inherently uncertain should be the starting point to develop new approaches to UFM in which the climate resilience, particular flood resilience, of the urban environment is enhanced.

- An important aspect of organizing participation is the provision of information in the participatory process to inform stakeholders. Tools for inter-active design combined with tools for integrated spatial evaluation are lacking to support this participatory planning due to weak link between developers and users. In particular, there is a need to develop proper analytical instruments and planning tools and to facilitate cooperation between various disciplines such as (urban) planners and water managers. It is seen as essential to inform the spatial planning process of (1) relevant issues of flood risk, especially to human safety, of (2) the impact of the proposed development on flood risk, and of (3) the effectiveness of possible mitigation measures. The degree of detail in the assessment must therefore correlate with this objective, following Table 1. It is suggested that within a master planning exercise detailed flood risk assessments are required to fully consider flood risk and its management with appropriate precision. For the project a 'macro-scale' inundation model has been developed in SOBEK for all risk areas in Dordrecht as a city, and a more detailed model for the pilot area Stadswerven. This detailed model can be used for a careful analysis of the interaction between different site development options and the consequences for flood resilience and flood risk, which is then used as input to reconsider the spatial plans.

Table 1. Characteristics of macro, meso and micro approaches of flood risk assessment (Messner and Meyer, 2005)

Scale	Size of research area	Objective	Demands on precision	Amount of input data required	Amount of resources required per unit of area
Macro	National	Comprehensive flood mitigation policies	Low	Low	Low
Meso	Regional	Large-scale flood mitigation strategies	Medium	Medium	Medium
Scale	Size of research area	Objective	Demands on precision	Amount of input data required	Amount of resources required per unit of area

- Risk communication is aimed at making the public more aware of the flood risk and broadening the responsibility for floods. The idea is that if the public better informed, they can take more responsibility over the consequences of their settlement choice. However, given the fact that the demand exceeds the supply for housing in the Netherlands, the settlement choice is rather limited [10]. Hence, the question arises if the public really has an alternative. Broadening the scope of individual actions in relation to issues such as settlement choice, insurance, precautionary building measures, is therefore a prime requisite in increasing the (sense of) personal responsibility.

5 Conclusions and outlook

Much scientific research is being conducted relevant to the challenges posing climate change to cities. These studies have generated sufficient knowledge to justify adaptation. Yet, there is, to date, insufficient research for effective adaptation planning [5]. As consequence, its transfer into practical application is still hampered. Moreover, local governments generally have little understanding of the opportunities and threats at stake, which means that translation of strategies into policies and investments, and participation in research is still much limited. In some cases, however, local alliances of stakeholders have an incentive to address opportunities and obstacles to climate-proofing urban areas in relation to flooding. In this respect the three partners in the UFM consortium, London, Hamburg and Dordrecht represent example cases. All three are situated near the mouth of a major river in densely populated and economically highly active regions, and within the influence of the sea. Simple lack of space further necessitates the search for combinations of flood accommodation with urban development. The UFM project will provide relevant practical examples with the development of long term integrated Urban Flood Management (UFM) plans through collaboration of public and private stakeholders in real life cases. The activities will result in urban flood management strategies aimed at creating a physical and social urban environment where the potential occurrence of a flood, even in case of an exceptional flood above design level, will result in minimal physical and social damage. However, the delivery of increased system resilience is as yet a major challenge. There is a key need to create the conditions in the participatory design process in which such resilience can emerge – it is not possible to impose an integrated UFM plan for resilience on an area. This is facilitated by the provision of good quality information and planning tools in the participatory process to inform stakeholders of the consequences of different development options for flood resilience and flood risk.

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Benchmarking in Dutch Urban Water Management: An Assessment

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1 Introduction

Although drinking water provision and sanitation have long been considered as natural monopolies, the ongoing liberalisation of public services in the European Union is also influencing the water sector. In the Netherlands, the liberalisation trend has led the actors responsible for drinking water provision, wastewater collection, and surface water quality to start benchmarking processes in order to make the performance of the sector transparent and encourage learning across organisations. Benchmarking is regarded as what Keehley et al. (1997) characterise as "a process for identifying and importing best practices to improve performance", and the organisations involved have chosen for what Andersen and Pettersen (1996) categorise as a combination of 'performance benchmarking' and 'competitor benchmarking': comparison of performance measures across organisations that deliver the same product or service.

Urban water management in the Netherlands is implemented by three different actors: drinking water companies produce drinking water, municipalities construct and maintain the sewer system that collects and transport urban wastewater, while water boards design, build and operate wastewater treatment plants (Bressers et al. 1994; Kelder 2000). These actors did not coordinate their benchmarking processes. The association of Dutch drinking water companies VEWIN was the first to act, publishing a first benchmark for drinking water production and distribution in 1999 (based on 1997 data), and publishing new benchmarks every three years.

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The Association of Water Boards published wastewater treatment benchmarks in 1999 and in 2002, and aims for a third in 2008. The umbrella organisation for municipal sewer utilities RIONED led a ‘benchmarking pilot’ for wastewater collection and transport in 2002, and published an official sewerage benchmark in 2005.

In a 2003 policy paper, the Dutch national government puts forth its vision on the water chain (DNG 2003), promoting benchmarking as an important instrument for actors to make transparent how they serve these public interests: public health, reliable drinking water provision, affordable water services, environmental quality, and customer protection. The following paragraph inspired the research presented in this paper:

> Depending on the success with which [benchmarking] is applied by the parties concerned, it will be considered in a later stage whether it is needful to make this instrument mandatory for all links in the chain and to see whether on the long term an integral (waste)water benchmarking should be developed. Furthermore, the national government will strive to make the benchmarks be as much as possible in keeping with the public interests that are to be guaranteed in the water chain.
>
> (DNG, 2003)

This quote gives rise to several questions. First, what is seen as successful application of benchmarking? Second, if the indicated public interests are considered as norm, how well have the parties concerned performed by this standard? Third, what are the risks of benchmarking the links of the water chain separately? And finally, what policy options does the Dutch national government have to impose its vision on the current benchmarking practice?

In search for an answer to these questions, the sectoral benchmarking processes have been assessed (Jonker 2006) using the conceptual notions that will be presented in the next section. This assessment (reported in Section 3) reveals a significant gap between the performance indicators that have been used in the benchmarking processes, and the policy objectives set by the national government. To assess to which extent independent sectoral benchmarking can contribute to performance of the water chain as a whole, the interdependencies between the actors concerned is evaluated using a causal model (Section 4). The findings (discussed in Section 5) indicate a need for coordination, but some considerable policy barriers remain.

2 Conceptual notions

2.1 Benchmarking

The term 'benchmarking' is somewhat ambiguous. The term may refer to comparing quantified performance levels across different organisations, but also to "a process of continuously measuring and comparing one's business processes against comparable processes in leading organisations to obtain information that will help the organisation identify and implement improvements" (Andersen and Pettersen 1996). Throughout this paper, the term 'benchmarking' will be used in the sense of this last definition. For a narrower scope, the term 'performance benchmarking' denotes the process of defining and measuring performance indicators, and comparing across organisations *without* the continuous cycle of learning and improvement, as it will depend on the purpose of the performance measurement whether such iterations take place.

According to the literature on benchmarking (Andersen and Pettersen 1996; Camp 1989, 1995, 1998; Jenkins and Hine 2003; Keehly et al. 1997), the primary motivation to start a benchmarking process is its outcome: performance improvement in terms of net profit, or savings and increased customer satisfaction in not-for-profit organisations. The process itself is considered beneficial because it motivates the participants for change (through understanding the relation between their work and the organisation's performance, and opening up to innovative ideas) and avoids reinventing the wheel (by learning from best practices in other organisations).

Andersen and Pettersen (1996) show the importance of carefully choosing *what* to benchmark: business performance (which indicators?), business processes (which processes and what aspects?), or business goals and strategies, and *against whom* to benchmark: other departments within one's own organisation, other organisations that produce similar goods or services, or any other organisation having processes similar to those to be benchmarked (e.g., payroll or billing).

Another important choice concerns the way(s) in which the results obtained through performance measurement and comparison are used. Besides performance improvement by learning from best practices, there are other purposes for which performance benchmarking can be used: transparency (providing insight in the structure of costs and prices, and how these differ across organisations), accountability (public organisations and the responsible administrators become more accountable to their constituents when comparative results are made available to the public on a periodic basis), and ‘comparative competition’ (surrogate competition for public utilities, where a regulator evaluates the relative performance of several utilities on a comparative basis).

Compared to the potential contribution of performance measurement to an organisation’s productivity (via feedback and learning) as well as the legitimacy (via transparency and accountability), its potential ‘perverse’ effects receive but little attention in the general benchmarking literature. De Bruijn (2002) and De Bruijn and Van Helden (2006) convincingly argue that performance measurement can provoke strategic behaviour (‘fixing the numbers’ to look good, meanwhile making the measurement useless as feedback for learning), sub-optimisation (reducing input while ignoring opportunities for true innovations), loss of professionalism (focusing on ‘what *scores* best’, rather than on ‘what *is* best’), and bureaucracy (the performance measurement becoming a toy for managers).

The urge to display these types of behaviour will be stronger as the management function of performance measurement moves up on a scale that ranges from ‘mere feedback’ via ‘incentive to exchange experiences and adopt best practices’ and ‘public appraisal and ranking’ to ‘basis for rewards or penalties’. Actors will also tend more towards perverting behaviour when their performance cannot be expressed in a small set of quantitative indicators because (1) it involves making tradeoffs between competing values, (2) it depends on the performance of other actors, or (3) the causality between their output and the eventual outcome that is desired (e.g., the causality between minor sewer leaks and public health) may be contested, making the focus on output unwarranted. These conditions make that actors perceive rewards and penalties on the basis of ‘simple and straight’ indicators as extremely unfair, and as a justification for perverting the performance measurement system (De Bruijn 2002).

The risk of evoking perverting behaviour can be mitigated by observing three principles when designing a performance measurement system: (1) *cooperation*: managers and professionals must jointly define performance measures to prevent distrust and unfair appraisal, (2) *variety and redundancy*: the set of performance indicators, their operationalisation, and the ways of appraisal must be varied, to serve the interests of a variety of stakeholders, and (3) *dynamics and liveliness*: the performance indicators must be adaptable over time as circumstances change (De Bruijn, 2002).

As will become clear in the next subsection, the urban water chain is a complex system. The production and distribution of drinking water, and the collection, treatment and disposal of wastewater are interdependent and sensitive to numerous exogenous factors, and require multi-value tradeoffs and specialised knowledge and skills. This implies that benchmarking processes in this context need to be designed according to the aforementioned principles, or run the risk of evoking perverting behaviour. The extent to which the principles have been put to practice in the Netherlands, and the apparent consequences of the design choices made will be addressed in Section 3.

2.2 The urban water chain

The term 'urban water chain' denotes the infrastructure for the production, distribution, and consumption of drinking water, and the collection, treatment, and disposal of wastewater. Good performance of the water chain is crucial for public health and the environment. The diagram in Fig. 1 (based on Schütze et al. 2002; DNG 2003) depicts the four links of the chain, and their interactions with the surrounding water system.

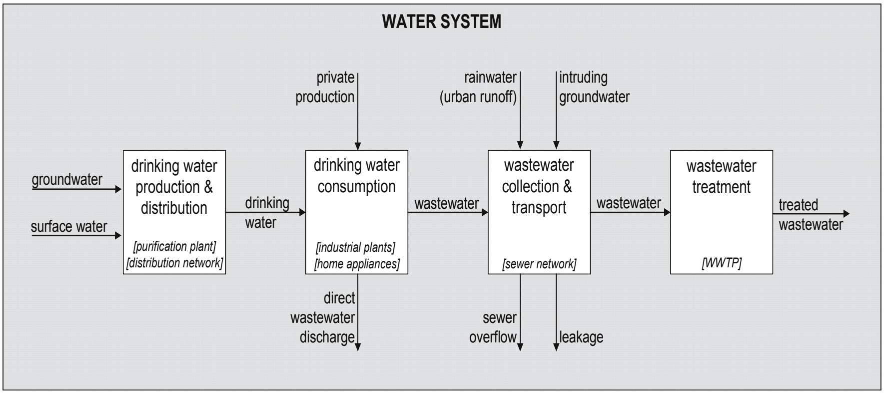

Fig. 1 Schematic representation of the urban water chain

The urban water chain is a subsystem of the water system that comprises surface water and groundwater, and their relations with the soil and the atmosphere (evaporation and precipitation). The arrows in Fig. 1 denote the pertinent relations between the four links and the water system:

- Groundwater and surface water are extracted for large scale production of drinking water, but also for production on a smaller scale by industry and private persons (wells).
- Wastewater may be discharged directly (without treatment) to surface water or (via septic tanks) to groundwater, but is usually collected and transported (via the sewer network) to a wastewater treatment plant (WWTP), where pollutants are removed before the water is discharged to the surface water.

- Untreated wastewater may still flow out of the sewer system due to leaks, or when a peak in wastewater causes the sewer system to overflow. When part of the sewer network lies below groundwater level, ground water may enter through leaks, lowering the system's wastewater transport capacity.
- Rainwater running off hard surfaces (roads, roofs) enters the chain when it is led to the sewer network. Depending on the network architecture and the pollution of the runoff, rainwater and wastewater can be collected and transported separately to avoid sewer overflow and the ensuing pollution of groundwater and surface water.

The technical infrastructure of the urban water chain has a long economic life span, and is capital-intensive, while the public interest (continuous water supply, no health risk, no inundation by stormwater) requires a high level of reliability of all functions. Management of the urban water chain (and the tradeoff this requires between costs and benefits) becomes more complex when, as is the case in the Netherlands, different actors are responsible for the links in the chain. The next section focuses on how this institutional structure has co-determined the benchmarking practice in the Dutch water sector. The interdependencies (direct or via the water system) between the four links suggested by the arrows in Fig. 1 will be elaborated in more detail in Section 4.

3 Benchmarking practice in Dutch urban water management

In the Netherlands, different actors are responsible for different links in the water chain. In the remainder of this paper, the second link (consumers) will be ignored, being 'passive'. The drinking water companies are responsible for the first link (intake of crude water, purification, and distribution), the municipalities for the third link (collection and transport of wastewater), and the water boards for the fourth (treatment and discharge of wastewater). Each of these organisations has a different legal status, a particular administrative structure, and specific mechanisms for financing its activities (Bressers et al. 1994; Dalhuisen et al. 2003; Kelder 2000). This makes the three links rather autonomous entities, a situation that is considered as rather exceptional (Schütze et al. 2002). For a detailed account of the institutional context, the reader is referred to (Van Dijk et al. 2004).

The actors in the urban water chain have independently developed and executed benchmarking processes for the activities for which they are responsible. As stated in their benchmark reports, and in related publications in newspapers and professional journals, the motivation to start with benchmarking was to improve performance and to be able to justify this performance to external stakeholders and the public at large. It seems warranted to assume that the performance indicators used in the benchmarking processes reflect the performance objectives of the three links in the water chain. To assess whether these performance objectives concur with the vision the Dutch national government has formulated on the water chain, the published performance indicators have been compared with the public interests that are central to this vision (public health, reliable drinking water provision, affordable water services, environmental quality, and customer protection). To facilitate cross-sector comparison, the performance indicators have been summarised in Table 1a and 1b. The topic categories in this table correspond almost one-to-one with the categories used in the original benchmark reports, although the labels differ. The original cluster names will be specified when the findings are discussed for each link.

3.1 Drinking water production

The objective of the benchmarking process of the drinking water companies was to increase the transparency of their performance, and to provide an instrument to help to improve the company processes. The benchmarking process that was developed by the association of drinking water companies VEWIN is executed each year for internal use (learning), and published once every three years for public accountability. The first benchmarking report (VEWIN 1999) was based on performance data collected over 1997. In 2003, eleven drinking water companies (covering 81% of all network connections) participated. As of 2004, participation is mandatory by law.

The performance indicators for drinking water production and distribution were grouped under four topics: Water quality (Primary product or service in Table 1a and 1b), Quality of service, Environment, and Finance. The indicators were defined in a bottom-up process in which various stakeholders participated, but compatibility with IWA indicators (Alegre et al. 2000) was aimed for, although perhaps less rigorously than in Germany and Austria (Theuretzbacher-Fritz et al. 2005).

The second column of Table 1a and 1b shows the performance indicators that have been developed and used. In addition to these indicators, the benchmark includes a number of exogenous factors that can explain most of the observed differences: crude water resource (surface water requires more treatment than groundwater), assets (impact capital costs and depreciation), customer size, network complexity, and personnel intensity.

The public benchmarking reports for 1997, 2000, and 2003 show that the performance indicators used cover most of the policy objectives formulated by the national government. A striking omission is that no indicators have been developed for the reliability of drinking water provision, while this is considered to be an important public interest, and reliability indicators have been defined and used in other countries (Alegre et al. 2000). Less striking, but noteworthy is that the Quality of service indicators are based on surveys, and hence provide subjective rather than rather than objective performance data.

Table 1a. Benchmarking indicators as used by different sectors

Topic	Drinking water companies	Municipalities	Water boards
Primary product or service	drinking water quality[a] purification effort	problem points per 100 km duct: - hydraulic - environmental	nitrate removal ≥ 75% phosphate removal ≥ 75% oxygen-binding compound removal ≥ 90% % contractual obligations fulfilled
Quality of service	maintenance & repair metering & billing address mutations customer contact understanding responsiveness reliability presentation	complaints per inhabitant complaints per km duct response time problem resolution time	satisfaction[b] of: - municipalities - licensing authorities - industry - neighbouring citizens
Information		% sewer recently inspected: - total - weighted by age	

[a]Index relative to legal norms.
[b]Indices based on a survey by TNS-NIPO; these indicators were added in 2002.

Table 1b. Benchmarking indicators as used by different sectors

Topic	Drinking water companies	Municipalities	Water boards
Environment	energy consumption use of chemicals & other residuals, pollutants & emissions % reuse of residuals in other industries desiccation	% connected area % sewer conform base standard	nitrate removal > 75% phosphate removal > 75% energy consumption raw material & additives processes verbal per installation untreated emissions due to system failure environmental information system odour[c]
Finance	drinking water price (per m^3) connection fee (per year) production cost (per m^3)[d] cost per connection[d] company profit[e] company solvency[e]	cleaning & maintenance cost: - per km sewer - per km cleaned	levies wastewater transport cost wastewater treatment cost residual processing cost cost of residual processing by third party
Organisation		plan ambition plan realisation person years per inhabitant person years per km sewer % budget overrun % time overrun	
Innovation			technological innovation[f] knowledge sharing & utilisation new services

[c]Indicators concerning the environment were added in 2002.

[d]Costs are differentiated to taxes, capital cost, depreciation, and operational cost (with further differentiation).

[e]Indicators added in 2003.

[f]Scores by an independent jury.

3.2 Sewerage

Following the example of the drinking water sector, the umbrella organisation for the sewerage sector RIONED first experimented with a pilot benchmarking process in 2003, in which 39 municipalities participated. In the official benchmarking process of 2004, 35 municipalities took part, 20 of which also participated in the pilot. Thus, 54 municipalities were involved, less than 10% of the total number, but covering 45% of the Dutch households and 30% of the Dutch sewer infrastructure. In 2006 and 2007, two more clusters of about 30 municipalities each have started, and RIONED plans to continue at this pace in the coming years.

The third column of Table 1a and 1b shows the performance indicators that have been developed (in an open, bottom-up process) and used in the sewerage benchmarking process (RIONED 2005). They were categorised in five topics: Sewer system state (split into Primary product or service and Information in Table 1a and 1b), Environment, Expenditure (Finance in Table 1a and 1b), Organisation, and Nuisance & complaints (Quality of service in Table 1a and 1b).

Besides the performance indicators in Table 1a and 1b, 36 exogenous factors were measured, covering size, demographic aspects, urbanisation, traffic volumes, soil type, and growth factors. Statistical analysis identified five different types of municipalities, affording a more meaningful comparison within types.

The gap between the performance indicators and the policy objectives formulated by the national government is relatively wide. Good wastewater collection and transport sanitation evidently contributes to public health and environmental quality, but unlike the water quality index for the drinking water companies, the performance indicators for Primary product or service only count the ‘problem points’ (leaks of bottlenecks) in a municipality’s sewer system. The performance in terms of, for example, the emission volume of untreated wastewater is not measured. Likewise, indicators for energy consumption or use of materials are missing under the topic Environment. The indicator ‘sewer conform base standard’ is an input norm, rather than an indicator that reflects the actual system performance.

Maintenance cost is the only performance indicator related to the policy objectives ‘affordable water services’ and ‘customer protection’. Capital costs and levies are notable omissions. An important observation made in the benchmark report is that it presently is extremely difficult to derive this information from the municipal accounting systems.

The new topics (Information and Organisation) are noteworthy. The fact that the municipalities defined performance indicators under topic Information reflects their lack of adequate information on the condition of their sewer systems. The indicators under topic Organisation show that municipalities wish to improve their planning processes.

3.3 Wastewater treatment

The objective of the benchmarking process for wastewater treatment was firstly to make their performance as a local government transparent, secondly to improve performance. The first benchmarking process, developed by the Association of Water Boards, took place in 1999, a second in 2002. In this process (Postma 2003), all 27 water boards responsible for wastewater treatment participated.

The set of performance indicators for wastewater treatment was developed as a Balanced Scorecard (Kaplan and Norton 1996), grouping indicators under five topics: System functioning (Primary product or service in Table 1a and 1b), Environment, Finance, Innovation, and Stakeholders (Quality of service in Table 1a and 1b). The performance indicators were developed in a participatory process involving different stakeholders in wastewater treatment (households, municipalities, industry, and legislators). The fourth column of Table 1a and 1b shows the performance indicators that have been developed and used. Unlike the other two benchmarks, no exogenous factors were measured.

The public benchmarking reports for 1999 and 2002 show that the performance indicators used cover most of the policy objectives formulated by the national government. However, the published indicators do not provide insight in performance with respect to the interaction with the surrounding water system. Notably, indicators on emissions related to discharge of WWTP effluent are missing. Similar to the drinking water benchmark, the Quality of service indicators are based on surveys, and hence provide subjective rather than objective performance data.

In summary, the development processes were (and appear to continue being) performed independently. Although the drinking water sector seems to have set the example for the two other sectors, and representatives of each sector have participated in workshops, there has been no sign of structural knowledge sharing between the three links. Likewise, although the national government supports the development of benchmarks, its involvement in the process has been negligible. All three links of the urban water chain have developed performance indicators in a participatory, bottom-up process. This, combined with the emphasis on transparency and learning, rather than ‘naming and shaming’, has effectively mitigated the risk of perverting behaviour, and resulted in benchmarks that are appreciated and used by the organisations. On the other hand, assessment of these indicators shows the benchmarks to cover only partially the policy objectives formulated by the Dutch national government, the difference being largest for the municipalities. The focus of the latter to improve their performance in obtaining management information, planning, and plan realisation suggests that the sewerage divisions of municipalities are presently in the least favourable position to improve their primary processes.

4 Resource dependence in the Dutch urban water chain

The lack of inter-sectoral cooperation in the development and use of benchmarks could indicate that the different links in the water chain are less dependent on each other for their performance than the relations in Fig. 1 suggest. To investigate the interdependence between the actors, a method based on Dynamic Actor Network Analysis (DANA, cf. Bots et al. 2000; Bots 2007; http://dana.actoranalysis.com) was used. DANA supports a range of analyses, based on a set of 'perception graphs' – causal maps that represent for each actor in a given policy context their subjective perception of the policy problem. A perception graph models for some actor a the variables that a considers to be relevant, the actions by which actors (a, but also others) can affect some of these variables, the extent to which changes in one variable will cause changes in other variables (on a seven-point scale), and the outcomes of interest for a, that is, changes in certain variables with which a associates positive or negative utility (also expressed on a seven-point scale). Inference on a perception graph can reveal which actions contribute to (or inhibit) the attainment of the desired outcomes. The resource dependence analysis (Pfeffer and Salancik 1978) makes use of this feature.

For the present analysis, the actors were assumed to have different means and ends, but otherwise to have similar mental models of the urban water system in terms of the pertinent variables and the causal relations between them. By consequence, this model, based on (Jonker 2006) and represented as a causal map in Fig. 2 a–b is not a genuine perception graph, but rather an 'analyst view' on the water chain.

The variables that actors can change directly through their actions (decision variables) are indicated in bold italic font, preceded by a symbol indicating the actor capable of influence. As actors have different objectives, these are not visualised in the diagram (as part of the actors' perceptions they would be in DANA), but described in the following paragraphs and then summarised in Table 2.

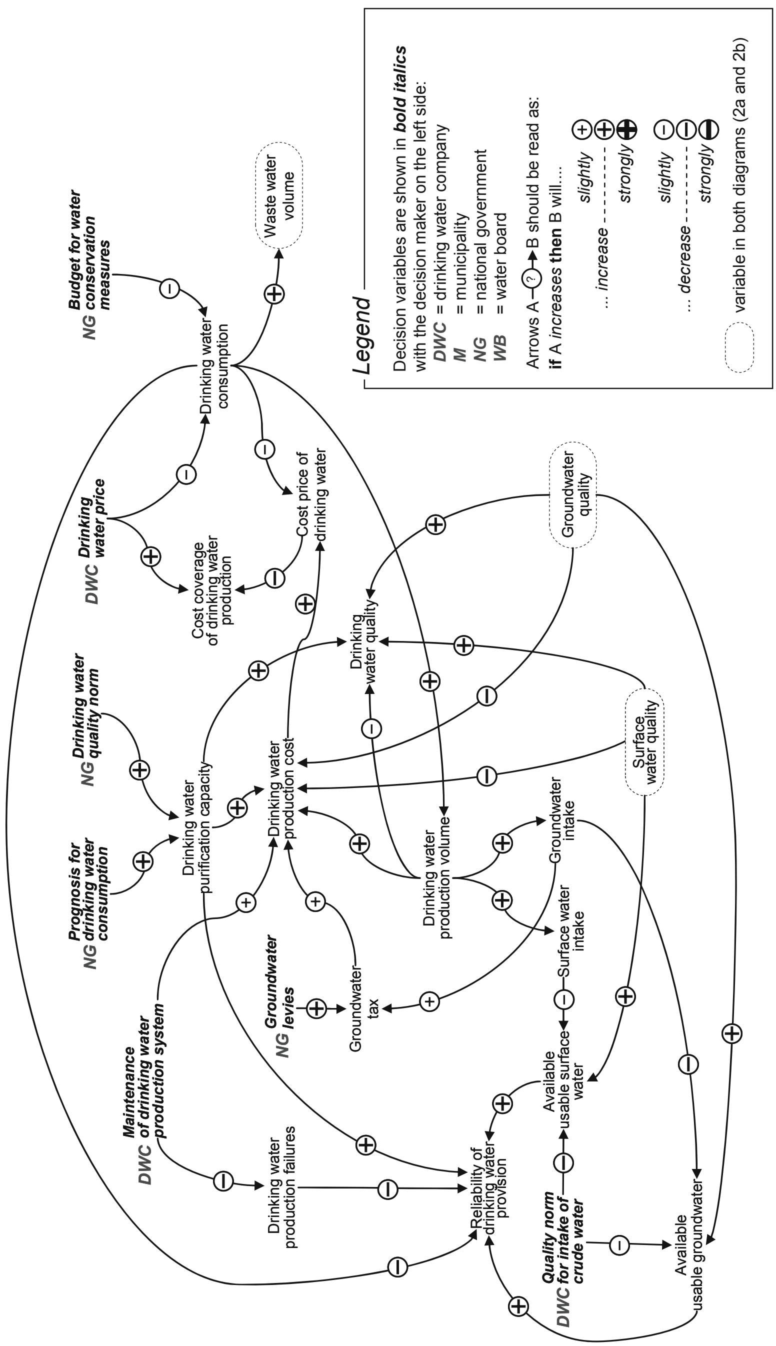

Fig. 2a Causal influence between variables in the Dutch urban water chain: drinking water production

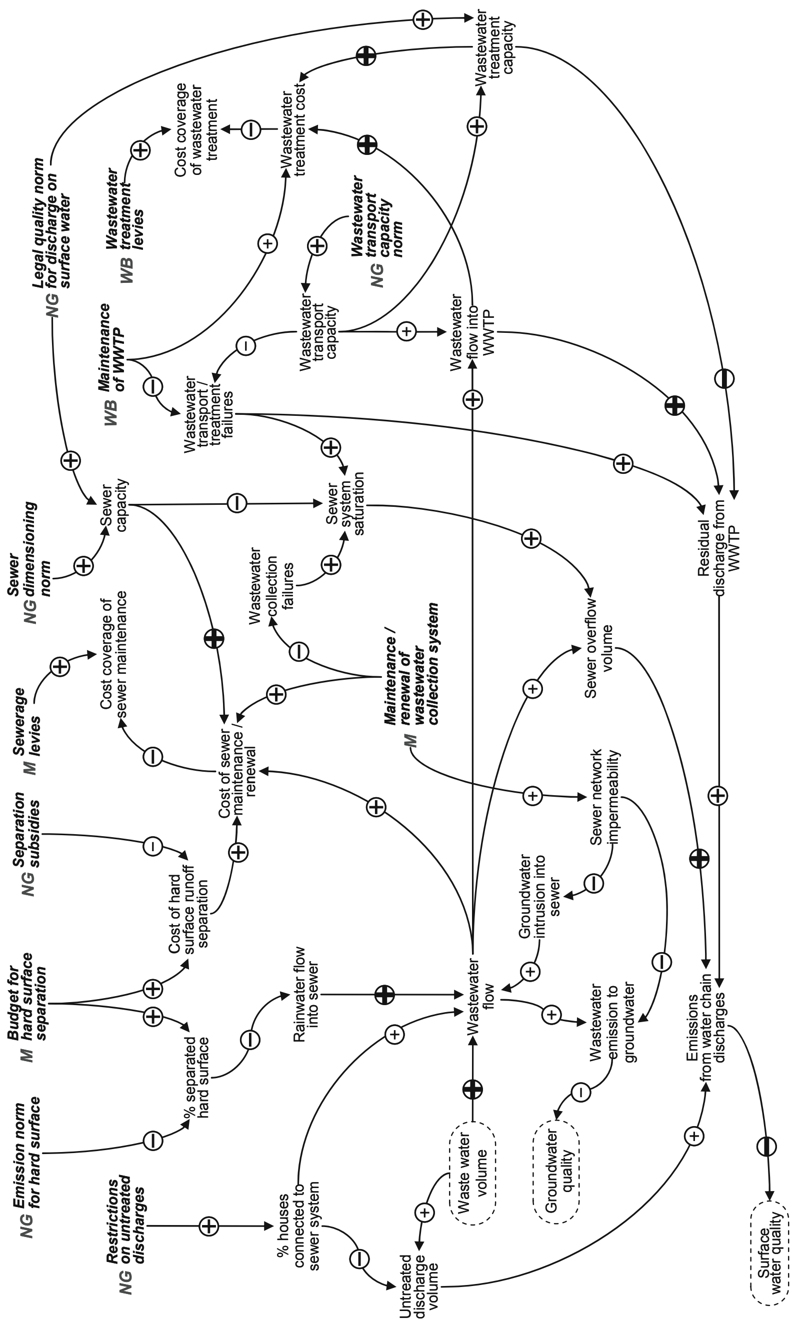

Fig. 2b Causal influence between variables in the Dutch urban water chain: wastewater collection and treatment

The consumers of drinking water (households, but one could also consider industry) would like to pay less for drinking water and water-related services, and have cleaner surface water (suitable for all recreation purposes). They are content with the present quality of drinking water, and the reliability of its provision (the drinking water service in the Netherlands is of a very good quality and almost never fails), but they are loath to see these standards be lowered.

The drinking water companies aim for more efficiency: improved performance (higher quality and reliability) and lower production costs. They prefer to reach these objectives by improving their installations, and by securing the availability of high quality crude water resources. As in most cases the local governments (province, municipalities) are their only shareholders, drinking water companies prefer not to change the price of drinking water as long as their revenue covers the costs.

The municipalities aim to improve their environmental performance by connecting all houses to the sewer system, and to reduce emissions due to overflows and leakage. Over 98% of the Dutch households is connected to the sewer system, but problems occur because of the condition and the existing capacity of the sewer system. For sewerage, full cost recovery as described in the Water Framework Directive (EC 2000) has not yet been achieved. Nevertheless, as the municipalities take the concerns of their electorate to heart, they will strive to keep the water-related expenses for citizens at their present levels, provided that the tax revenue covers the costs.

The water boards have two responsibilities in this context: as operational water manager, they must provide efficient wastewater treatment, and as local water authority they are responsible for the quality of groundwater and surface water. To maintain surface water quality (the quality of the surface water improved in the last decade), wastewater collection and transport failures and sewer overflows should be avoided. The effluent from waste water treatment plants (WWTP) meets current quality standards, and the water boards wish to defer the high cost of additional WWTP capacity as long as possible.

The primary concern of the Dutch national government is public health and environmental quality. The present drinking water quality, and the reliability of its provision are high, and they should remain that way. To realise zero emission of pathogens, sanitation of houses and avoidance of sewer overflows are top priorities. Meanwhile, groundwater and surface water quality levels should be maintained. Separation of hard surface (preferably with storage capacity for rainwater) is seen as a promising tactic, provided that the runoff is not polluted. To protect citizens against monopolistic behaviour, water-related costs should not increase. Reducing drinking water consumption is not a priority, as it is quite low related to other western European countries; its unanticipated decrease in the last few years actually led to a surplus in production capacity.

Table 2 summarises the objectives per actor. The table shows that there is no conflict between the actor goals. However, as most of the decision variables impact several outcome variables, often of different actors, and not always in the desired direction, interdependencies exist and tradeoffs may be required.

Table 2. Summary of actor objectives[a].

Variable	C	DWC	M	WB	NG
% houses connected to sewer system	-	-	↑	-	↑
% separated hard surface	-	-	↑	-	↑
Available usable crude surface water	-	NOT ↓	-	-	-
Available usable ground water	-	NOT ↓	-	-	-
Cost coverage of drinking water production	-	NOT ↓	-	-	-
Cost coverage of sewer maintenance	-	-	NOT ↓	-	-
Cost coverage of wastewater treatment	-	-	-	NOT ↓	-
Cost price of drinking water	-	↓	-	-	-
Drinking water consumption	-	-	-	-	NOT ↑
Drinking water price	↓	-	NOT ↑	-	NOT ↑
Drinking water production failures	-	↓	-	-	-
Drinking water quality	NOT ↓	↑	NOT ↓	-	NOT ↓
Groundwater quality	-	-	-	NOT ↓	NOT ↓
Reliability of drinking water provision	NOT ↓	↑	NOT ↓	-	NOT ↓
Residual discharge from WWTP	-	-	-	NOT ↑	-
Sewer network impermeability	-	-	↑	-	-
Sewer overflow volume	-	-	↓	↓	↓
Sewerage levies	↓	-	NOT ↑	-	NOT ↑
Surface water quality	↑	↑	↑	NOT ↓	NOT ↓
Wastewater transport/treatment failures	-	-	-	NOT ↑	-
Wastewater treatment levies	↓	-	-	NOT ↑	NOT ↑

C consumers, *DWC* drinking water companies, *M* municipalities, *WB* water board, *NG* national government.
[a]Objectives are denoted as desired changes in particular variables. ↑ indicates that the actor associates a positive utility with an increase in the variable, and a negative utility with a decrease, while ↓ indicates the inverse. NOT ↑ indicates that the actor associates a negative utility with an increase, but is indifferent to a decrease, while NOT ↓ indicates the inverse.

The extent to which the goal attainment of one actor can be influenced by the actions of other actors can be inferred from the causal model and displayed graphs. The striped bars in the charts in Fig. 3, reflect the range by which – according to the causal model in Fig. 2 – the actor indicated along the horizontal axis can influence the goal attainment of the actor specified by the chart title. As the consumers have no decision variables, they have no means to change the goal attainment of any actor, and hence no striped bar. By consequence, the first bar of every chart indicates the goal attainment of the actor in case nobody would act ('base case'). The high goal attainment of the water board in the 'base case' is explained by the fact that six of its seven goals have the form NOT change. By contrast, the 'base case' satisfies only two of the six consumer goals (33%).

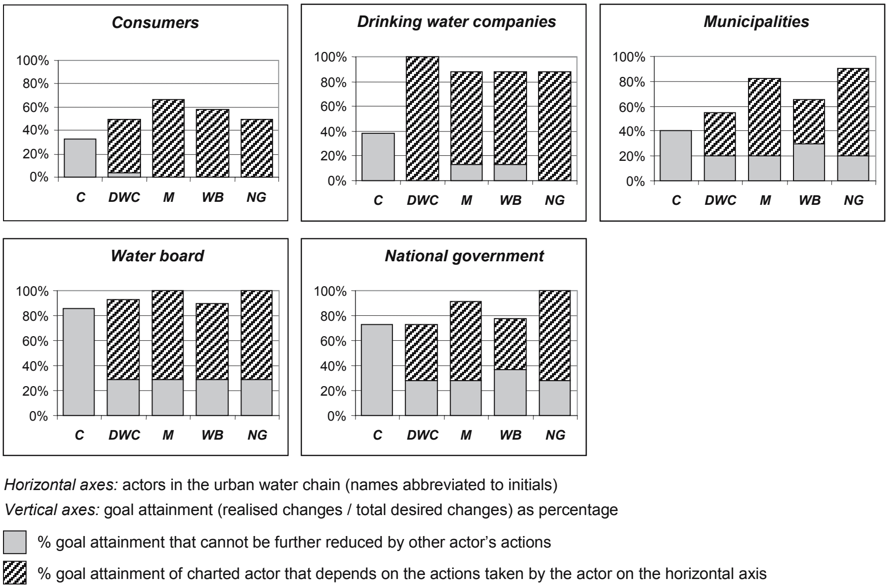

Fig. 3 Resource dependence of actors visualised as bar charts

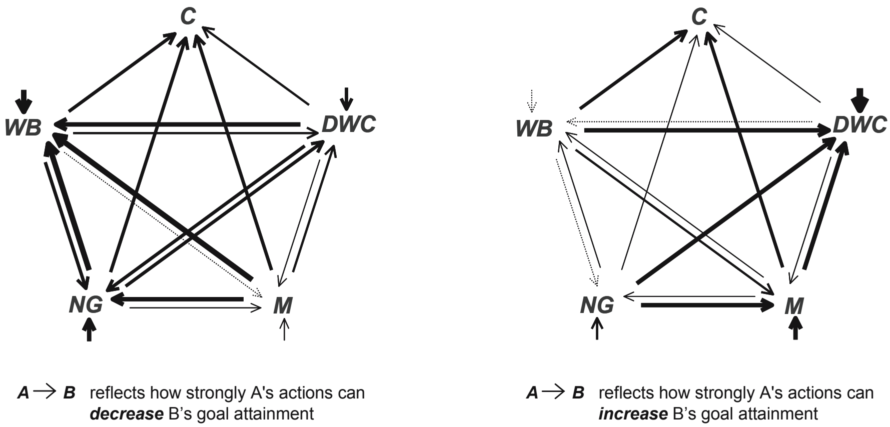

Fig. 4 Resource dependence of actors visualised as networks

The taller a striped bar, the more influence the corresponding actor has on the charted actor. The chart for the drinking water companies shows that this actor can through its own actions attain all of its goals, but also cause a 'worst case scenario' of 0% goal attainment. To give another example, the graph of the water board shows that municipalities can through their actions realise the water board's seventh goal (sewer overflows ↓), but also frustrate up to four goals that are attained in the 'base case'. The diagram in Fig. 4 shows how the 'making or breaking power' that actors have for other actors can also be depicted as a networks, where the thickness of the arrows reflects influence (positive or negative) of one actor on the goal attainment of the other.

The high goal attainment percentages in the graphs in Fig. 3 suggest that the actors jointly have sufficient means to attain all goals. Indeed, when input in the causal model of Fig. 2, the coordinated strategy in Table 3 leads to 100% goal attainment for all actors but two: the municipalities attain 95% due to their limited influence on the impermeability of their sewer system, and the consumers attain 79% because cost coverage precludes a significant drop in sewer levies.

The apparent existence of win-win solutions would seem to make it in everyone's interest to cooperate. However, the model takes a long-term perspective, whereas the coordinated strategy will create immediate winners and losers. Separation of hard surface, for example, is costly for the municipalities, whereas the benefit (lower wastewater volume, hence no need for additional WWTP capacity) is for the water boards. Given that political horizons are relatively short, cooperation is unlikely to occur in absence of incentives, enforceable regulations, or crisis conditions (Rees 2006).

Table 3. Coordinated strategy that maximises goal attainment

Actor	Instrument variable	Change[a]
DWC	Drinking water price	↓
	Maintenance & renewal of wastewater collection system	⬆
	Maintenance of drinking water production system	⬆
	Quality norm for intake crude water	↑
M	Budget for hard surface separation	⬆
	Sewerage levies	ꜜ
WB	Wastewater treatment levies	⬇
	WWTP maintenance	↑
NG	Budget for water conservation measures	↑
	Drinking water quality norm	o
	Ground water levies	ꜜ
	Hard surface emission norm	ꜜ
	Legal norms for discharge	ꜛ
	Prognosis for drinking water consumption	o
	Restriction on untreated discharges	⬆
	Separation subsidy	ꜜ
	Sewer dimensioning norm	↑
	Wastewater transport capacity norm	o

C consumers, *D*WC drinking water companies, *M* municipalities, *WB* water board, *NG* national government.
[a]the arrows reflect the 7-point change scale: *strong decrease* ⬇↓ꜜ o ꜛ↑⬆ *strong increase*

The validity of the causal model, and hence of the inferred strategy, may be questioned. Groundwater levies, for example, so far have not induced the drinking water companies to use surface water instead of groundwater, which suggests this policy measure is ineffective as a tactic do reduce desiccation areas (areas affected by a permanent lowering of groundwater tables). Moreover, the model does not represent the more subtle institutional interdependencies between actors. For example, as local water authority, the water board can compel the municipality to separate hard surface, whereas it is not always transparent whether the water board acts in the interest of surface water quality or to optimise conditions for its own performance.

5 Discussion

The ideas and findings presented in the previous sections give rise to new questions. First of all: Is the normative standpoint that warrants the assessment of the benchmarks made in Section 3 – “performance indicators should provide insight in the attainment of the policy objectives set by the national government" – justified? Given the formal autonomy of companies, municipalities, and water boards, this is debatable. But assuming that the policy objectives concur with the public interest, it is also defendable. Complete benchmarks would not only be desirable as a policy instrument (performance improvement), but also as a means for democratic control (transparency and accountability).

Secondly, is it likely that the sectoral benchmarks will develop, and eventually become 'complete'? Assuming that the actors' objectives are aligned with the public interest, and that benchmarking continues to be seen as an effective tool for performance improvement, this may well happen. The national government could assume a more active role, but only as stakeholder/participant in the process, because imposing performance indicators 'top-down' may evoke perverting behaviour that renders the benchmark ineffective. But 'completeness' with respect to the public interest as represented by the national government does not necessarily mean 'sustainable'. For new indicators to enter the benchmark, some actor has to champion it first. Unless there is pressure from outside the peer group, one would expect this to happen only when this actor believes that it outperforms its peers on this indicator. Additional research, tracing in detail when indicators first appeared during the development of the benchmarks, and by whom it was proposed first, is required to test this hypothesis.

Thirdly, what is the contribution of an analysis of interdependencies as proposed in Section 4? Evidently, insight in how one's actions affect the interests of others may lead to better coordination, provided that actors do not misuse their knowledge of the vulnerability of others (an aspect that deserves much more discussion than space allows here).

Fourthly, assuming that the insights obtained will be used for good purpose, is the method used in Section 4 adequate? Here, much depends on the causal model – not only its validity, but also its acceptance. To become an authoritative representation that can be used in discussion, it were better if the model in Fig. 2 had been constructed, confirmed, and validated – using the vocabulary proposed by Refsgaard and Henriksen (2004) – with stakeholders participating in the modelling process. This would not only enhance the acceptance of the model, but a participatory modelling process would also create opportunities for social learning (Pahl-Wostl, 2002). The causal diagram could be extended first to include all factors that are indicators in the benchmarks but not present in Fig. 2 (e.g., quality of service, energy consumption), still in participatory fashion (Robertson and Richardson 1997; Van den Belt 2004), to a System Dynamics model that would afford more exact quantification. This would resolve the biggest shortcoming of the causal inference used in the analysis presented in this paper: no distinction between additive and multiplicative effects.

Finally, a question to suppress the modeller's reflex should be posed: Is a more detailed, quantitative model functional in the context of a benchmarking process? For the purpose of doing a 'quick scan' to identify the most important dependencies between actors, a qualitative causal map probably suffices. Support for inferring strategies and determining their consequences under different scenarios (note that some important exogenous factors are missing in the model in Fig. 2) may help. However, moving from a crude +/– logic to ratio-scale equations would raise the expectations with respect to the model's validity (or more specifically, its range of accuracy), and consequently raise the modelling effort required to a much higher level.

6 Conclusion

The observations made in this paper confirm that management of the urban water chain in the Netherlands is a complex endeavour. Comparison of the benchmarking efforts across the three links in the water chain has highlighted the differences in current practice: the drinking water companies' efficiency benchmarking process is mature, while the sewer system performance benchmarking process of the municipalities will have to evolve further.

Relative to the policy objectives of the national government, the performance indicators give an incomplete overview of the urban water system performance, as information concerning reliability of drinking water provision, actual pressures on the environment (emission volumes), and financial consequences for citizens (levies) is lacking.

The causal analysis has made clear that actors strongly depend on each others' actions to attain their performance objectives. These interdependencies can perhaps be mobilised to induce the actors to develop their benchmarking processes in concert, taking into account each others' objectives, and thus develop benchmarking as a tool for performance improvement of the urban water chain as a whole. An additional benefit of such a concerted effort would be that a (more) complete set of indicators would (on the long term) provide insight in the effects (for different actors) of policy measures, such as subsidising separation of hard surface, or changing pollution norms. Thinking beyond benchmarking, a keener awareness of the interdependencies might also pave the way for considering more radical options, such as organisational integration of different links in the urban water chain.

Although the institutional changes that this development towards integrated water chain management requires are bound to be slowed down by the multitude of stakeholders involved, and some major financial problems (notably the outstanding maintenances of the municipal sewage systems) will have to be solved, there may be opportunities to start pilot projects for participatory integrated water chain benchmarking on a regional scale. The primary aim of such process should be to improve the cooperation within the chain, and to involve the Dutch citizens in the process of achieving sustainable water use by increasing their awareness of the issues at stake. This approach may lead to the sense of urgency that is needed to bring about institutional changes on a larger scale.

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Adapting scale use for successful implementation of Cyclic Floodplain Rejuvenation in the Netherlands

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Abstract

The adaptive management concept of Cyclic Floodplain Rejuvenation (CFR) has been implemented at the operational level in Dutch river management. The floodplains of Beuningen, situated to the west of Nijmegen functioned as a pilot study. Current river management formed the reference framework within which the CFR approach. By comparing and contrasting processes of importance within different floodplain management disciplines on a bio-geomorphological scale classification, differences in the scale preferences of involved actors were identified and understood. The tool developed to distinguish these different preferences in scales is the Integrated Scale Hierarchy. We concluded that the ability of river managers and conservationists to scale up for the purpose of CFR was a necessary condition for the success of operational CFR. The constraining arguments for focusing at the current floodplain level of management as opposed to the river reach level more suitable for the implementation of CFR measures, were then subjected to validation. We found the concerns for navigational safety and increased managerial complexity to be valid whereas the arguments relating to hydraulic effectiveness and conservation appeared to be ill-founded. Consequently, scaling up to the reach level remains a challenge for managers of the restrained lowland rivers of The Netherlands.

1 Introduction

Peoples' perspectives on river systems can vary depending on their disciplinary background and their role with regard to river management (Karstens et al. 2007). These different perspectives can among others be recognised in the use of different scale classifications to understand the river system. Within these scale classifications people often have 'preferences' on which levels they focus since the processes and characteristics of their interest are most prominent at that specific level and subsequently seem to be best safeguarded there. The diversity of preferences leads to a situation in which multiple scale classifications and multiple levels of scales are in use to understand and manage river systems. In general, the use of multiple scales and levels can contribute to insights in the complex river system, since river systems cannot be comprehended as a whole by limited human cognitive abilities (Jewitt 1998).

When applying particular concepts in practice it is useful to explore if and how the different uses of scales and levels contribute to or limit the implementation of the concept. This paper deals with a concept called 'Cyclic Floodplain Rejuvenation' (CFR) that has been developed to resolve 'nature-safety dilemmas' in lowland rivers by imitating the natural ecological and morphological functioning of the river, thereby enhancing its robustness and resilience to flooding (see Box 1). Because of its operational character, the concept seems promising in the light of adaptive river management, which has often been criticized for the limited translation into practice since its introduction by Holling (1978) and Walters (1986) (Lee 2000).

It is at the operational level of river management that the effects of human interventions become apparent and trade-offs have to be made between the different user functions (e.g. Bormann et al. 1994; FEMAT 1993). Accordingly, it is at the operational level that the conditions for, and barriers to, actual management become apparent. Therefore, the introduction of CFR near Nijmegen in the Netherlands in a pilot setting provided an opportunity to study exactly these constraints. In particular, requirements of use of scale and level that the concept imposes on the managers themselves could be studied. However, to value these constraints and requirements the context needs to be understood. This consists of a changing European and national water policy directives, such as the European Water Framework Directive and the Dutch Room for the Rivers Policy. In addition, changing societal values regarding the value of nature and the need to adapt to climate change, lead to a growing importance of ecosystem-based management. Comparing and contrasting different preferences of scales and levels at the background of the needs of the concept with its roots in bio-geomorphology, leads to the insights that for successful CFR application a change in use of level of several practitioners like conservationists or operational river managers, or, in general, the ability to flexibly zoom in or out depending on the type of problem and concept used, is needed.

Box 1. The concept of Cyclic Floodplain Rejuvenation

Cyclic Floodplain Rejuvenation (CFR) originates from the understanding that morphological processes continuously rework sediments in a river and provide the means of resetting vegetation to pioneer stages. Erosion and sedimentation processes simultaneously create the channels for water flow and the diversity of substrate necessary for the establishment and growth of riverine and alluvial species (Smits et al. 2000, p. 279). A natural river is characterised by a diversity of ecotopes, resulting in a mosaic landscape both longitudinally and in cross-section, with pioneer vegetation located close to the main channels and forests further away. In addition, grazing contributes to the mosaic pattern of the landscape by maintaining certain areas as open grassland and to the structure of the forests in others (de Bruin et al. 1987). Because it is precisely these resetting morphological processes that are most restrained by the safety from flooding focus of Dutch river management, CFR specifically aims to imitate these and thus 'close' the natural cycle. Furthermore, since these processes are ongoing, CFR is a management approach that needs to be implemented adaptively over time. When designing for CFR measures, both the location and type of intervention need to be selected (Peters et al. 2005). Typical CFR interventions include the excavation of secondary channels, lowering of a floodplain or the resetting of vegetation in combination with grazing (Duel et al. 2001). These interventions should occur at locations where natural morphological processes are strong or where the diversity in vegetation and succession is low. Since CFR seeks to address the 'nature-safety dilemma', they also have to be effective in hydraulic terms and ensure that the discharge capacity of the river decreases to meet (at least) the legal requirements along the river. The choice of location is therefore a trade-off between these hydraulic, ecological and morphological criteria.

In this paper, after giving a brief explanation of CFR, the method of analysis will be explained to show how we collected data and developed the argument for necessary changes in scale use when applying CFR (section 2). The case description (section 3) contains parts of the design process of the CFR application to show which arguments were used and trade offs had to be made. Section 4 theoretically explores eight different perspectives used for river management. Sections 5 and 6 try to integrate the different uses of scales of major actors within the field to find barriers in terms of scaling to successful CFR application.

2 Methods of Analysis

Participation in the pilot project provided insights in the actor field, the trade-offs to be made and specifically the arguments actors used to focus at specific scales. Initially we focused on the design of a CFR measure. The process we followed was the initial development of a ‘long-list’ with potential interventions, developed in cooperation with involved scientists. These underwent a feasibility screening by a river engineer. An environmental manager and an ecologist ranked and refined the remaining options based on ecosystem-based principles.

These expert judgments were combined with an iterative process of literature study and document review and further interviews with two river engineers, three environmental managers, one river manager, one local administrator and three riverine scientists. The semi-structured interviews were aimed at refining the CFR designs and acquiring information from the actors involved in the operational management of rivers, were conducted in the period from June 2004 to December 2004. Subsequent analysis yielded information on the perspectives of the actors and the processes and characteristics forming their foci. Based on the arguments the actors used to define their playing field, we were able to distinguish eight different perspectives. These we further explored in theory, four of which had a basis in natural sciences and four had a mere managerial basis. The scales used within different disciplines were then compared and contrasted with the scales used for CFR by displaying major processes and characteristics of each perspective on the scale classification used for CFR - Biogeomorphology. For this purpose we developed the Integrated Scale Hierarchy, which in fact is a visual display of processes from different disciplines on a single reference scale. Combining the required scale and level of analysis suitable for CFR with the preference of each actor (i.e. the level the actor focuses on because of the perceived playing field) yielded insights into the changes of actors needed in terms of scale use for the application of CFR. This information was confirmed and complemented by a survey undertaken at a CFR workshop in January 2005.

In addition, the validity of the arguments presented for existing preferences in scale was evaluated. For the hydraulic argumentation, this involved simulating the effects of CFR measures using a two-dimensional hydraulic model of Dutch river branches (Waqua) in combination with the Blokkendoos (a management simulation tool with pre-calculated measures from Waqua). The effects of CFR measures on water levels at a larger spatial scale were evaluated and the maximum distance over which a measure could be effective was investigated. Information from interviews and literature review formed the main sources for validation of the conservationist and river management argumentation, which focused on issues such as existing landownership and the legal responsibility for compensating for decreases in river discharge capacities.

3 Case Study: Cyclic Floodplain Rejuvenation at Beuningen

3.1 Historical context

The floodplains along the Waal in the Netherlands have been cultivated for centuries. Whereas this agricultural and pastoral tradition waned over the past two decades, there has been an increase in the awareness of the importance of riverine nature. Accordingly, many of these areas were allowed to change from grasslands to alluvial forests. Beuningen, located on the floodplains of the Waal near the Dutch city of Nijmegen (figure 1), is one of the floodplains that had been 'abandoned to nature' over two decades ago. However, since the natural dynamics of the river have been affected (restrained) by engineering works such as groynes, previous excavation of the floodplain and cultivation practices, the erosive processes, which would naturally reset such vegetation stands have been constrained. In addition, the initial low grazing intensities did not match those under semi-natural conditions. As a result the floodplains of Beuningen became covered by densely vegetated stands of alluvial forest with limited variation in species and successionary stages.

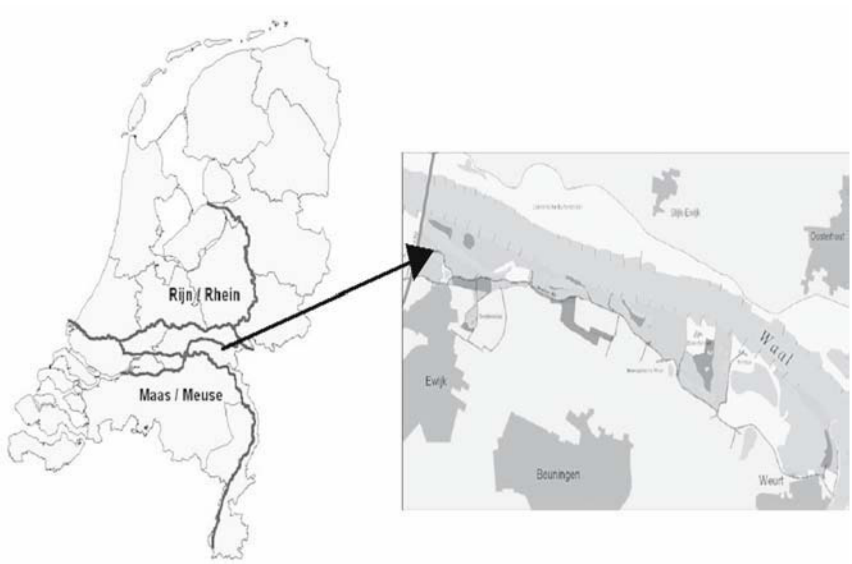

Fig. 1 Location of the floodplains of Beuningen along the Waal River in the Netherlands (sources: RWS-RIZA and Stichting Ark)

Such vegetated alluvial stands reduced the discharge capacity of the river and increased the danger of flooding (Mannaerts 2004). According to Dutch law, action had to be taken to alleviate this increased risk. Instead of simply removing the 'obstacles', that is chopping down the forest, more elegant solutions, enhancing ecological variation and succession, were sought. This resulted in the development and testing of the Cyclic Floodplain Rejuvenation (CFR) concept at Beuningen, initiated by a cooperation of the local nature organisation (Stichting Ark), the river manager (Rijkswaterstaat-RWS) and the Radboud University Nijmegen.

3.2 Societal Context

A broad range of actors are involved in the use and management of the floodplains at Beuningen (an overview is given in table 1). The tasks of flood prevention and maintaining the waterway lie with the river managers employed by the Dutch ministry of Transport, Public Works and Water Management. Generally, their disciplinary training is in the fields of engineering, hydrology or geomorphology. As such, they routinely consider issues such as the costs and safety of civil structures, the maintenance of navigation routes (e.g. by dredging), the stability of the waterway (e.g. minimization of navigational hazards caused by changing sedimentation patterns), the maintenance of the discharge capacity of the river (hydraulic effectiveness) in conducting their tasks. On the strategic level they develop river basin plans, often in cooperation with upstream countries, and EU directives are incorporated in the management. Furthermore, at the national level flood defense standards are developed.

The management of the nature areas along the river lies with environmental managers. These can be subdivided into two groups; those tasked with the conservation of species and those concerned with the character and naturalness of river landscapes. Their disciplinary training in biology or environmental sciences is similar.

Local government authorities are also involved with planning and issuing permits related to nature areas, agriculture, housing and other economic uses of the river and its floodplains (e.g. excavation or recreation). However, the authority for regional planning (with a focus on coherence in spatial planning and economics) lies with the provincial authorities.

Landowners, both private and public, strive after quality of life, which can range from making a living out of the area (e.g. by farming) to maintaining river dynamics and the riverine ecosystem. There about 30 landowners on the floodplain at Beuningen, each of whom is legally responsible for removing obstacles to flow and not reducing the discharge capacity of the river. In considering CFR measures, the landowners focus on their legal rights and responsibilities within the borders of their land.

Table 1. Tasks and backgrounds of actors involved in Beuningen and the boundaries they perceive

Actor	*Dominant Task*	*Underlying Discipline*	*Elements setting the Playing Field*
Water Manager	Flood Prevention Maintaining Waterway (navigation)	Engineering Hydrology Geomorphology	Costs Stability Waterway Discharge Capacity Decision Making Complexity (e.g. number of actors involved)
Environmental Manager	Conservation Biodiversity Nature Development	Biology/ Ecology Environmental Sciences	Local Values Potential for Nature Development (e.g. current land use, soil quality) Interrelations micro and macro (ecological) processes
Local Government	Local Planning and Development	Public Administration	Administrative Boundaries Local Spatial Plan
Provincial Government	Regional Planning Economic Development Water Management	Public Administration	Administrative Boundaries Spatial Quality
National Government	Water Basin Planning	Public Administration Engineering	(Inter) National Agreements (e.g. on waterways, ecological quality) Flood Defense Levels
Land Owner	Quality of Life	Various	Land Boundaries Legal Responsibilities and Rights

3.3 Design of CFR measure

The design of the CFR measure was first meant to decrease the local water level with 5,6 cm (Mannaerts 2004). Furthermore, navigational conditions should not be influenced (e.g. by change in sedimentation patterns). Because of limited time availability and the responsibility of the land owners at Beuningen, it was decided to only focus at Beuningen and exclude other possibilities downstream. Within these constraints designs were based on the following eco-system based principles:

- Imitation of natural processes,
- Increasing diversity of ecotopes
- No land permanently inaccessible to grazers
- Preservation of local ecological values such as sand dunes

The interventions included the excavation of a number of side channels (with varying characteristics) where the hydraulic resistance was highest. The secondary channels were designed to pass through the area with highest elevation and densest vegetation (see figure 2 for an example), creating (semi-permanent) islands and increasing the discharge capacity of the river sufficiently to compensate for the increased hydraulic resistance provided by the forests should a flood occur (Peters et al. 2004; Vreugdenhil 2005).

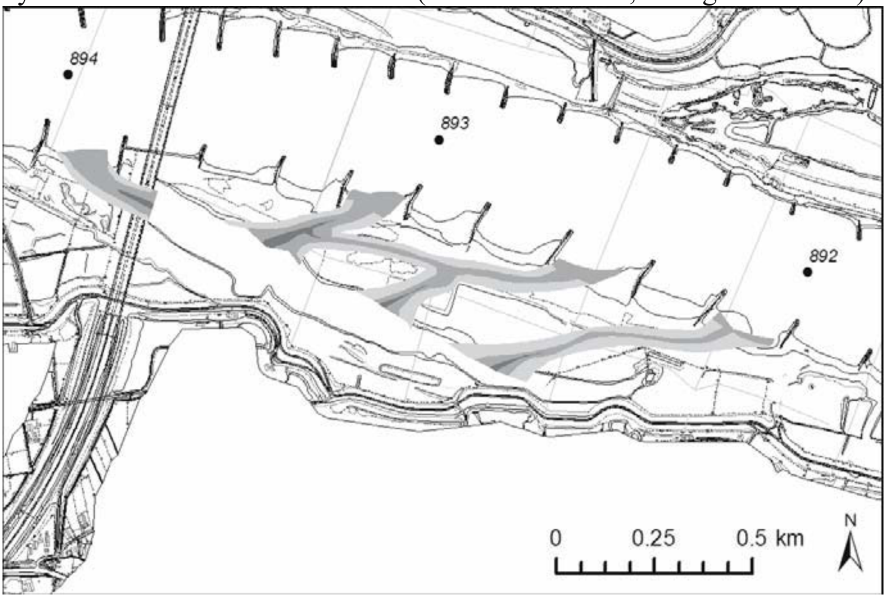

Fig. 2 Example of a CFR intervention at Beuningen. A number of secondary channels with varying characteristics cut across the sandbar creating a diverse landscape with semi-permanent islands (Source: Kater 2006).

4 Disciplinary and Managerial Perspectives

In order to understand preferences within scale classifications used for understanding and analysing river systems and contrast these with CFR needs, we first need to explore a variety of perspectives. Four bio-physical scale classifications were identified. These derive from a geological, ecological, hydrological and a bio-geomorphological understanding of a river. In addition, scales of analysis relevant to river engineering, river management, planning and public administration were identified (see table 2 for overview).
Each of the scale classifications is based on a hierarchy. A hierarchy is defined as a formal organization of various spatial or temporal sizes or levels graded from small to large (Haufler et al. 1997). Hierarchy theory divides a physical or environmental system into levels that share time and space scales and that interact with higher and lower levels in a systematic manner. In moving from a lower to a higher level, less detail and more information on the context become available. In moving from a higher to a lower level, more detailed information becomes available and patterns and relationships become less obvious (Jewitt 1998).

It should be kept in mind that each of the scale classifications described in more detail below is not definitive for the different disciplinary fields, but is presented as a means of illustrating the different perspectives held by the actors actively involved in river management in the Netherlands.

Table 2. Overview of perspectives explored (section 4) and dominant use of these perspectives within CFR application (section 5).

	Perspective (section)	Disciplinary preferences within CFR application (section 5)
Bio-Physical Scales	Geomorphological (4.1)	-
	Ecological (4.2)	Conservation Riverine Ecology
	Hydrological (4.3)	-
	Bio-Geomorphological (4.4)	Bio-Geomorphology/ CFR
Scales of Analysis	River Engineering (4.5)	-
	River Management (4.6)	Operational River Management
	Planning (4.7)	Local planning Regional planning River Basin planning
	Public Administration (4.8)	-

4.1 A Geomorphological Perspective

In geological terms, rivers are temporary features. On a time scale of millennia, their geomorphology can be influenced by seismic activity, the rates of sea level change and many other factors. River basins can originate, join together or even disappear on this time scale. On a time scale of hundreds of years, the influence of man on the form of a river can be significant. This is evident in the Netherlands where reclamation of land and the construction of dykes have altered the form of the river and its surrounding landscape. However, according to Cooper et al. (1999), it is the understanding of the functioning of a river or estuary on a time scale of decades that provides the context for interpreting observed changes. Therefore, riverine geomorphologists generally focus at this meso-scale on spatial features of interest to them. The classification of spatial scales is related to morpho-dynamics that shape catchments and flows and move particles in processes ranging from scouring to river evolution.

4.2 An Ecological Perspective

Petts and Amoros (1996) describe the river as a three dimensional system, in which complex ecological interactions can be distinguished. Their hierarchy of scales range from the drainage basin to mesohabitats via sectors, sets and units. At a drainage basin level the river is regarded as a continuum. Characteristics of sectors include the variety in channel patterns, process regimes and biotope types. Sets are ecological units associated with specific landforms, strongly influenced by morphological processes. Units are characterized by typical animal and plant communities indicative of the habitat conditions and generally arranged in spatial successions along topographic gradients in certain 'mosaic patterns' (Geerling et al. 2006). Mesohabitats include individual units such as a sand bar.

The drainage basin is the preferred scale for analysis of rivers from a riverine ecologists viewpoint, since at this scale the river may be viewed as a continuum. In contrast, a conservation ecologist often focuses at the mesohabitat level, because it is here that the concept of species niches can be applied in practice.

4.3 A Hydrological Perspective

Schultze (1995) describes the problem of hydrological modelling as one of "dealing with a system characterized by large temporal and spatial fluctuations, irregularities and discrepancies which occur more or less regularly through a series of dynamic, non-linearly lagged responses with feedback between elements of the system”. In this he concurs with Dooge (1984) and the Committee on Opportunities in the Hydrologic Sciences (COHS 1991) when they describe the hydrological cycle as transcending a wide spectrum of space and time scales. Dooge (1984) defines these spatial scales as varying from that of an individual water molecule (length scale of 10^{-10} m), through the scales associated with turbulent flow (length scale of 10^{-2} m) to a water basin scale of 10^4 to 10^5 m and beyond. Processes of interest at the larger scales include for instance rainfall patterns and flow regimes. For each of these hydrologists, the primary purpose in distinguishing the different space and time scales is to achieve clarity on which processes are taken into account in their hydrological models.

4.4 A Bio-Geomorphological Perspective

Bio-geomorphology focuses on the interaction between geomorphology and ecology. Classification systems have been developed to emphasize the relationship of a river and the aquatic habitat it provides, to the landscape over a wide range of scales, including that of the catchment. (Jewitt 1998). Based on the classification of Frissell et al. for small mountain streams (1986), Klijn (1997) developed a classification for river systems such as the Rhine. Baptist (2001) used this as a basis for his biogeomorphological classification (see table 3). The underlying rationale is to try and associate spatial scales with the factors that determine long-term behaviour of the river, as well as the more dynamic behaviour of the smaller scale river habitats. Processes of importance include rejuvenation of vegetation at segment level or pattern forming and succession at the reach level.

Table 3. Biogeomorphological classification of the scale of analysis (Baptist 2001)

Level	Length (m)
River Basin	$10^5 – 10^7$
Segment	$10^5 – 10^6$
Reach	$10^3 – 10^5$
Ecotope	$10 – 10^3$
Eco-Element	1 –10

4.5 A River Engineering Perspective

In contrast to the bio-physical orientation of the previous four perspectives, the engineering perspective is primarily one of flood prevention. In the

Netherlands, dikes were built to protect the surrounding countryside from flooding. In addition, the navigability of the rivers had to be improved. For both purposes the primary scale of design and analysis is the river branch or tributary. This is a pragmatic choice because it is at this level that the effects of engineering works can best be assessed and managed. Furthermore, micro levels are of interest to control the stability of the dikes. However, in maintaining the channels, the focus of operational control of hydraulic roughness is at a local level with every obstacle to flow being considered a potential threat to safety and the formation of banks as a threat to navigation.

4.6 A River Management Perspective

The Dutch Ministry of Transport, Public Works and Water Management (RWS) commonly make the following practice-orientated divisions in their management of a river: the river basin level such as the Rhine or Scheldt when they make integrated management plans and river branches (tributaries) when river engineering works and their effects are being considered.

In its operational management, RWS focuses on the attainment of sufficient discharge capacity to guarantee safety from flooding under reference conditions (such as peak discharges of 16 000 $m^3.s^{-1}$ at Lobith on the Dutch-German border). The law related to river management specifies that a land owner bears responsibility for ensuring that the discharge capacity of a river is not reduced by obstacles on his land and gives the RWS the authority to ensure that this is complied with. A starting point for searching possibilities to restore discharge capacities is to find the cause of the obstruction (e.g. construction works, vegetation development) and reset the obstruction or find compensation at or near the cause, which is in practice on the land of the responsible landowner. Furthermore, the stability of civil structures is of importance and is safeguarded at a local (floodplain or ecotope) level. Figure 3 provides an image of the scale classification used by RWS-RIZA.

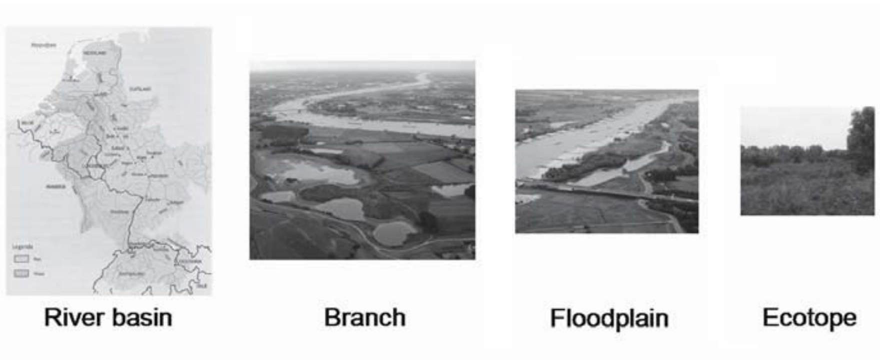

Fig. 3 Practice-oriented classification of riverine management scales used by RWS-RIZA (photos Bert Boekhoven, Emiel Kater)

4.7 A Planning Perspective

Levels that can be distinguished from a planning viewpoint relate to administrative borders such as the trans-national level, the national level at which national water resource policy plans are made, the provincial level where spatial plans are made, the local/ municipal level where local land use plans are made and the level of individual households. Water management boundaries usually cross these administrative boundaries. This is clearly the case for the large rivers such as the Rhine, which extends from Switzerland to the Netherlands, but is also true at Beuningen where municipal boundaries are smaller and cut across the area of the river for which RWS (Eastern Netherlands section) carries responsibility.

4.8 A Public Administration Perspective

In the Netherlands, local and provincial authorities carry responsibilities for enabling economic activities within their boundaries both now and in the future, upholding the law and administering policies agreed by higher authorities as appropriate. This means that the primary focus of a Dutch municipality through which a river runs is on the provision of public services, the collection of local taxes to fund these and the maintenance of the current level of well being. Municipalities and provincial authorities are also responsible for process management and communicating with the public. In addition, national authorities carry responsibilities for making international agreements on a river basin scale and transforming these into national policies. These often concern maintaining waterways and ecological quality, such as the EU Water Framework Directive. On a national level they set flood defense levels, based on which strategic plans can be developed.

5 Comparative analysis of disciplinary and managerial perspectives in relation to CFR and Adaptive Management

The major processes and characteristics from seven of the eight perspectives described above have been projected onto a scale classification used in bio-geomorphology (the eighth perspective). The bio-geomorphological classification was selected as a starting point, because it represents the perspective from which the CFR concept originated. An Integrated Scale Hierarchy resulted (figure 4). Examples of processes and characteristics include scouring for geomorphology, which could be depicted at the 'Eco-Element level' or the EU Water Framework Directive for public administration at the 'River Basin level'. The figure enables one to identify processes or characteristics active at one level and so to identify which scales of analysis actors from different disciplines share. For instance, regional spatial planners share a focus at the river reach level with the bio-geomorphologists committed to CFR, even though the exact spatial boundaries of their foci may differ.

As a next step, the dominant perspectives from the main actors (as represented in table 1) within the case have been located on the Integrated Scale Hierarchy. These include conservation management and riverine ecology, operational river management, Cyclical Floodplain Rejuvenation and local, regional and river basin planning. Conservationists have been positioned at the eco-element level since they focus on the preservation and protection of species and species niches. Operational Management has been placed on the floodplain/ecotope level since at this level hindrances to flow are identified and removed. This coheres with the Local planning. The CFR concept has been positioned at the river reach level, since it focuses on ecological processes as the succession and the development of mosaic patterns of vegetation along the river, and geomorphological processes of erosion and sedimentation. Regional planners usually focus at a similar level even though the exact boundaries and subjects of interest may vary. The Riverine Ecology perspective takes a truly ecological perspective on river management and focuses on adaptive water resource planning, the production, transportation and storage functions of a river and its resistance and resilience to change. Because of the interrelations of processes a large, basin, scale is needed.

In general, the ISH could contribute to identify existing differences in the foci of involved actors for a specific issue. Not only could this knowledge enlarge mutual understanding, it also visualizes the implications a concept poses on the involved actors in terms of scale use. In case of CFR in the Netherlands this means that Dutch river managers concerned with floodplain management need to adopt a bio-geomorphological perspective in addition to the predominantly engineering perspective in their operational management. Similarly, conservationists are required to think in terms of the abiotic processes supporting species establishment and succession in addition to understanding the biotic components. In contrast, riverine ecologists are required to include the need for local enlargements of discharge capacities. Therefore they should limit their scope to processes in areas that still contribute to this local enlargement of discharge capacities, instead of solely focusing on enhancing ecological processes neutral towards flood defense requirements. In general, the ISH stresses the need for flexibility when applying a particular concept, in this case of scale use, as already indicated by Gunderson (1999).

6 Moving from the theory to practice: perceived barriers to changing levels of scale

Clearly, a major implication of the implementation of the CFR concept is the requirement it places on those involved in its application to focus on the river reach level. For operational management this means the need for scaling up since it is a larger level of scale (from floodplain to river reach) than that commonly used at this discipline. Similarly, also conservationists need to expand their focus. From a conservation perspective, making large-scale interventions implies reduced local control and less knowledge of the state of species protection. Confidence in, and knowledge of, the ability of riverine species to deal with dynamic floodplain conditions is required. Indeed, the argument of the CFR proponents is that dynamic conditions can lead to a typical floodplain landscapes with a mosaic of ecotopes and an increased degree of variability within an overall robust system. Conservationists thus need to add knowledge of the effects of abiotic processes to their existing understanding of the biotic system. In contrast, riverine ecologists need to scale down to be able to combine the goals of nature development and flood defense. At a larger level solely ecological functioning would be enhanced thereby losing the link to the goal of increasing or maintaining certain discharge capacities, while the added value of CFR is exactly to synergize these goals.

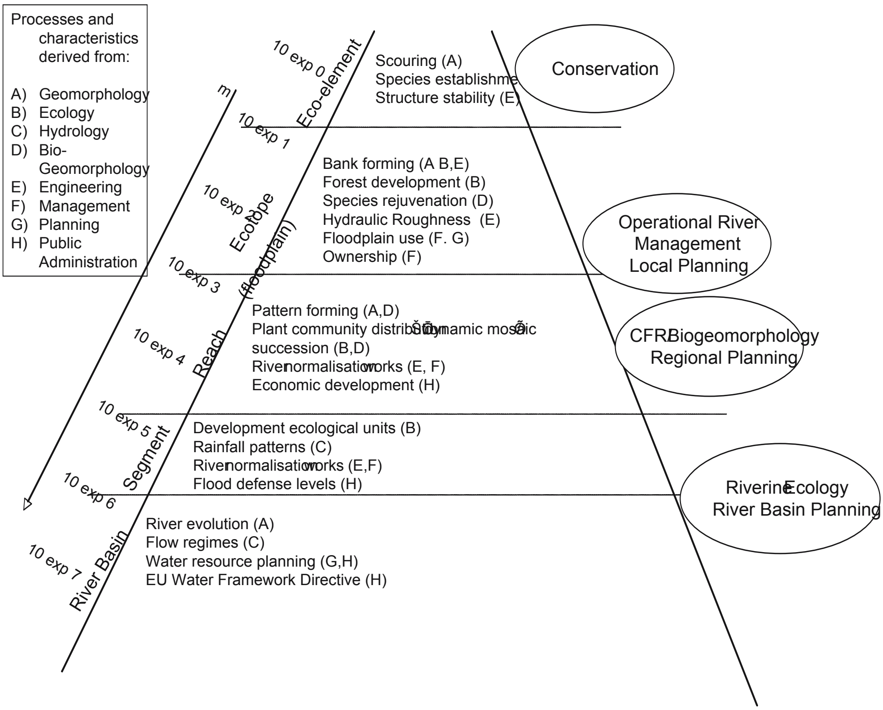

Fig. 4 Integrated Scale Hierarchy with processes and characteristics of interest per level derived from the different perspectives, depicted on a bio-geomorphological scale classification. The dominant scale preferences of the actors are indicated with ovals on the right side

The remainder of this section deals with the exploration of the implications of scaling up for operational river managers by examining the validity of the arguments they used in the case for confining the time and space scales of CFR implementation.

From a river management perspective, major arguments against scaling up included the need to safeguard navigation, doubts about hydraulic effectiveness and increased managerial complexity. To safeguard the navigational function of a river, the sedimentation and flow patterns in the channel should remain stable. Since these patterns are being affected by the excavation of large volumes of sand, smaller (local) measures at a floodplain level, thereby limiting morphological dynamics, are currently standard practice. However, knowledge of the response of the morphology to interventions is still very limited. This knowledge needs to be developed further before hard constraints for CFR implementation can be set regarding navigational safety.

Striving after hydraulic effectiveness means that river engineers and managers tend to focus near the cause of the increased hydraulic resistance and try to remove or reduce the 'obstacle'. Their argumentation for focusing at the floodplain level relates primarily to an effective lowering of high water levels and low costs, since the vegetation to be removed is limited or the sand volumes to be excavated are small. However, model calculations for Beuningen revealed that whereas interventions on the opposite bank of the river were less effective, larger interventions up to 20 km downstream were potentially as effective (Vreugdenhil 2005) as intervening at Beuningen itself. Thus, the exploration of potential interventions at other positions (in both the transverse and longitudinal directions) demonstrated further possibilities for achieving the legally required high water levels. So, although local conditions such as flow patterns, hydraulic resistance and the size of an intervention, greatly influence the actual effects on high water levels, the doubts about hydraulic effectiveness expressed by the engineers do not necessarily present a valid argument against scaling up in this case.

The argument that scaling up would significantly increase the number of involved actors (e.g. land owners and municipalities) is valid. The associated managerial complexity expressed in terms of time, communication requirements and financial structures, would also increase. However, while an increase in the numbers of actors can delay decision-making processes, it can also succeed in increasing the resource base of the involved parties and extending their power base. Previously unsolved problems can become amenable to solution by the linking of multiple, (partially) shared goals and combining resources.

The current legal context in which land owners are responsible for maintaining the discharge capacity is a strong argument for river management to focus at a floodplain scale. However, the law does not require the problem of decreased river discharge to be solved on the land of the responsible landowner self and thus possibilities arise for taking CFR measures at other locations. Land owners can be both private and public and because governmental organisations have the obligation to 'serve societal goals' there is a contestable argument to undertake CFR measures on governmental land at a location other than the problem location. This also provides a means for river managers to mainly deal with other public authorities that are land owners and whose land is available for CFR measures. Dealing with a non-coherent group of individual landowners could then be avoided and management complexity reduced.

In general, scaling up enlarges the variety of CFR options to be considered. Our analysis reveals that hydraulic, economic and conservationist arguments do not have to form a barrier to scaling up which clears the way for operational river managers and conservationists to potentially enlarge their focus, but barriers are possibly present in the increased managerial complexity and concern regarding navigational safety. Results from the survey indicate that the majority of actors agree on the increase in managerial complexity, but deem the opportunities to outweigh the risks.

7 Concluding Remarks

The implementation of the adaptive CFR concept at the operational level of river management demonstrated the need for river managers to adjust their disciplinary and managerial perspectives if the concept is to succeed in practice. In fact, current perspectives determine the boundaries within which CFR is being applied. In addition to spatial scales, different uses of time scales also seem to set boundaries, but the exact implications for CFR need to be further explored.

In general, the Cyclic Floodplain Rejuvenation concept is applicable to restrained lowland rivers. Its application to other types of rivers such as mountainous streams would require different scale classifications. Furthermore, CFR is not the only adaptive concept useful for ecological restoration and functioning at the operational level of river management. However, in translating the theoretical concepts of adaptive management into practical applications at the operational level via CFR or other concepts, it is essential to recognise and explore the bio-geomorphological conceptual roots and identify the associated constraints these impose.

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Current and future impacts of climate change on river runoff in the Central Asian river basins

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Abstract

We investigated the impact of climate change in the Aral Sea basin (Central Asia) using long term observational time series of three indicators - air temperature, precipitation, and change in river discharge. For each indicator data of approximately 200 measurement locations (hydrological and meteorological stations) were considered. Changes and trends in the data were identified using statistical methods and modeling. Missing data in individual time series were estimated using correlations between related stations.

The results show that the annual air temperature in Central Asia started to increase considerably after 1950. The time series of mean annual temperatures show trends of increasing temperatures of varying magnitude. At some stations temperature trends are affected by human activities, especially in the vicinity of larger cities. On the contrary, no trends in precipitation or an increase in the amount of precipitation could be detected in the Central Asian region. No relation between precipitation and temperature increase could be detected.

Increasing temperatures accelerate the degradation of glacier fields in the Pamir and Tian Shan mountains which are a major source of river runoff in Central Asia. The reduction in glacier area and changes in precipitation patterns will alter the flow regime of the rivers – a fact that has been stated before. In this article we present an assessment of the magnitude of the expected changes based on available climate related data and provide examples of the implications of climate change on the flow regime of the river. Analysis of river runoff time series revealed that total runoff has so far changed only little. However, the shape of the hydrograph has changed, which will have strong impacts on the main water users, especially irrigated agriculture.

Given the observed and expected impact of climate change in the Aral Sea Basin and the large uncertainties of predicting future river runoff the paper concludes that new water management approaches are needed that can cope with increasing variability and uncertainty in water availability and their consequences for current and future water users.

1 Introduction

In many places of the world trends of increasing temperatures have been observed (IPCC 2007). In the Central Asian countries of the Aral Sea Basin (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan) several authors have identified a continuing increase of air temperatures (Ososkova et al. 2000, Chub 2000, UNFCCC 1999, 2001, Agaltseva & Pak, 2007). Climate change has and will have a significant impact on the economies, people and ecosystems of those countries, because of their strong dependence on water resources provided by the two major rivers of the region – the Amudarya and the Syrdarya. The available water resources sustain large irrigation systems in the desert lowland plains which produce the region's food supply as well as valuable cash crops such as cotton. All main Central Asian rivers originate in the high altitudes of the Tian Shan, Pamir and Hindukush mountain ranges, where their water is generated from seasonal snow accumulations and glacier melt (see map Figure 1b). A change in air temperature has impact on the process of snow accumulation and the onset and duration of the spring and summer melt. It will thus change the flow regimes of the rivers - a fact that has already been observed over the past 50 years. This will affect irrigated agriculture which strongly depends on the given spatio-temporal patterns of water availability and distribution. Next to changing those patterns, an increase in temperature will increase evapotranspiration, which will make irrigated agriculture even more sensitive to water deficit

It is often difficult to directly detect trends in temperature time series because of strong interannual variability. Alternatively, the change in glacier area has been proposed as a good indicator for the estimation of long-term climate change because of its relative stability (Ososkova et al. 2000). Given the large components of glacier and snowmelt in run-off generation it is therefore possible to estimate climate change in Central Asia by comparing analyses of changes in long term runoff of the main rivers with analyses of changes in air temperature.

The authors of previous research concluded that the effect of climate change on river runoff will be significant but give little detailed analysis of the magnitude of the expected changes and their effect on flood dynamics (Ososkova et al. 2000, Chub 2000, UNFCCC 1999, 2001, Agaltseva & Pak, 2007). It has been suggested by Agaltseva & Pak (2007) that the possible reduction of runoff in the Amudarya river will amount to 15 % of a mean year. Climate models project a temperature increase of 1.8-2.9°C in the upstream areas by 2050 (Tajik Meteorological Service, Dushanbe 2002) and an increase of 1-2°C in the lowlands by 2030 (Agaltseva 2005). The wide range in predicted temperature change and impacts on river runoff underlines the uncertainty of those assessments. However, as more observations become available the quality of estimations of climate change impacts will increase. The given paper is a contribution to the process of reducing the uncertainty related to climate change and its impact in the given river basins.

Fig. 1a Map of Central Asia with the two main rivers Amudarya and Syrdarya

In this paper we present the results of an assessment of the ongoing climate change in the Aral Sea Basin and its impact on river runoff using time series data from all available hydrological and meteorological stations in the region. To our knowledge this is the first analysis of all available long term data of temperature, precipitation and river runoff in the Central Asian region with respect to current change in climate and river runoff. Furthermore, we estimate future changes in the shape of the hydrographs of the rivers based on the detected historical trends.

2 Methods

The temperature and precipitation data used in the presented analysis were obtained from the Main Hydrometeorological Service of Uzbekistan (UzHydromet), the Hydrometeorological Service of Tajikistan (TajHydromet), and the Central Asia Meteo DataBase (Williams & Konovalov, 2007). Data ranged from the years 1875 to 2004. In the databases both temperature (mean value) and pre-cipitation (sum) data were given in monthly resolution. Runoff data were obtained from the Uzbek Ministry of Agriculture and Water Management and UzHydromet in daily and monthly averages.

2.1 Temperature

Temperature trends were computed for the period of the last 50 years (1950 to 2001) at 194 meteorological stations in Central Asia (for the location of the stations see Figure 4). Despite the fact that some stations have observation time series of more than 150 years we restricted the analysis of the overall trend to the last 50 years. Only stations where the data gaps in the time series was in total less than one year were selected. The overall trend in the temperature time series over the past 50 years was determined by a linear regression. At each station the coefficient of variation (CV) was calculated to assess the stability of the trend. The trends presented in Figures 1a, 1b, 2, 3, and 7 are moving averages with a window size of 7. An average of 7 years around was selected based on the length of the time series and the characteristics of variations. The same method has been applied for trend analysis of the precipitation and runoff data.

2.2 Precipitation

Precipitation in winter and the temperature regime determine snow accumulation and glacier formation in high altitudes. An estimation of changes in precipitation and precipitation trends was carried out using time series of observations from more than 50 meteorological stations located in the foothills of the mountains and in the mountain zones. Trends were identified using the same approach as described above.

2.3 River Runoff

Human activities of the past 50 years have completely changed the natural river flow of all of Central Asia's rivers. The severity of those changes makes it impossible to compute the natural river flow in the middle reaches of the rivers. Besides, after the collapse of the Soviet Union water use policies in some of the upstream countries have changed significantly, e.g. hydropower generation has become more important. As a result of those recent changes in river management gauges in the middle reaches cannot be used for statistical analysis any longer. Therefore, correct estimations of runoff changes can only be based on runoff time series of the tributaries in the high mountains. We collected data for all existing periods of observation for the upper part of Naryn and Karadarya rivers (Syrdarya river basin), the upper part of Vahsh and Piandg rivers (Amudarya river basin), and the Zerafshan river (ancient tributary of the Amudarya). Rivers like the Syrdarya and Zerafshan receive most of their water from seasonal snow fields. Their runoff thus depends on annual precipitation only. Rivers like the Amudarya on the contrary are to a significant amount fed by high altitude glaciers, which determine its flow regime.

3 Results

3.1 Temperature changes

In Central Asia a trend of increasing temperatures has been detected (Ososkova et al. 2000, Chub 2000, Agaltseva & Pak 2007), as can be seen exemplary for the Tashkent meteorological station (Fig. 1b).

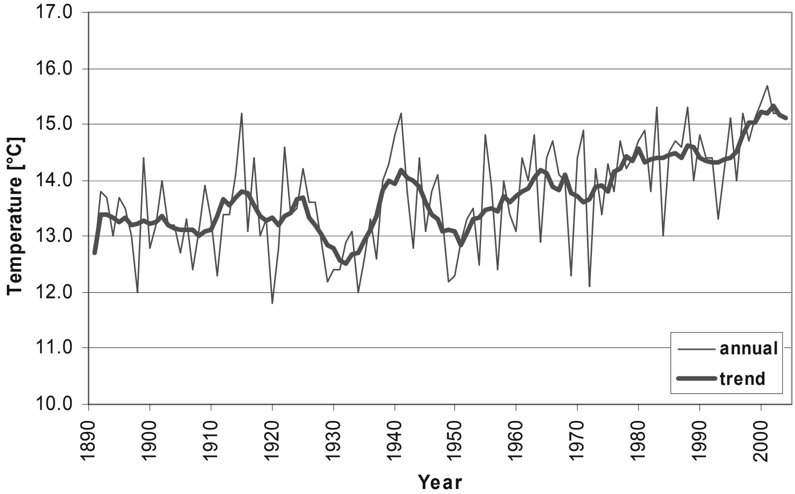

Fig. 1b Temperature observations (mean annual temperature) and temperature trend (moving average) at the Tashkent metereological

The figure shows that the temperature increased constantly especially in the second part of the century. The trend analysis also reveals a cyclic behavior of temperature fluctuations, with an increase of temperature reoccurring every 18-20 years. The reason for this cyclic behavior is not yet known.

In the high mountains, e.g. at the Fedchenko glacier, however, a trend in increasing temperature is not as clearly distinguishable (Figure 2).

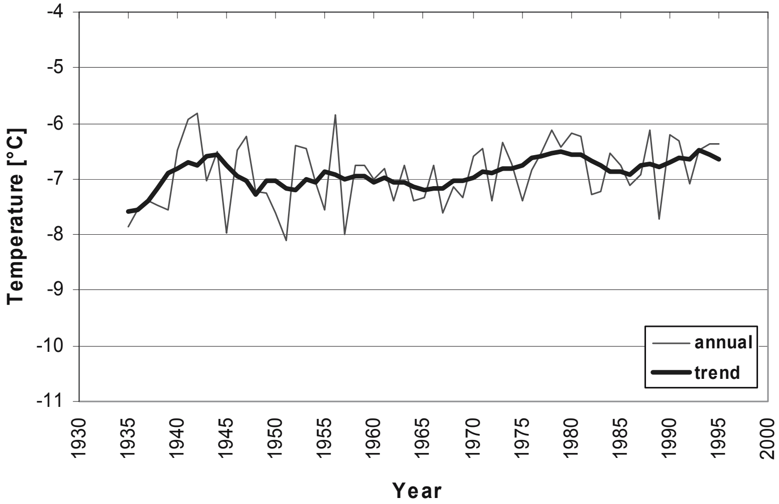

Fig. 2 Temperature observations (mean annual temperature) and trend (moving average) at the meteorological station on Fedchenko glacier (Tajikistan)

We have analyzed more than 40 stations located at higher altitudes in the mountains. For 90% of them a small temperature in-crease has been detected; generally, the temperature increase is smaller than in the lowlands. The average annual increase in the mountains is approximately 0.5-0.8 Co over the past 50 years. In the lowland desert regions, e.g. in the delta region of the Amudarya river, the heating of the atmosphere is much stronger. This difference can be seen very clearly in Figure 3.

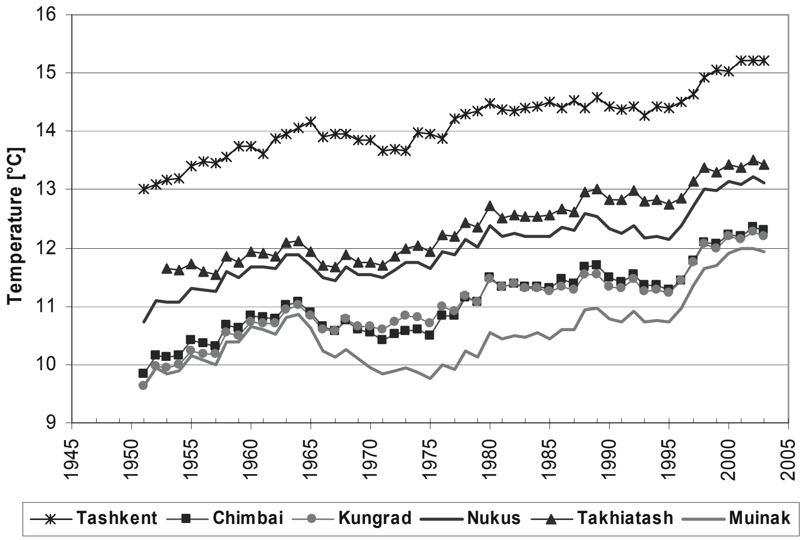

Fig. 3 Temperature trends (moving average) based on mean annual temperature observations at various stations in the foothills of the mountains (Tashkent) and the lowland delta region of the Amudarya river (the others)

Our regression analysis of all available temperature time series has shown that the air temperature in the Aral Sea Basin in Central Asia has in the last 50 years increased as much as 0.6 - 1.2oC with a maximum of 2.2 °C (at Nurek station, close to the Tokhtogul lake hydropower complex). Figure 4 represents a map of the region with information about the rate of temperature increase at the individual meteorological stations.

The meteorological stations with a small temperature increase are mainly located in the foothills of the mountains and the mountains themselves. The stations with larger temperature increase are situated in the lowland desert region or in the river valleys. There are two stations with a very strong temperature increase - Tashkent and Tokhtogul (city of Naryn – large circles). Tashkent is a large city with more than 3 Mio inhabitants. Here, local factors are imposed on the general warming trends. Tokhtogul station is located at the border of a large artificial lake with a volume of 19 km^3, which was built in the second half of the 20^{th} century. This large water body and a large hydropower plant associated with it influence the local climate and contribute to the observed warming. These two outliers demonstrate the direct human impact on the local warming of the atmosphere.

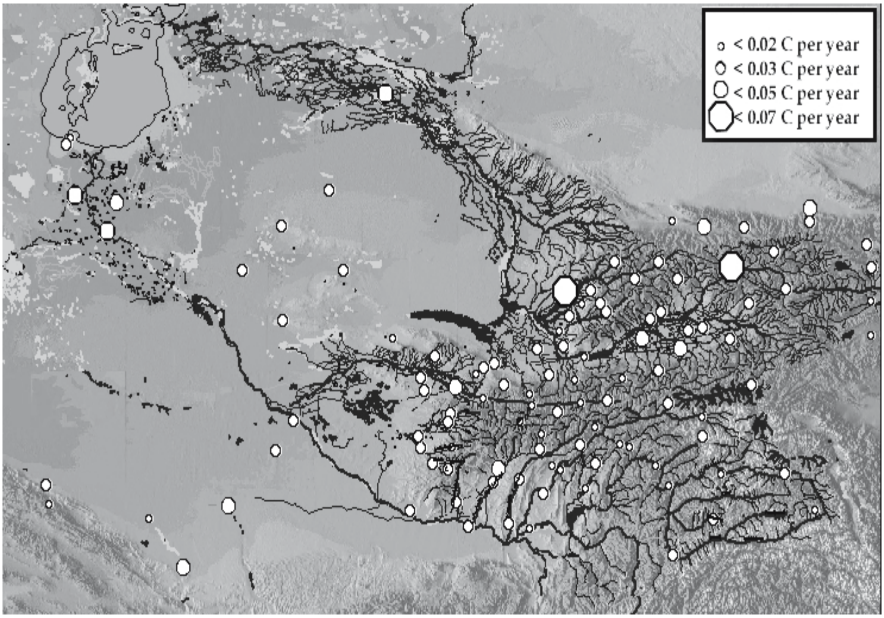

Fig. 4 Map of the Aral Sea Basin in Central Asia with locations of observed temperature increase (in the period from 1950-2007)

A comparison of the annual summer and winter air temperatures showed that they increase within the same range as the annual temperature.
The authors of previous studies (e.g. Chub 2000, UNFCCC 1999, 2001, Agaltseva & Pak, 2007) have presented slightly different values of warming in Central Asia as found in this study. This discrepancy is related to two main factors: differences in the methods used for trend estimation, and the selection of the time period for climate change investigations.

3.2 Changes in Precipitation

Figure 5 gives an example of the precipitation pattern at Tashkent meteorological station.

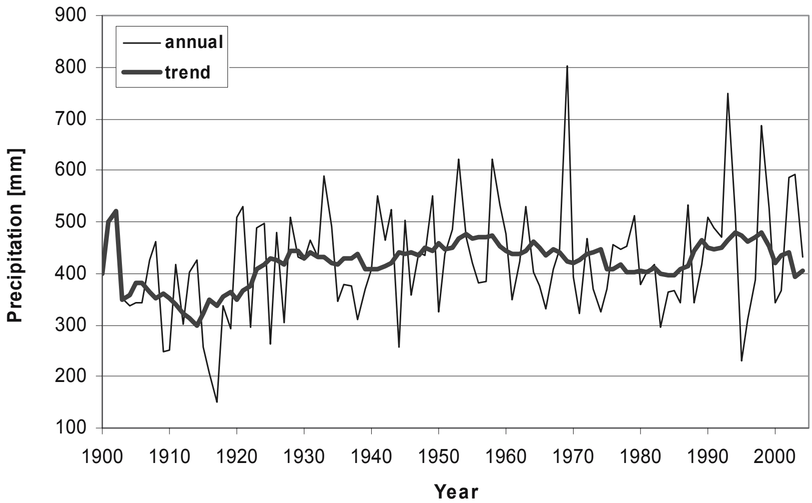

Fig. 5 Observed annual precipitation and precipitation trend (moving average) at the Tashkent meteorological station

The measurements show that against the background of high natural variability there is no significant trend in precipitation. Other sta-tions with short term observations of precipitation at different loca-tions in Central Asia also do not show any considerable changes in total annual precipitation. Naturally the precipitation patterns strongly depend on the location of the station, the exposition of its slopes and other relief features. Prediction of the total annual pre-cipitation in Central Asia is very difficult. However, it has been ob-served that in dry years a water deficit occurs in all rivers, and flood-ing events during high water years take at multiple locations. Exceptions from these general patterns are very rare. It can therefore be assumed that the average precipitation trends in one sub-basin can be considered as an indicator of common trends for the whole region (UNFCCC 1999). The correlation between the runoff in the Syrdarya and the Amudarya rivers is very high. The correlation co-efficients between the runoff in Naryn (Syrdarya), Zerafshan (Amu-darya), Vahsh (Amudarya), Piandg (Amudarya), Kafirnigan (Amu-darya) are within the range of 0.25 to 0.7.

Observations indicate that the patterns of precipitation are changing, which might be related to an increase in average winter temperatures in some regions of Central Asia (e.g. Tashkent). Nowadays the snow cover in the region of Tashkent lasts only 5-6 days per year while summer rains occasionally occur, which was rarely the case in previous times. Rainfall has increased in the spring and early summer periods (see e.g. precipitation at Tashkent station, Figure 6). However, the analysis has shown that the total amount of precipitation did not increase significantly, e.g. only 12 % at Tashkent station from 1925 - 2001. The change in precipitation pattern without a change in total amount of precipitation is expected to change the shape of the flow regime in the Central Asia rivers without affecting the total-discharge.

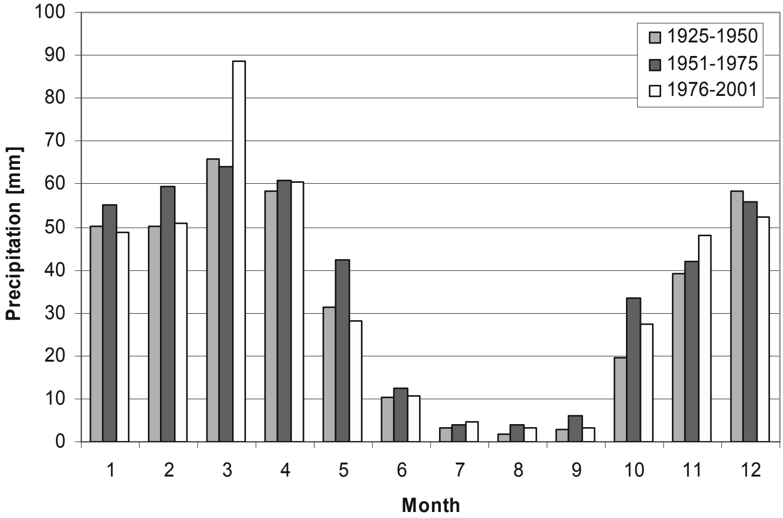

Fig. 6 Average monthly precipitation at Tashkent station in the periods 1925 to 1950, 1951 – 1975, and 1976 - 2001. An increase in precipitation in winter and early spring from 1925 to 2001 can be seen.

3.3 Changes in river runoff

We expect a correlation between the temperature and discharge for the rivers that receive their water from glacier melt. Of the rivers of Central Asia mentioned above only the Naryn river has a time series that is long enough to make this comparison. Figure 7 shows that for the upper Naryn river an increase in temperatures is coupled with an increase in river runoff.

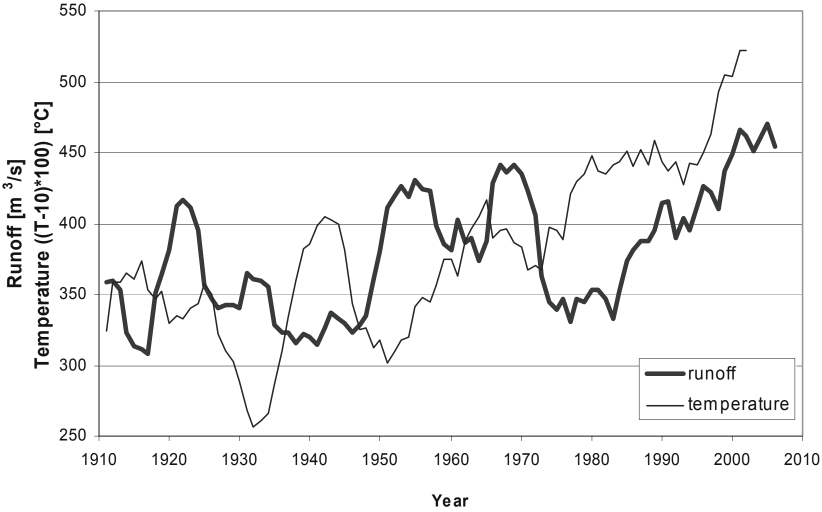

Fig. 7 Comparison of the runoff trend at Naryn gauging (mean annual runoff, moving average) station with the temperature trend at Tashkent meteorological station (mean annual temperatures, moving average). Temperature observations are scaled by subtracting 10 and multiplying by 100.

The average precipitation at Naryn station has not changed over the period of observation. However, the runoff (trend) increased. This can only be explained as the result of a decrease of the ice field in the high mountains. Once the glaciers have been largely reduced or disappeared river flow will only be supplied by snowmelt. The melting of snow occurs more easily and faster than that of ice and thus the peak of seasonal flooding will occur at earlier times in the year. The remaining glaciers will continue to provide water in the hot summer periods; however this input will play a decreasing role. Currently a temporary increase of runoff as a result of reduction of the glaciers is taking place. Because the total amount of precipitation did not change significantly changes in total runoff are only small. They are mainly caused by the decrease in glacier area.

However, there are other problems of climate change that are related to changes in the river flow regime, that is the temporal distribution of the runoff over the year. We can estimate the impact of those alterations by analyzing the change of an average hydrograph over time. The time periods for the estimation of the hydrograph were selected based on periods with real measurements only, excluding any reconstructed data. Figure 7 shows the hydrograph of each selected time period for the Zerafshan river as a typical example for the on-going change. Similar changes have been identified at several other stations, such as Naryn (inflow to Tokhtogul reservoir), Vahsh (in-flow to Nurek reservoir), Piandj-Hirmangou, and Zerafshan-Dupuli.

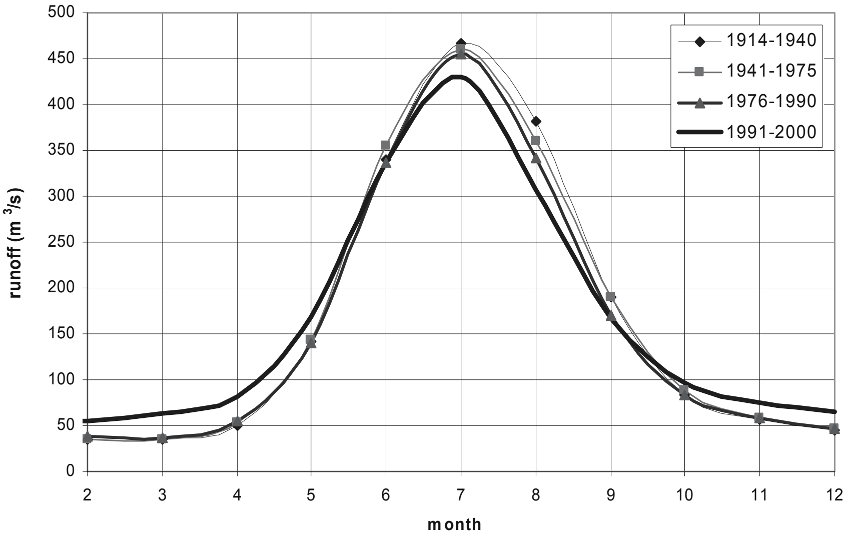

Fig. 8 Changes in the shape of a typical hydrograph demonstrated with the example of hydrographs at (gauging station Dupuli) in the Zerafshan river

Additionally, we computed the position of the center of mass for the graph of every time period. The positions of these centers correspond statistically to the water availability distributions within a year. We propose that these positions correspond to the time of peak of the hydrographs. The peaks occur at the following times:

1914-1940: month 07, day 03
1941-1975: month 07, day 02
1976-1990: month 06, day 30
1991-2000: month 06, day 26

Such a shift in the timing of the peak flow has already been suggested by UNFCCC (1999). Next to the observed shift, the summer flood peaks have decreased and winter flows have increased. On the other hand, the total annual runoff in the different periods has changed by less than 3%. However, because of the shift in timing of peak flows the situation has become less favorable for irrigation.

We identified a shift of the hydrograph of the Zerafshan river of up to 7 days for an assumed temperature increase of 1.5 °C. If the trend of climate change will remain the same and the response of the river flows stays at the same level, the flood peak will move towards the middle of June. Such an early flood peak will pose serious problems for current irrigation practices, because after the peak river flow decreases strongly. If the water demand of irrigation will remain the same as today or even increase due to increased evapotranspiration there will be a serious mismatch of supply and demand. The situation is aggravated by the fact that the large scale agricultural production in most of the riverine countries make fast adjustments of cropping patterns and agricultural technology difficult.

The problems associated with those changes in the hydrograph are most apparent in the Amudarya river basin. Currently the natural flow of the Amudarya river almost corresponds to the irrigation needs (Figure 9).

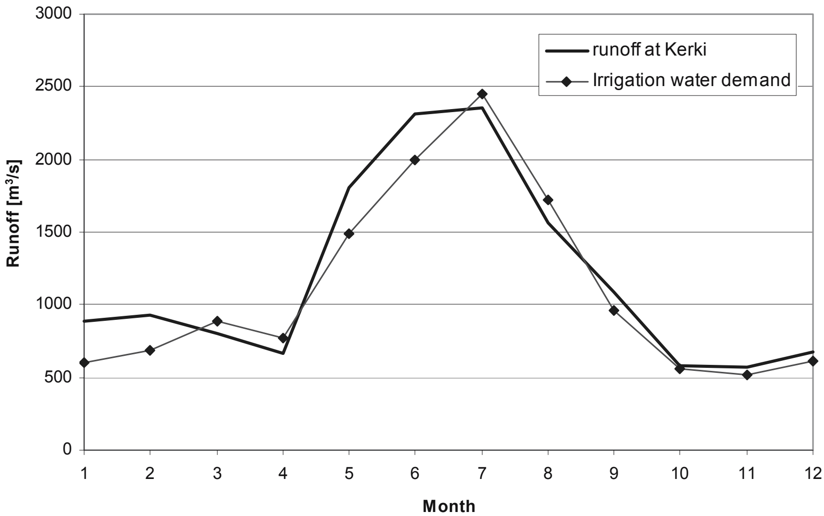

Fig. 9 Comparison of mean monthly river runoff in a dry year and average monthly intake for irrigation in the middle reaches of the Amudarya river (Kerki gauging station)

Figure 9 shows the correspondence of the runoff in dry years in the middle reaches of the Amudarya river with the irrigation needs in that river stretch. It is evident that the water situation in the Amudarya river will become more difficult when the timing of water availability changes. The most sensitive time, the time of potential water deficit, is the period after the main flood peak. From month 7 to month 10 the water demand for irrigation is almost equal to the water availability. Climate change will shift this period of potential water deficit ahead. The runoff presented in the graph is based on average years, thus in extreme years the deficit will even be much stronger. Therefore the probability of a critical water deficit in the Amudarya river will increase. If the runoff graph is moved to the left by at least one week there will be a period of water deficit from month 7 to month 10. Water demand will be higher than the water availability for the entire period. There are no reservoirs along the Amudarya river that are large enough to cope with this shift in water availability and there are no possibilities to redistribute the water within the year on the scale of future needs.

4 Discussion and Conclusions

The impact of climate change and its effect on river runoff in the Aral Sea Basin of Central Asia has been assessed using long term time series of temperature, precipitation and river runoff at 194 hydrometeorological stations in the mountain and lowland areas of Central Asia. Based on the presented analysis we come to the following conclusions:

1. Climate change has been and is still taking place in Central Asia.
2. The average annual temperature has increased from 0.6 - 1.2°C in the past 50 years with a maximum of 2.2°C.
3. The annual volume of precipitation has changed very little.
4. The average annual runoff has changed very little, with a small increase in the past 20 years.
5. The shape of the hydrograph of river flow in the Amudarya has changed almost all over the Central Asian region, with the peak shifting towards earlier times in the year.
6. The summer flood peaks have decreased while winter flow has increased. These changes create a deficit of water during the vegetation period (especially in the Amudarya river basin).
7. It is expected that the continuing reduction of the glacier because of the increased temperature in the highlands results in an increase of the winter flow, a decrease in the base flow and en earlier peak in the summer flow.

Moreover, analyses of future climate scenarios for the next 20 years show the conservation of the current amount of runoff but an increase in interannual variability (publication forthcoming). Our expectations for the more distant future are more pessimistic, mainly because of the reduction of glacier fields, the deterioration of the conditions for formation of snow cover in the mountains and the increase in evaporation related to the increase in temperature. The glaciers play an important role in smoothing interannual fluctuations in water availability. More research is needed on the future implications of climate change and impacts on river runoff using regional climate models and scenario analysis.

To adjust to these changes and make water management more efficient it is necessary to develop and implement approaches of adaptive water management in the river basins of Central Asia. This includes developing processes and institutions that involve more actors at different scales and providing opportunities and mechanisms for learning and policy adjustments such as to enhance the possibility to react flexible to short and long term changes in water availability. Information exchange on all levels has to be improved. Moreover, water allocation, which is currently geared towards the needs of irrigated agriculture, should be better balanced to serve the needs of multiple users, including fisheries, hydropower and environmental flows. Development of alternative water uses increases the response options water users have to changes in water availability and might act as a natural insurance mechanism against variability and uncertainty of river flows. Measures should also include giving water users, whose water use is currently strongly restricted by national regulations, more options to react flexible to changes in water availability.

Besides, efficient water allocation planning can be greatly enhanced by improving the quality of forecasts of river flows. Since independence of the Central Asian republics forecasting has become more difficult, especially for the downstream riparian countries, because of the deterioration of measurement infrastructure and information exchange. Improved measurements of the snow cover in the mountains as well as runoff generated at the beginning of the snow melt will open possibilities for better estimation of the flow regime of the upcoming season. However, given the uncertainties of climate change impacts it is also necessary to develop strategies to deal with the high variability and uncertainty in future water availability through a variety of measures such as alternative cropping schemes, better information management, water exchange between regions, more flexibility in water allocation, etc as described above. Given the complexity of the water management situation in the main river basins of Central Assia no single measure or strategy will resolve current and future problems. Rather mechanisms need to be developed that allow identifying and implementing suitable responses and adaptation strategies at the various scales.

Acknowledgments

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Adaptive and Integrated Management of Wastewater and Storm Water Drainage in Kolkata – Case Study of a Mega City

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Abstract

Situated between the tidal river Hugli on the west, the overflowing swamps on the east, and having tidal creeks surrounding, Kolkata suffered chronically from drainage congestion and water logging (Fig 1), especially during monsoon period with large run-off. The city proper has a combined sewer disposal system laid in west to east direction as per natural slope of the basin. The drainage is disposed through channels and canals partly via wetland ecosystem with sewage-fed fisheries for natural sewage treatment and partly directly to river Kulti, which further carries the discharge to Bay of Bengal. The added areas lack proper central sewerage collection system by the municipality and sewage management is done by septic tank, surface drain, conduits laid underground and deposited to the canals and local ponds resulting in pollution and health hazards. Though works have been done by the Central and State Government Organizations, the results have not been totally satisfactory due to many factors on the face of tremendous force of unprecedented urbanization. Recently, increasing awareness about environment, pollution, health hazard and sustainability has generated some actions taken up for better drainage solution in an adaptive and integrated manner. The municipality and local government are introducing measures, which are anticipated to minimise the adverse impacts on environment.

Key words: Drainage in Kolkata, Earlier Works, Problems, Environmental Management Planning, Recent Measures Taken

1 Introduction

Tremendous rate of urbanization has taken place within overpopulated Asian cities and in their surrounding fringe areas demolishing historic and old existing buildings, quarters and fabrics; reclaiming land from agricultural lands, water bodies and wetlands; constructing upon open spaces; destructing urban agriculture and trees; using non-renewable energy resources, water and materials; producing huge and toxic waste polluting the environment; changing biodiversity, ecology, climate, social structure, tradition and culture; and as a whole intensifying an adverse environmental impact, particularly on a regional scale. In many mega cities, the rate of housing and commercial development has not been matched with the development of necessary infrastructure. This has resulted severely in the failure of civic service systems particularly in the sector of water supply, drainage and sewerage, supply of electricity and urban traffic system. The character of climate during monsoon in south Asian region has been observed as changing with frequent occurrence of heavy rainfall in short periods. During monsoon period, many south Asian cities are observed as having the problem of urban flooding because of inadequacy and congestion of drainage system. Cities like Mumbai, Kolkata and Dhaka are worst examples of such phenomenon. The problems in the cities are manifold and interlinked among each other and any attempt to find issue-oriented solution for one item fails because of not adopting a holistic approach to solve all problems together under a broad environmental management planning for the city. Implementation of any adaptive and integrated policy needs participation of all sections of the community and society in cooperation with efficient urban governance mechanism without corruption.

1.1 Case study: Kolkata

Kolkata (alias Calcutta) is a linear city grown along the eastern bank of river Hugli (Ganges) during the last 250 years. It is the capital city of the State West Bengal in India. The Kolkata Municipal Corporation (KMC) area of the present day consists of 141 wards comprising an area of 185 sq km. 41 wards (101-141) have been added to the city proper (with 1-100 wards) during the last twenty years on the face of tremendous population increment and rapid urbanization (NATMO, KMC, 1996, 2004). According to the last Census Report of 2001, the population of the municipal area was 4580544 and population density was 24760 per sq km. In Kolkata, numbers of construction of high rise buildings and mega projects during 1996–2016 (projection) are all time high in the history of urban development in Kolkata. Population growth and spontaneous development after globalization and economic growth have not been supported with planning and construction of required adequate urban infrastructure. So, huge drainage and sewer load on the city's existing system along with poor maintenance of existing drainage infrastructure has resulted inundation of most parts of the city during monsoon with all its ill effects on people and urban properties.

2 Climate, Soil, Topography, Geomorphology

Kolkata has a tropical monsoon climate with excess of humidity with annual maximum and minimum temperatures in summer and winter are generally 39^0C and 9^0C. Kolkata has an annual average rainfall around 1500mm with irregular distribution. More than 80% of the annual rainfall occurs in about 90 days from 15th June to 15th September during the monsoon season (Das Gupta, 1991). The high rainfall intensity during monsoon period produces very large run-off. On 19th July 2006, rainfall in some parts of the city has been recorded as 180mm in 12 hours (@ 15mm per hour) (Mayor, KMC 2006).

Many areas of Kolkata have a thick fine silty clay layer with little permeability in the ground top soil. This retards quick absorption of rainwater into the ground resulting in high recharge lag time. Other areas have top soil with sandy river-belt deposit, which has greater absorption quality of rainwater into the ground.

The natural slope of the ground of the city is from west (river bank of Hugli) to east (fringe area with wetlands). Topographical ground configuration has land undulations in various areas of Kolkata (though apparently having a flat basin). Within the Kolkata Municipal Corporation area, there exist numerous water bodies (3500), wetlands, water channels and canals (11) (KMC, 2006). The surrounding rivers and streams have tidal nature (flushing basin pockets during high tides).

3 Drainage Systems in Kolkata

3.1 Drainage System in City Proper

The KMC area generates roughly 600 million litres of sewage and wastewater everyday and more than 2,500 metric tons of garbage (KMC 2006). The city proper has a combined sewer disposal system laid in west to east direction following natural slope of the city. The KMC area has been divided into basins and sub-basins. The elements of drainage installations are (i) conduits for trunk and branch drains, (ii) open channels – lined or unlined, (iii) outfalls – with or without gates, (iv) pumping stations, (v) canals, (vi) water bodies, (vii) wetland and (viii) river (Kulti). The drainage is carried by underground sewers to pumping stations, which dispose the load to channels and canals. The channels and canals dispose drainage partly to eastern wetland system and the rest to river Kulti, which flowing over rural areas and swamps in the Gangetic Delta, carries the discharge to Bay of Bengal. Approximately, from a household to the estuary of Bay of Bengal, the distance the sewer travels is 60 Km. Huge quantity garbage is deposited at Dhapa Dumping Ground at the eastern fringe.

3.2 East Kolkata Wetland System

The east Kolkata wetland ecosystem, included in the 'Ramsar List' in 2002, is spread over 12,500 hectares (with 5850 hectares of water body). It has 254 sewage-fed fisheries (being inter-distributing swamps with embankments and having depth varying between 0.5-1.5m), agricultural and solid waste farms and some built up areas. Approximately 250 million litres of sewage is flown into it everyday. Here, after a few days, the organic compounds of the sewage and wastewater are biodegraded by plankton population in the shallow ponds with photosynthesis by solar radiation and planktons are consumed by fish. This way, the sewage is treated naturally and the nutrients are converted and stored in fish for human consumption. The cumulative efficiency of reducing the BOD of the sewage wastewater is above 80% and for coli form bacteria 99.99% on an average. Annually about 11,000 metric tonnes of edible fish and daily 150 metric tonnes of vegetable are produced from the wetland system. This stands as a unique example of treatment of one-third part of sewage and drainage of the city naturally and integration of drainage management with ecosystem and environmental flow towards environmental sustainability of the city.

3.3 Drainage System in Fringe Areas

Many parts of the fringe areas of the city do not have centralized sewer collection system. There, sanitary sewage is stored in individual septic tanks and the storm water (with sullage) is separately drained through municipal conduits or surface drains or open ditches falling to nearby channels and canals. In some cases, sullage, rainwater and outfall from septic tank (without treatment chamber) are drained to the nearby pond adding pollution, environmental degradation, mosquito, and health hazard (Chakravarti, Chowdhury, 2004).

4 Rate of Urbanization

Tremendous rate of urbanization has taken place within Kolkata proper and in surrounding fringe areas reclaiming land from agricultural lands, rural areas, open spaces and water bodies, during the last four decades on the face of huge population increment and influx. Large, high-rise buildings took place replacing smaller old buildings with more open space and green (grass and vegetation) cover.

During April 2005 to March 2006 (Financial Year), total number of Building Proposals sanctioned by the Kolkata Municipal Corporation is 3000, out of which, buildings proposed above 14.5m (Ground + IV floors) height are 68 numbers and up to 14.5m height are 2932 numbers. Total floor area sanctioned for construction is 10,580,147 sqm (Rakshit, 2006). This is simply to understand the magnitude of development in Kolkata. The huge upsurge of unprecedented development in Kolkata started since 1996 and gradually gained momentum.

The east Kolkata area has been subjected to construction of a satellite town (Salt Lake City), a major bypass (Eastern Metropolitan Bypass), large commercial, institutional and other buildings and housing developments, a recent township called “Rajarhat – New Town”, proposal of construction of “Barasat-Raichok” expressway (according to agreement between the State Government and a developer company from Indonesia in July 2006) in north-south direction through the eastern region.

In the architectural design of single or two buildings from 11m (three to four storeys) up to a height of 36m (twelve storeys) in a small/large plot, the mandatory open spaces at all the sides of the building(s) in the premises are paved and utilized for pedestrian and vehicular circulation, open car parking and surface drainage of the premises. Thus, the sewer load has increased tremendously due to population increment and increment of surface run-off area having been 100% of the plot area multiplied by the area of such development (KMC, 2006).

5 Earlier works done for improvement of Drainage

5.1 Report of WHO, Basic Development Plan by CMPO, Works by CMDA & GAP

In 1966, the World Health Organization prepared a Master Plan for sewerage-drainage and water supply in Kolkata, the first ever such plan for any mega city in Asian developing countries. A Basic Development Plan with land use projection up to 1986 was also prepared by the Calcutta Metropolitan Planning Organization (CMPO) in 1966. Several measures for improvement of drainage were suggested in the Master Plan. Later, Calcutta Metropolitan Development Authority (CMDA, now KMDA) was formed to implement the prescribed projects. Implementation of works recommended was commenced in the early seventies. KMDA undertook several works like silt removal, construction of relief storm-drains and additional sewers, construction and augmentation of pumping stations, etc. The Central Government funded for the 'Ganges Action Plan (GAP)' which started in 1980s with an objective of "purification of river water" by stopping of disposal of wastewater, industrial and other pollutants and garbage into the river while treating the wastewater in sewage treatment plants in Kolkata Metropolitan Area. Under this programme, three lifting stations and three sewage treatment plants have been constructed and operational in south of Kolkata.

Fig. 1 A part of Kolkata under inundation in 2006.

6 Problems

Whatever measures taken by all authorities concerned, the overall result even after completion of many projects remain quite alarming during monsoon with showers lasting for a few hours. The main problem that is suffered by people is urban flooding during monsoon period (June to September) in almost all parts of Kolkata in varying intensity with consequent damages. The problems related to inundation are many from damages to buildings and properties to ill health condition, disease and death of people; death by accident, drowning and electrical short circuit; stop of life's works, education, business and related loss; and gross environmental pollution and degradation.

(1) It has been observed by the Indian Institute of Tropical Meteorology in Pune and the Indian Meteorological Department (Government of India) that character of monsoon has been changing during some years. Heavy shower has become frequent occurrence during monsoon in Kolkata and some parts of the State while some western parts and the adjoining western region of the State suffer from lack of adequate rainfall. From early 1900s to 2000s, West Bengal now receives 10 cm more rainfall than earlier recording (Jayan & Mudur, 2007). This perhaps has a link with quantity of local air pollution and global warming influencing climate change. It has been declared by the Kolkata Municipal Corporation that according to the drainage management capacity of the municipal system, no water stagnation will happen in any part in Kolkata if the rainfall is within 6mm per hour (KMC, 2004). During monsoon period, many times the rainfall per hour exceeds the mark of even 15mm and it becomes beyond the draining capacity of the KMC. Nature's fury added with huge population and urban development and incompetent management of drainage system altogether pose a critical problem on property and life of people under inundation during monsoon in the city.

(2) In Kolkata, population is ever increasing, population influx from surrounding region of the State, other neighbour States and from Bangladesh (illegally) is quite high. Road in terms of area occupies only 6% of Kolkata's municipal area, which itself is a constraint for providing good civic service systems. Parks and open spaces are also very inadequate. After long decades of economic gloom, now the city enjoys economic boom of certain merit through various investments in large and small industries, retail and business. The city is in the process of metamorphosis in somewhat spontaneous and uncontrolled way. Imposition of strict control over development may adversely affect the much desired economic development within the city and region. Meanwhile, upgrade and capacity increment of

drainage system could not have been done at per the pace of unprecedented urbanization with population explosion during the last two decades. Capital investment in development of real estate, housing, commercial buildings by private (promoters and developers) and by public-private partnership companies are much higher than investment in maintenance and upgrade of existing and development of new infrastructure by Government. This results in failure of civic service systems, be it drainage or supply of electricity in the city.

(3) Full benefit from the works executed for drainage capacity improvement has not been realized due to lack of proper periodic maintenance of the completed works. Moreover, faulty planning and/or execution of drainage improvement works create more disastrous results. Some of the old and major underground brick sewer lines of the city are dilapidated and require immediate repair and restoration (Ghosh, ABP 2007).

(4) Frequent repair and upgrade of existing service systems and networks, and laying of new ones require excavation of the roads and relaying of road surfaces with macadam. It has become the common practice in road-repairing work by the municipality that the existing top layer of the road is not taken out; rather a new macadam layer is laid on the existing layer thus increasing the level of the road after repair work. By this, especially at the historic part of the city where the buildings are older than a century, the ground levels of the buildings are rendered lower than the top-up road. This causes inundation of the premises and area. Many architects and engineers have pointed out this fact and stressed for rectification of the method of road-repairing, but the municipality does not rectify its method.

(5) In the city, many people throw garbage in plastic packets in the surface drains, road gutters, conduits, channels and canals. Road side shops and market places and slums add congestion of drains by garbage and plastic regularly. Plastic element in drainage system creates choking of drainage system causing congestion of run-off during monsoon (KMC, 2006).

(6) The outfall channels and canals which carry sewage and drainage discharge have been silted up and polluted. The State Irrigation Department which is responsible for dredging of canals has not done substantial work in this account. The trunk-drains have also been silted up in the normal process but there are only limited programmes of silt removal (Chowdhury). The river Kulti which finally carries the load to the bay of Bengal through Sunderbans Delta also needs dredging.

(7) Drainage load of Kolkata city and surrounding region is flown through river Kulti down south to Bay of Bengal via Sunderbans. Hence, excessive human settlement and subsequent unscientific land reclamation at Sunderbans Delta would result in great problem of drainage manage-

ment for Kolkata and the environmental degradation of the city's canals and the city itself.

(8) Dhapa Dumping Ground is shrinking rapidly, and the issue of environmental degradation by open-air garbage dumping is raised. During heavy shower, the garbage dumped locally and temporarily across the city before being deported at Dhapa enters into the drainage system and chokes the conduits, as well as floating in the logged water spreads pollution and health hazard.

(9) A comparative study of satellite images with the administrative map of the eastern wetlands area by the State Environment Department reveals that wetlands have shrunk from 6100 hectares in 1992 to 5850 hectares in 2004. 250 hectares of water bodies have been filled up illegally. Also revealed that of the existing 5850 hectares of water bodies in the wetland, only 4400 hectares are 'active wetlands' and the rest is degraded and silted (Kamboj, 2004).

(10) Many water bodies across the city have been filled up illegally for construction of residential buildings, and by local garbage deposition, thus diminishing the run-off and sullage storage capacity of the basins and impairing local climate, ecology and environment.

(11) In the eastern fringe areas, large numbers of low-rise-high-density dwellings and high-rise buildings built on previously rural/agricultural lands in unscientific ways of plot divisions and with narrow road spaces have blocked natural drainage path and created difficulty for providing proper sewage and drainage facilities by the municipality (CBE, Chakravarti, 2004).

(12) Construction of highways and major roads in the eastern region, like Eastern Metropolitan Bypass has formed physical barriers and impedes natural drainage of the city which is according to the topographical slope from west (river bank) to east (wetlands).

(13) Though Kolkata has apparently a flat basin with gradual slope towards east, many parts of the city have topographical depressions like saucers which enhance holding water for a long time during rainfall and inundation.

(14) Present work for the south-eastern extension of the Metro Railway over the Tolly's Nullah (an offshoot canal of river Hugli) has rendered the canal into a defunct and dead one adding environmental hazard.

(15) Urban development projects are under different departments of the Central, State and Local Governments and various joint sector and private organizations among which, there is little coordination for which undesired results happen (Ghosh, 2004).

(16) A related environmental problem is that the groundwater level in the city is receding alarmingly. In a report submitted to the Calcutta High

Court by Scientists of the Central Groundwater Board recently, it has been stated that groundwater (aquifer) level in the city has been depleted by 7m to 11m (ABP, 11.08.2007). The reason for this is construction of a large number of high-rise buildings in the city and indiscriminate boring of deep tube wells for extraction of groundwater. The quantity of extraction of groundwater everyday in Kolkata municipal area has been estimated to be as around 868.9 million liter. The Government has not been able to increase the supply of filtered water from the river as according to the huge and ever-increasing demand of water from excessive population and housing development in the city. Only a little quantity of the rainwater reaches up to the aquifer because of a large surface of the city having buildings, pavements and roads; the city not having enough parks and open spaces with green and vegetative cover; and the permeability of the soil of thick fine silty clay type in most part of the city being poor. The groundwater depletion has been resulting in the city's subsidence and contamination of Arsenic with groundwater creating severe health problem to hundreds of thousands of people.

Hence, drainage problem in Kolkata stands as a unique case in south Asia, and looking into the matter by case-specific management attitude (of like the Western world) would fail to solve problem because the problems are multiple and related to ever-growing population, poverty, education, health and hygiene, urban hydrology, environmental pollution and overall energy crisis along with the problems from the plural society having deep attachments with religious, cultural and traditional roots and practices, plus the attitude of bearing unacceptable conditions in life, lack of mindset for doing maintenance and exercising civic order, multiplied by the lack of coordination among various departments of Government and civic bodies and conflicting interests of political parties.

7 Recent measures taken

It has become urgent and important to take up an integrated approach of management of drainage under broader physical, scientific, technological, ecological and environmental parameters for attaining environmental sustainability of the city. On the one hand, the city's capacity to drain out excessive quantity of rainwater during monsoon is not adequate; on the other hand, because of depletion of aquifer, a huge quantity of water needs to be recharged in aquifer. To address both the critical issues, an integrated and adaptive environmental management planning has been introduced out of dire needs, though rather spontaneously by the learned professionals like architects, engineers, planners, environmentalists and partly by the Government. The drainage solution is in minimizing municipal sewer and drainage load first by some means, and then increasing the capacity of infrastructure. The effort is also to provide drainage facility at maximum areas of the city and it's added and fringe areas towards rendering the city an environmentally sustainable one. Increasing awareness about pollution, ecological and environmental protection and sustainability, among various sectors of the community and administrative organizations has helped taking some measures for management of drainage load in an integrated way.

(1) Intervention by State Pollution Control Board

The West Bengal Pollution Control Board (WBPCB) empowered to enforce the Water (Prevention & Control of Pollution) Act, 1974 has directed (in 2004) all Municipal Corporations and Local Authorities to ensure while granting permission for construction of any housing complex located within their jurisdiction having around 100 flats or more, or covering a super-built up area of around 6000sqm or more, that the wastewater from the housing complex is treated through its own 'treatment system' before discharging into the road sewer main of the Municipality or so (KMC, Chowdhury, 2004).

(2) In-house sewage treatment

It has become mandatory by the directive of the KMC that all large housing, commercial and other development projects in and around Kolkata have to treat wastewater (except storm water from roofs of the buildings) in the in-house Sewage Treatment Plants (STP), and the treated water can either be utilized by the inhabitants or be discharged into the municipal sewer main where it exists or to the nearby canal or pond designated for it.

(3) Rain water harvesting

The storm water from roofs of the buildings is collected separately into a storage tank with provision for filtration, treatment and recharging it into the aquifer or storage. Rainwater harvesting helps reducing drainage problem, and provides water for use (Gupta, 2004). Hence, rainwater harvesting and treatment of wastewater have become part of the architectural and construction management business, providing better environment and sustainability, and economic generation to such consultants, labourers and other people.

(4) Open area with vegetative cover

In any large architectural project, a large portion of the open area (mandatory open space being 60% of the plot area) is directed to be treated with green cover (grass lawn and trees) as children's playground and recreational area, which helps in minimizing quantity of run-off to some extent and provide for some rainwater recharging into the ground. More often, some old trees are being kept by architects in their positions and integrated into the new design of the built forms as components of the environment (KMC, 2004).

(5) Conservation and retention of water bodies & recovery of Wetland

The Government enforces the West Bengal Inland Fisheries Act, 1993 (Amended) to restrict filling up of any water body. The Municipality is keeping vigilance and taking legal action against any offender and reclaiming the water body at the offender's cost. The State Environment Department has declared the 'East Kolkata Wetland (Conservation & Management) Ordinance 2005' to define the wetland area. The State Department of Land & Land Ceiling has also kept proper vigilance on any attempt of urbanization in the area.

(6) Desilting and cleaning of sewer lines, outfalls and canals

Work is being done in this regard. 14 vehicles with Jetting cum suction pump machine to suck and dredge silts deposited in the sewer lines have been bought from abroad during 2002-2005 and engaged in operation. Previously and till date in some areas where width of road is narrow, human beings use to remove silts manually. The State Government acknowledges the need to dredge and conserve canals. A number of canal restoration and rehabilitation projects have been started by the State Irrigation Department and the KMC.

(7) Solid waste management

The Kolkata Environmental Improvement Project (KEIP) has proposed for construction of a new Sanitary Landfill site spread across 114 hectares at Dhapa. The proposal has been cleared by the East Kolkata Wetland Management Authority and will be constructed within 2008. As sustainability value addition, it will have – (a) composting and recycling units, (b) waste to power conversion unit, (c) planned pisciculture and (d) a green belt (KEIP, 2006).

(8) Slum improvement programme

The KEIP's slum improvement programme has included works like (i) widening, realignment and lining of drains, (ii) construction of sewer/drain lines and (iii) provision of solid waste containers, along with other works to upgrade environmental condition of slums in the city.

(9) KMDA's recent works

The Government has taken up a Trans Municipal Project with financial assistance from The Central Government under the "National Urban Renewal Mission" to be implemented by the KMDA with an objective of improvement of the drainage and sewerage system of the city's northern fringes across five municipalities (KMDA, 2006). Moreover, the KMDA has been doing several works for improvement of drainage in and around Kolkata.

(10) Kolkata Environmental Improvement Project (KEIP)
This is a multi-agency endeavour to arrest environmental degradation in fringe areas where drainage & sewerage networks are inadequate. Its work has included – (i) efficient interception and collection of sewage by providing secondary sewers, (ii) build trunk sewers in addition to existing trunk lines, (iii) develop separate storm water drainage systems including pumping stations where necessary, (iv) laying new underground conduits in narrow roads and connect properties to the new networks, (v) construct/rehabilitate pumping stations, and (vi) upgrade treatment plants and construct new ones where necessary (KEIP, 2006).

(11) Gross physical planning and fund investment by Government and Municipality
A total of Rs.2520crore (around US$550 million) is being spent over a period from 2005 to 2009 by the Government and Municipality through the Jawaharlal Nehru National Urban Renewal Mission (funded partly by US Aid, partly by Central Government), Kolkata Environmental Improvement Project (funded partly by Asian Development Bank), and Project Nikashi (Drainage). The major works taken up under these projects are – dredging and re-excavation of canals, revamp of drainage and sewer system and network, drainage development, new pumping stations, repair and restoration of old pumping stations, automation in pumping stations, procurement of sewage-cleaning machines, etc.

(12) Role of NGOs & other organizations
Recently, various organizations have been advocating for and working on decentralized sewage treatment systems in fringe areas of Kolkata where central sewer collection systems are absent. Through anaerobic treatment system, how wastewater can be treated to produce water for irrigation, agriculture and pisciculture are demonstrated to public and various authorities. It is appreciating that the private organizations, builders and developers are coming forward to take up this environment friendly solution. The KEIP has engaged NGOs to understand through them the need of the beneficiaries in compatibility with the ecological requirements and involve beneficiaries in all its development activities.

8 Conclusion

The problem of drainage system failure and subsequent inundation of many parts of the city is a regular phenomenon during monsoon since many decades. Mitigation of this problem not only needs proper environmental planning in an adaptive and integrated way, but also sincere participation and effort of all sections of the community and administration. To find fund support for investment in the drainage system development and management is no more very difficult in present time. The difficulty is in proper planning and management of the works within multiple constraints and in a plural society where mitigation of poverty in a large section of population having been utmost important to attain sustainability of the city. Another most important work is to inform and educate people about environmental pollution and the role of people in the process of mitigation of pollution for environmental sustainability. The students of architecture, civil and environmental engineering need to be educated the new thinking and the modern technological solutions in drainage systems and be taken part in community discussions. Proper emphasis is to be given on education, research, capacity building and participatory programmes of stakeholders and public for broadened awareness, proper cooperation and practical pro-sustainable activity in this regard to achieve the community's common goal.

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About Ways for Improvement of Water Use in Irrigation of Uzbekistan

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1 Introduction

Parallel to the technical questions, institutional aspects of development in water sector and water saving strategies in irrigation occurred as one of the global aspects of a problem of water resources in the world and some regions particularly, apart of political and food problems (Madramootoo 2001; Van Hofwegen and Svendsen 2000; Burt and Stuart 2001; Molden.et al 2001).

The important components of irrigation are organizational reforms of the centralized government irrigation management such as transfer of power and decision mandate to water users directly, creation of water user associations, introduction of water payment, modernization of irrigation and drainage infrastructures, improvement of water management quality, and groundwater protection. Madramootoo (2001) stresses that in order to solve complex water problems it is necessary to investigate and to apply in practice:

- Effective methods of irrigation, which take into account water and energy aspects,
- Modernization and automation of irrigation systems
- Transition from supply-based practices of irrigation water distribution to demand-based ones
- Advanced regulating hydraulic structures for reduction of water losses in the downstream area

- Reduction of seepage from canals
- Development of advanced methods of irrigation scheduling for crops
- Reduction of irrigation according to crop water requirements
- Improved crop patterns and genetic qualities that raise productivity by smaller consumption of water
- Introduction of advanced agronomical methods
- Improved management of on-farm water use , including exact planning of irrigated lands
- Reuse of drainage and other waste water
- Improved drainage, especially on salinized land and wetlands.

According to (Molden et al 2001), potential ways for improvement of water resource use in agriculture are:

- Development of water supply by increasing reservoirs and water intake structures. Tertonom (2000) calls these activities as management of water supply;
- Reduction of water withdrawals for the useful purposes by water saving practice.

Production of more products per unit of used water, which leads to increasing of water effectiveness.

The efficiency of irrigation water use in farms often is about 20-50 %. The rest - 80-50 % - is simply lost. In this context, Molden (2001) stresses that water saving is an attractive option as compared to construction of new reservoirs and intake structures, which often require high financial, social and ecological inputs (World Commission on Dams, 2000). The change from farm to basin perspective shows that because of reuse of the «lost» water, the losses are much less, than is considered.

There is no doubt in the given approaches and suggestions to solution of problems in the water sector. However, these methods do not take into account institutional aspects, events and conditions of agricultural environment as a consumer of water resources in Uzbekistan. It should be noted that for irrigated zones subjected to salinization the thesis that water losses are much less in the irrigation systems as a whole than direct losses in the field because of re-use of "lost" water in downstream areas seems to be doubtful since water of worse quality is re-used. Thus, any water losses under such conditions aggravate environmental and land reclamation problems.

The authors of the paper, having wide experience in irrigation and seriously caring about the future of this branch, have expressed their view about the ways of possible improvement of this situation. Parameters and scales of irrigation in Uzbekistan for the past period of time are described in advance.

The analysis of some data characterizing current situation in the water sector indicated to low efficiency of water use and allowed outlining the strategy for improvement. A methodological approach was chosen and general assessment of scenarios for system rehabilitation and for water saving technology application (sprinkling, drip irrigation, etc.) was made. This approach can be used for concrete irrigation systems and supplemented by economic part, which can be advanced, proceeding from the additional data on productivity of water and land.

2 Water resources of Uzbekistan

Multiple problems seriously threaten water use in the region as a whole, particularly in Uzbekistan (Ghassemi et al 1995; Kipshakbayev and Sokolov 2002; Khamidov 2002; Khudaiberganov 2002; Mamatkanov 2002; Djalalov 2002; Ikramov 2002 Dukhovny and Sokolov 2005).;
.Major of them are:

- occurrence and aggravation of problems in intersectional and interstate water allocation;
- growing shortage and deteriorating quality of water resources;
- expansion of saline irrigated areas;
- deterioration of environmental conditions.

Table 1 shows data on surface water volumes and location of formation in the Central Asian region (CAR). The total surface water is estimated at about 117 km3, of which Uzbekistan accounts for approximately 10 -12 %. Underground water resources amount to about 17 km3. Table 2 shows groundwater distribution among the countries. One should note that about 85 % of underground waters are formed in plains through percolation from irrigation canals and fields, and therefore, in most cases, these resources cannot be considered as additional reserve without detriment to surface water.

Currently, water consumption amounts to about 70 km3 in Uzbekistan. The republic receives most water from neigh boring countries – Kyrgyzstan and Tajikistan – according to signed interstate Agreements.

In Uzbekistan, major share of water resources (80…90 %) is uses in irrigated agriculture (Fig. 1); therefore, the main issue of rational water use is related to efficiency of irrigation systems and distribution of water on the fields.

Table 1. Surface water resources in CAR countries (Kipshakbayev and Sokolov 2002)

• *Country, where* • *given flow is generated*	• *River basin of Syrdarya km^3*	• *River basin of Amudarya, km^3*	• *Total, Aral Sea basin, km^3*	• *%*
• Kazakhstan	• 2,43	• -	• 2,43	• 2,1
• Kyrgyzstan	• 26,85	• 1,60	• 28,45	• 24,4
• Tajikistan	• 1,01	• 49,58	• 50,59	• 43,4
• Turkmenistan	• -	• 1,55	• 1,55	• 1,2
• Uzbekistan	• 6,17	• 5,06	• 11,23	• 9,6
• Afghanistan and Iran	• -	• 21,60	• 21,60	• 18,6
• China	• 0,76	• -	• 0,76	• 0,7
• Total	• 37,22	• 79,39	• 116,61	• 100,0

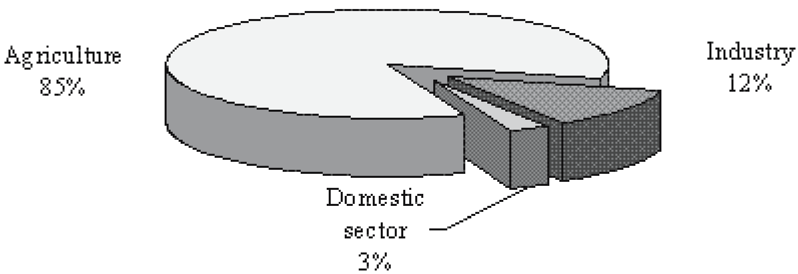

Fig. 1 Water use pattern in Uzbekistan.

Table 2. Underground waters resources in Uzbekistan (Kipshakbayev and Sokolov 2002)

• Countrie •	• Total • explored • reserves,km3	• Amount renewable • for abstraction and use,km3
• Uzbekistan	• 18,46	• 7,80

3 Problems of use of water resources in irrigation: a history, modern condition and ecological consequences

History and future growth of population, irrigated area, and water use in Uzbekistan shows Figure 2.

Specificity of irrigation development in the region until 1950 was that the main attention was paid to engineering aspects, i.e. to improvement and construction of intake structures, reservoirs, and canals.

In the 1950s, for the first time in the region, a reform was undertaken to shift to furrow irrigation. This allowed wide mechanization of land treatment and considerable improvement of irrigation uniformity and water use efficiency. Improvement of irrigation technique against the background of drainage produced positive results, namely crop yields achieved the relatively high level. However, putting into operation of new large irrigation schemes (in the zones having poor natural outflow of surface and ground waters) has led to intensive water-logging and salinization of land. In those zones, drainage was not a panacea for growing problems, though it was wisely designed and well-constructed.

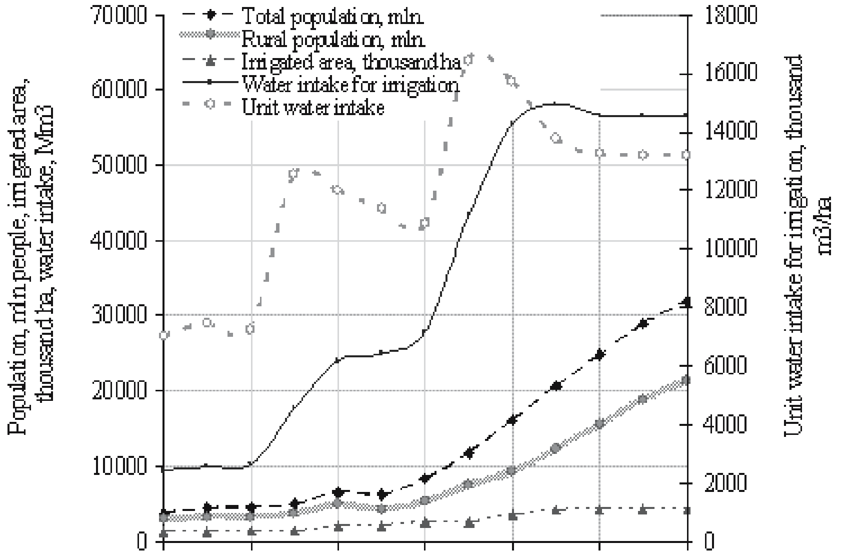

Fig. 2 Growth of irrigated area, water use and population in Uzbekistan.

In old irrigation schemes those problems were solved either through natural drainability or by the so-called "dry drainage" – outflow and accumulation of salts on non-cropped land. Archaeologists thought that similar problems occurred in many ancient states led to gradual downfall of the latter ones.

Despite the occurrence of similar problems at the beginning of XX century during development of large land schemes in Mirzachule (Hunger Steppe), any effective ways for their solution, except for intensive draining of given area, have not been proposed and implemented. While water resources were practically unlimited, to a certain degree, drainage prevented salinization and water-logging for a long time, though this solution was expensive and had many negative environmental consequences.

In the 1960s to 1990s, irrigation was intensively developed in Central Asia. During that period, the irrigation infrastructure got the major modern characteristics: the seasonal flow regulation reservoirs and the unique long-term regulation reservoirs were constructed on the main river-sources (Syrdarya River basin and partially Amudarya River basin). Those include also powerful HEPS, cascades of unique pump stations, and main canals of inter-basin flow transfer. Engineering systems of irrigation and drainage were constructed on large schemes of new land development (the Hunger, Djizak, Sherabad, and Karshi steppes; Kyrkyz scheme).

Irrigation development followed the Decisions of the Federal and Republican Governments, especially the Development Master-Plans at different levels, such as federal, republican and basin (the Aral Sea, the Amudarya and Syrdarya rivers) (Yegorov 1954; Averyanov 1959; Golovanov 1975; Reks LM and Kireicheva 1976; Minanshina 1978; Kovda VA 1981; Sevryugin and Morozov 2000,2001etc.). Such large-scale plans were developed by outstanding experts from various departments and well-known designers and scientists, including topographers, hydraulic engineers, irrigators, soil scientists, hydrogeologists, hydrologists, agro-economists and others.

Why at such design studies, which in many aspects till now are samples of system engineering of the integrated water resources management, there was a problem of the Aral region?

None has yet identified and analyzed major mistakes made in the Water Sector Development Master-Plans and in other design works that guided the irrigation development.

The mistakes imply, first of all, inadequate conditions for application of modern irrigation techniques – the basis of land reclamation in arid zone. Especially this concerns irrigation of high-permeable and saline land. Many scientists (Parfenova and Reshetkina 1995; Pankova at all 1996; Averyanov 1959,1978; Reks and Kireicheva 1976; Minanshina 1978; Kovda 1981) have indicated for a long time that irrational irrigation water use would cause critical economic and environmental effects since the term “land reclamation” meant “improvement”, i.e. correction of natural disadvantages rather than creation of new ones. In Uzbekistan, for example, 25% of irrigated land is high and very high permeable. It means that furrow irrigation in this land will cause over-use of irrigation water minimum two-three times under unfavourable moisture regime for crop growing. Moreover, all wasted water is not simply lost but creates untypical, for arid zone, problems of soil water-logging and salinization in adjacent area.

Areas with critical level of salinization have increased recently (Fig.4). Due to very poor drain ability and irrational water use, intensive water-logging and salinization are observed in the Khorezm province and the Republic of Karakalpakstan located in downstream of the Amudarya River (Figs. 3, 4).

In order to analyze current and impending problems, let consider how water is used in irrigation agriculture, which consumes 80 - 90% of water as mentioned above. Though the efficiency coefficient of water-transporting systems is about 50 %, we will touch mainly water use at field level. Field water ensures crop production, while forming water and salt regime of the soil and most of drainage flow.

Work (Sevryugin and Morozov 2000,2001) analyzed the losses through surface runoff and deep percolation and the uniformity of soil wetting through furrow irrigation, based on standards and scientific recommendations on optimal parameters for typical natural conditions, and according to adopted zoning (Laktayev 1978, Design standards1985,1997). Though those recommendations are developed for ideal conditions that are actually unattainable (good levelling; uniform, regarding roughness and density, furrows with banked-up tails; equal water distribution among the furrows, etc.), the standard water losses are from 30 to 50 %, and watering uniformity is not more than 0.7. In practice, those indicators are never achieved, and the uniformity of soil wetting is always related to over-use of water through surface runoff and deep percolation. Thus, only 25…35 % of the total water diverted for irrigation from rivers is used efficiently.

The analysis of relative water productivity (amount of water used per unit output) for various watering methods (Sevryugin and Morozov 2000) shows that application of water-saving irrigation technique (as compared to furrow irrigation) allows the increase of water productivity by 1.8 times in medium permeable soil (about 50% of irrigated land in Uzbekistan) and by 4.0 times in high permeable soil.

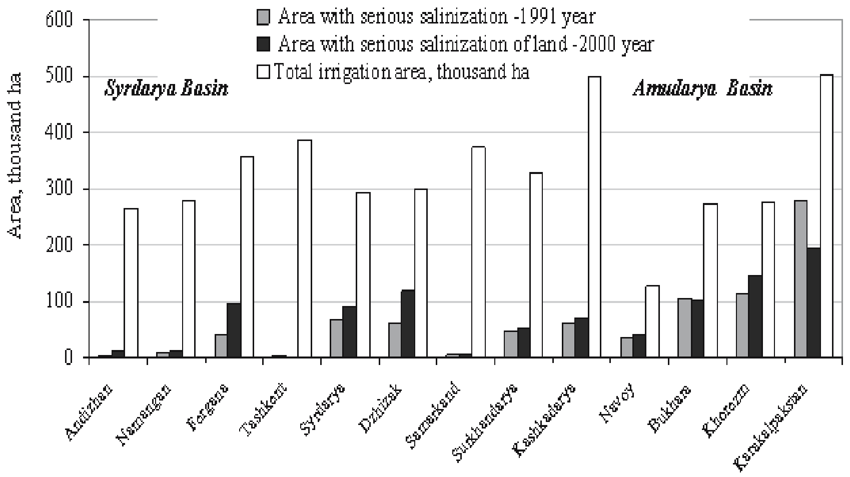

Fig. 3 Distribution and dynamics of saline irrigated land in Uzbekistan's provinces (data source: Ministry of Agriculture and Water Resources)

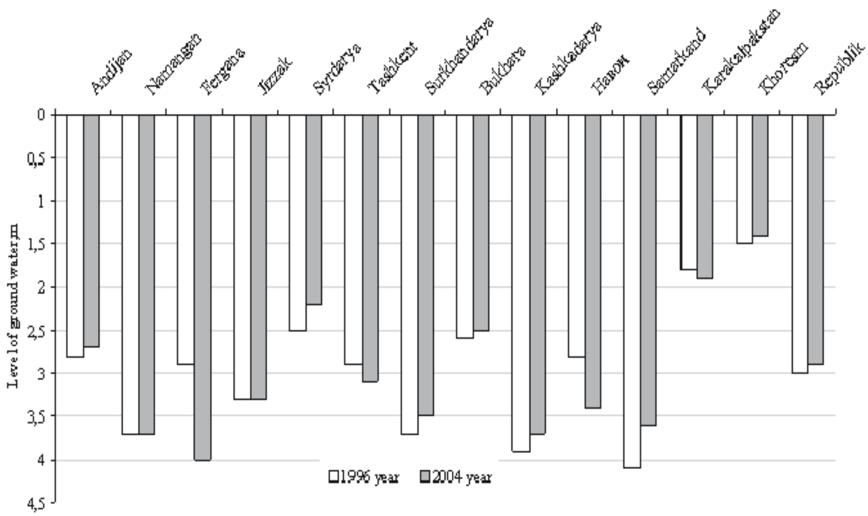

Fig. 4 Mean annual groundwater levels in Uzbekistan's provinces

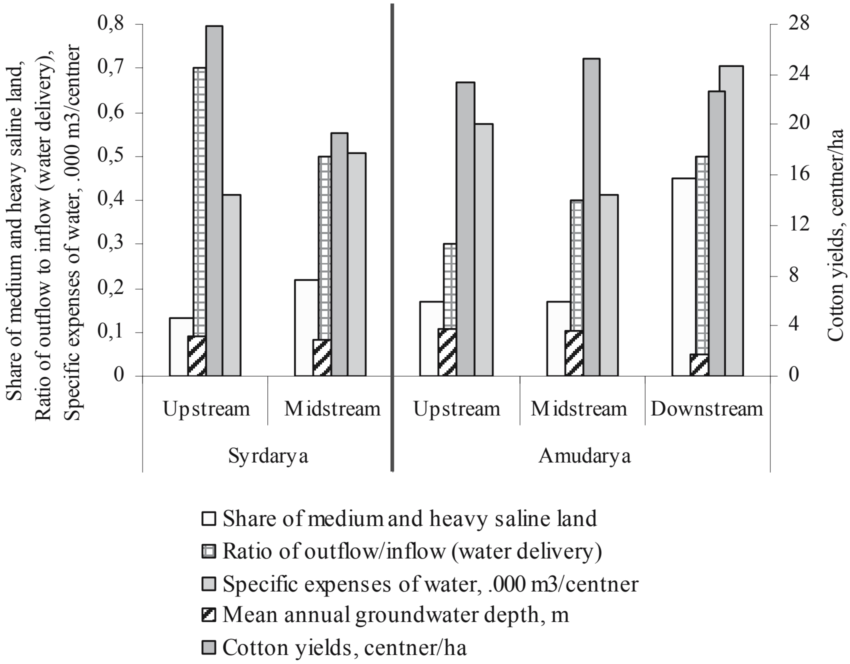

Fig. 5 Parameters of use of water and influence it on soil salinity and yield of cotton

Table 3. The state of irrigation and drainage infrastructure, water use and related indicators of the Syrdarya River and Amudarya River basins

Indicators of irrigation and drainage infrastructure	Syrdarya River basin		Amudarya River basin		
	Up stream	Mid stream	Up-stream	Mid-stream	Down-stream
Irrigated area					
Total, thousand ha	907,6	958,9	329,2	1279,4	759,6
Share of medium and heavy saline land	0,13	0,22	0,17	0,17	0,45
Mean annual groundwater depth, m 1996/2004	3,2 3,5	2,9 2,4	3,7 3,5	3,6 3,4	1,7 1,8
Inter-farm canals and collectors					
Total length, km	8.355	4.599	1.532	5.795	5.615
Inter-farm canals unit length, run.m/ha	9,2	4,8	4,7	4,5	7,4
Share of lined inter-farm canals	0,4	0,4	0,5	0,5	0,1
On-farm canals					
Total length, km	41.892	28.416	13.057	57.797	33.302
On-farm canals unit length, run.m/ha	46,2	29,6	39,7	45,2	43,8
Share of lined on-farm canals	0,1	0,4	0,3	0,2	0
Collector - drainage network					
Length of open collector-drainage network, km	26.849	42.354	10.080	26.616	30.361
Share of on-farm network (out of total)	0,6	0,3	0,5	0,4	0,7
Unit length of subsurface horizontal drainage, run. m/ha	2,4	24,7	13	6,3	1,2
Indicators of irrigation waret eficiency					
Unit water delivery at district boundary, thousand m3/ha	11,5	9,8	13,4	10,4	16
Unit water outflow at district boundary, thousand m3/ha	8	5	3,8	3,9	7,9
Ratio of outflow to inflow (water delivery)	0,7	0,5	0,3	0,4	0,5
Cotton yields, centner/ha	27,8	19,4	23,4	25,2	22,7
Specific expenses of water, tH.m3/centner	0,41	0,51	0,57	0,41	0,7

Syrdarya river basin: Upstream - Andizhan, Namangan, Fergana provinces; Midstream - Dzhizak, Syrdarya, Tashkent provinces;Amudarya river basin: Upstream-:Surkhandarya province; Midstream- Bukhara, Kashkadarya, Navoy, Samarkand provinces; Downstream- Rep.Karakalpakstan, Khorezm province

The Table 3 and Fig.5 characterize a common condition of irrigation systems, water use, reclamation parameters and cotton yields per zone: the river Syrdarya - upstream and midstream; the river Amydarya - up-, mid- and downstream.

The general conclusion on the data of Table 3 and Fig. 5 is that the most problematic zones in terms of water use in Uzbekistan are: the upstream of the river Syrdarya and downstream of the river Amudarya. In the first case it is possible to see very large drainage flow, and in second - the large volumes of withdrawal and outflow of water, highest inputs of water per unit production under shallow groundwater conditions promoting growth of soil salinity.

Such the situation is possible to explain: by losses of water at the expense of the longest earthen channels and excessive leaching of lands in the winter period.

One should note that field water losses, besides wasteful use, cause deterioration of land. Under initially hydromorphic conditions and fresh groundwater, the latter is recharged and the area is water-logged. Under stable automorphic conditions, nutrients are removed and downstream areas are water-logged. Moreover, secondary salinization is intensified in soils subjected to salinization.

Many development (Concept of scientific and technological progress in water sector and land reclamation in Uzbekistan 1991, Master-plan of development of irrigated agriculture and water sector in the Republic of Uzbekistan up to 2015 (2001), Dukhovny and Sokolov 2005 etc.) and reconstruction projects defended positions for intensive construction of drainage – panacea for all troubles – and reconstruction of irrigation network and completely ignored a possibility of applying perfect irrigation technique. The opinion that the perfect irrigation facilities are very expensive and their operation is quite burdensome for farmers occurred long ago. Moreover, currently half of irrigation water is pumped, and 70 % of it, when transforming into a category of losses, causes problems in land reclamation and ecology, and then, together with drainage water flows back and has worse quality.

What are the ways out of this situation? Certainly, nothing can be easily settled, corrected, and reconstructed. However, now we should start from structures, where direct (justified by water saving, energy costs and crop yields increase) and indirect (in land reclamation and ecology) economic effects are more visible.

In Uzbekistan, for example, half of total water diverted for economic needs (~ 60…70 km^3), including irrigation, is pumped (~ 30 km^3), and this is very expensive. Given the current conditions of irrigation canals, only about half of total diverted water reaches the fields. Water lost in the canals causes a number of problems:

- a share of water is irretrievably lost from canals' right-of-ways;
- another share creates artificial backwater conditions and contributes to water-logging and salinization since this water "extrudes" saline solutions from deep horizons to soil surface;
- a minor share of water losses is used in the fields, mainly in the zones of highly circulating groundwater, with low salinity.

The value of lost water is of particular concern under water pumping for irrigation systems (big pump stations, Table 4). There are also a number of small pumps lifting water to individual farm groups that are beyond the command zone of farm canals.

Table 4. Distributions of areas under water lift in Uzbekistan

Province	Total irrigated area, thousand ha	Of which, pumping irrigation, thousand ha	%% of total irrigated area	%% of pumping irrigation area
Andizhan	272,4	73,3	27,0	4,8
Bukhara	273,6	273,0	99,8	17,8
Dzhizak	294,9	78,7	26,7	5,2
Kashkadarya	504,4	372,6	73,9	24,4
Navoy	124,5	89,0	71,5	5,8
Namangan	278,0	77,7	27,9	5,1
Samarkand	372,8	62,6	16,8	4,1
Surkhandarya	329,3	223,0	67,7	14,6
Syrdarya	298,9	63,0	21,1	4,1
Tashkent	396,1	58,4	14,7	3,8
Fergana	356,8	113,3	31,8	7,4
Khorezm	275,0	45,0	16,4	2,9

Total 1529, 6 thousand ha =100 % (40 % at irrigated area)

During creation in Uzbekistan of large new systems of pumping irrigation, both water and power resources were not scarce. Therefore, the large land schemes were developed, with forced water lift for irrigation. Today it is obvious, that cost of such water is very great because of energy expenses. In this context, the need for water saving is most important for territory with pumping irrigation.

4 The preconditions and offers for improvement of water use in irrigated agriculture

What is the economically sound alternative way out of existing situation? First of all, we should shift to the so-called “integrated management” of water resources, interpreting this as establishment of order in the inter-state and intra-state water distribution between the systems and observance of tough schedule of water delivery to farms, with application of required limits that are obligatory for all water users (taking into account also the set priorities for non-irrigation users). Without this obligatory condition, any other activity will be unreasonable.

Then, based on present realities, we should develop applicability conditions for most effective and cost-effective perfect irrigation facilities and identify zones for their application.

The applicability conditions mean:

- technical acceptability and advisability, based on natural parameters;
- cost effectiveness;
- expediency of government support if application of perfect irrigation technique entails indirect effects in energy-saving, land reclamation, and ecology for neigh boring territories;
- expediency of soft lending to purchase the perfect irrigation facilities for one or another natural and economic conditions.

Table 5 shows distribution of irrigated area in Uzbekistan according to water permeability. It is clear that high and very high permeable land accounts for about 25 %.

Experts estimate that application of the perfect irrigation technique in these lands only may save about 30 – 40 % of total water used in irrigation in Uzbekistan, reduce energy use by 15 %, increase crop yields by 30 – 50 %, and solve land reclamation problems in high permeable schemes and in 10 % of adjacent land area. Besides, those schemes (only provided the perfect irrigation technique there!) may transfer to energy-saving (minimum and zero) technologies that are practically unacceptable for furrow irrigation technology since presence of stubble remains on the soil surface change radically water flux hydraulics in the furrow, irrespective of soil permeability.

As to half irrigated lands having medium permeability, there the effects of perfect irrigation technique application are not so impressive; however, here irrigation water productivity (i.e. use per unit production) may be increased almost two-fold, contributing, at the same time, to solution of land reclamation and ecological problems.

Table 5. Distribution of irrigated area in Uzbekistan according to water permeability

Administrative province	Irrigated land, thousand ha	of which, percentage of area where soil permeability			
		very high	high	medium	low
Karakalpakstan	501,9	9,5	29,1	29,1	32,3
Andizhan	281,1	6,2	18,8	22,4	52,6
Bukhara	273,7	13,2	0,8	32	54
Dzhizak	293,7	3,8	7	84	5,2
Kashkadarya	503,4	8	8,9	51,3	31,8
Navoy	125,7	5,2	27,6	43,2	24
Namangan	277,9	1,8	29,4	47,6	21,2
Samarkand	375,4	-	-	50,3	49,7
Syrdarya	298,9	1	7,5	68	23,5
Surkhandarya	329,8	7,7	16	43,6	32,7
Tashkent	389,2	-	24	64,8	11,2
Fergana	358,4	19,3	34	17,7	29
Khorezm	255,5	18,3	27,8	8,3	45,6
Total	4264,6	7,3	17,4	43,6	31,7

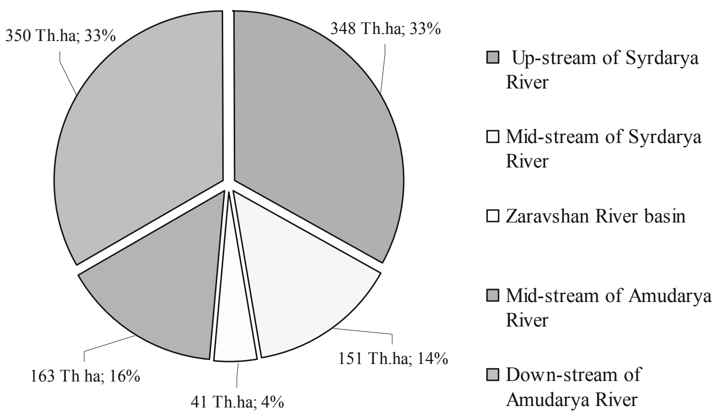

Fig. 6 Distribution of irrigated lands with high and very high water permeability by river basins

In the upstream zones of river basins, where lands are characterized by a combination of high permeable soil and deep groundwater (under their natural outflow), the water losses under surface furrow irrigation through filtration are very high. Therefore, one can consider them as territories for priority introduction of sprinkler irrigation and wider cultivation of crops irrigated by drip irrigation methods. It will give possibility to save water for downstream lands. In the future, these technologies are possible to use in zones characterized by slightly saline lands and non-compacted soil.

For medium-permeable lands under automorphic conditions of soil-formation, furrow irrigation leads to larger deep percolation of irrigation water causing drainage problems in downstream areas. In this context, the most acceptable irrigation regime, in view of cultural practices, is frequent watering with smaller depths, which is impossible to implement without the special (water-saving) irrigation technique. Only in case of low permeable soils it makes sense to keep furrow irrigation methods provided that the surface is ideally leveled. Besides, the areas of perfect irrigation technique application may be transferred to cheap crop production technologies (minimum treatment, zero technology)[1].

Despite the fact that improvement of furrow irrigation technology, for example alternate furrow irrigation, in some cases allows us to achieve higher field water productivity to 80 - 83 %, respectively, and leads to seasonal water savings from 200 to 300 mm when compared with actual water use in every-furrow (Horst et all 2005), in some cases (small size of fields located on rough grounds with the mixed soil types); the opportunities of modernization of furrow irrigation are lower than in case of sprinkling and drip irrigation (Burt et all 2001). The authors emphasize the best opportunities for management of these irrigation methods and for achievement of much higher yields than that from surface (furrow) irrigation.

The application of water-saving irrigation technique under automorphic conditions is possible and effective even at local scale. However, under hydromorphic and semi-hydromorphic conditions, with a risk of soil salinization from groundwater, the perfect irrigation technique (for instance, sprinkling, drip irrigation, etc.) should be applied in larger schemes. Otherwise, the soil may be subjected to salinization through influx of saline groundwater from adjacent conventionally irrigated area (Fig.7).

[1] The experience of developed and less developed countries shows that these technologies allow the very low-energy farming, while overcoming many economic and environmental problems.

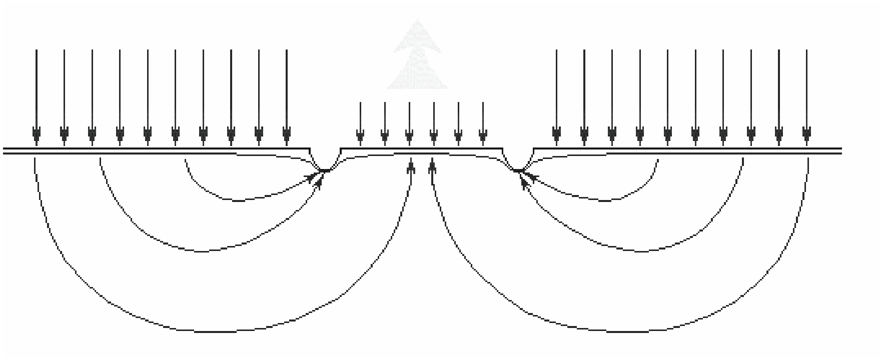

Fig. 7 Groundwater fluxes from schemes of conventional irrigation to areas with perfect irrigation.

Unfortunately, there is no available any comprehensive design study allowing the assessment of all engineering, economic, and ecological positives and negatives in transferring to perfect irrigation technique at regional scale or even at large system level. All “Master-plans…” considered as alternatives only various areas of new developed land and possibilities of their supply with water rather than application of different irrigation technologies. Only recently (when, per se, the region’s water resources are exhausted, and additional interstate agreements on water limits are adopted), we started to estimate how much old-irrigation lands should be rehabilitated in order to put into operation new land. Moreover, irrigation technique issues have not been addressed, and this was a big mistake. Regulation of inflow under intensive drainage, without provision of facilities for water distribution in the field is a way to yield losses and land deterioration. Investments in irrigated land rehabilitation without actual improvement of watering system do not contribute to achievement of effective water use. In recent times, a very experienced irrigator (manager, scientist, and expert) R.A.Alimov, based on actual water inputs under low canal efficiency coefficients and extensive surface watering, estimated the irrigation capacity of available water resources at 2,0 million ha for Uzbekistan (Alimov RA,1967).

Table 6. Distribution of irrigated areas in the Republic of Uzbekistan according to groundwater impact on soil moistening (% of irrigated area) source: VODPROYEKT, 1998

• Administrative units, river basins	Soil classification according to moisture conditions		
	• Automorphic, (groundwater depth more than 3 m)	Semi-hydromorphic (groundwater depth within 2-3 m)	Hydromorphic (groundwater depth less than 1,5-2.0 m)
Andizhan	28,2	17,0	54,8
Dzhizak	67,8	29,3	2,9
Namangan	61,4	0,1	38,5
Syrdarya	1,7	76,8	21,5
Tashkent	43,4	7,4	49,2
Fergana	26,6	2	71,4
Total, Syrdarya River basin	229,1	132,6	238,3
• Karakalpakstan	17,7	47	35,3
Bukhara	10,6	31,4	58,1
Kashkadarya	13,8	79	7,2
Navoy	34,3	64,4	1,3
Samarkand	52,6	45,6	1,8
including, upstream zone	89	11	0
downstream zone	29,9	67,1	3
Surkhandarya	51,5	27,3	21,2
Khorezm	0	38,6	61,4
Total, Amudarya River basin	299,4	411,4	189,3

Today this area is 4, 2 million ha. Keeping irrigated agriculture in the same way, that is business as usual, means putting up with low water efficiency.

Recommendations on application of optimal parameters of furrow irrigation (i.e. maintaining optimal furrow lengths and inflows too furrow) are not always practicable in small farmers' fields.

What are the prospects of perfect irrigation technique application in Uzbekistan, and which natural conditions can contribute to efficiency of such technique under current economic situation?

Through application of perfect irrigation technique, we can reduce irrigation norms (several times), improve watering uniformity and water productivity.

First of all, we need to improve irrigation technology on about 0,5 M ha of irrigated land with stable deep groundwater (Table 5), that is automorphic conditions of soil moistening (without groundwater contribution), where water losses during watering exceed several times the design crop demand. Water lost through deep percolation does not flow back and causes water-logging of downstream areas. As a rule, water is pumped to these lands, and therefore, it is easier to shift to perfect irrigation technique here, especially since its local application is feasible.

More irrigation water can be saved on about 1, 0 Mha of irrigated area with high and very high water-permeable soils in Uzbekistan (Table 4).

Table 7 shows the results of preliminary estimation of different water use patterns in alternative options. The following options are considered:

- option 1, - business as usual;
- option 2, - only rehabilitation of canals
- option 3, - improvement of irrigation technology.
- option 4, - rehabilitation of canals and improvement of irrigation technology.

The resulted figures indicate to probable effects from implementation of given options when using limited water resources. These estimations need detailed elaboration, which is impossible without involvement of multiple design and survey teams, as well as funds. But those deserve more attention.

The Table 7 shows that the maximum effect in rational irrigation water use can be achieved through reconstruction of canal systems and application of water saving technologies on the fields. In this case, it is possible to reduce specific water withdrawal at the head of systems more than two times and to decrease by five times outflow (discharge and drainage water) through reduction of water expenses on field by 30-40 % and reduction of losses for transportation by 16 %. Received at this expense water resources will enable to increase irrigated area on 4, 33 million hectare (approximately twice in relation to existing area).

Table 7. Change in indicators of water and land resources use under various irrigation system improvement strategy options

Indicator	Strategy options			
	1 Current-state	2 Only reconstruction of canals	3 Only water-seving irrigation technology	4 Rehabilitation of canals +improvement of irrigation technology.
Mean weighted irrigation norm (net-field), m3/ha.	6521	6521	5000	4500
Efficiency coefficient of irrigation technique	0,68	0,68	0,9	0,9
Technical efficiency coefficient of irrigation systems	0,8	0,89	0,8	0,89
Efficiency coefficient of irrigation systems	0,64	0,8	0,72	0,8
Potential amount of return flow, m3/ha.	8507	5487	2716	1742
Irrigation norm (gross), m3/ha.	15028	12008	7716	6242
Irrigation norm (gross), minus return flow, m3/ha.	13072	10910	7309	6068
Limit of water resources for irrigation, km3	49	49	49	49
Irrigable area in Uzbekistan (without water use deficit), M.ha	3,75	4,49	6,7	8,08
Increase in irrigated area as compared to current state	-0,45	0,74	2,96	4,33
Unit water diversion for systems at all levels (share of the current one).	1	0,8	0,51	0,42
Water outflow from irrigated fields (share of the current one).	1	0,64	0,32	0,2

5 Conclusions and discussions

At insufficient financial assets and limited water resources in Uzbekistan, it will be necessary to solve a dilemma: where first of all it is necessary to put: in rehabilitation of irrigation infrastructure, or to raise culture of use of water on fields?

It is obviously that this sequence of investments for above-mentioned closely connected questions should be decided within borders of concrete systems simultaneously. The basis for the decisions should be technical and economic accounts.

Severe water loses from the irrigation system and fields in Uzbekistan occur due to number of objective reasons of technical and economic character such as deterioration of canals and irrigation devices, lack of means on modernization of canals and automation of systems of distribution of water, and also because of universal application traditional (water non economical) technologies of irrigation on furrow, without sufficient land reclamation and consideration of natural conditions. However according to hierarchical structure of water managment, farm fields are tail-end unit of the irrigation system, where farmers themselves beeng members of water user associations (WUAs) are responsible for water use in this last unit. Nevertheless, water use at farm level should not be ignored in governmental and other ivestment programs.

A water use strategy should rather take into consideration losses by irrigation of fields and not be restricted only by modernization of large-scale system of canals, pumping stations, establishment of water reservoirs etc. Water, which was distributed to fields, should be used rationally and farmer should have opportunity to achieve the optimal water use. Unsufficient irrigation technique leads not only to the reduction of effective use of water, but also the decreasing of land productivity due to salinity and water logging development.

For passing step-by-step arrangements of improvement of situation it is necessary to consider system of measures for the short-term, intermediate term and long-term periods (with detailed study for each zone and irrigation system), It is economically favorable to begin evaluation works and realization of the projects for systems, where water supply and water losses are most expensive. This considers massifs of irrigated land supplied with water by large pumping stations as wenn as territories with high filtrated and amorphous soil. Criteria of improvement at a choice of arrangements should be,: water saving; saving of power resources, increase of yields and efficiency of water, and also degree of reduction of harmful influences on an environment, such as salinity and flooding of territories.

Table 7 illustrated only basic estimations and provisional effects from application of different arrangements A test approach can be developed and supplemented by concrete physical and economic parameters for particular zones, basins of irrigation systems and water users associations, established with consideration of a hydrographic situation.

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Participatory assessment of water developments in an atoll town

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Abstract

Water development projects often fail, which represents a poor outcome given the limited progress against the Millennium Development Goals in providing people with adequate water and sanitation services. This may not be surprising given that water management has been identified as being in the complex system domain. According to the Cynefin framework, many traditional approaches are not suitable; but it suggests an approach based on the methods of probe, sense and respond. In line with this general framework, a participatory assessment methodology has been used to explore experiences in the atoll town of Tarawa in the Republic of Kiribati. After framing the case study, information was collected providing multiple perspectives and these include narrative sources. When reviewing previous experiences, project implementations are seen as probes or disturbances to the system from which patterns of behaviour can be sensed. For this purpose, the critical factors leading to success or failure are described using network representations. These are then used to inductively sense system patterns, and the conclusions thereupon reinforce key recommendations in a recent United Nations report. Additionally, the findings in this paper feed into a larger study where Agent-based simulation and Bayesian networks are used in a participatory setting for integrated assessments.

Key words: Development, Cynefin, Water service delivery, Complexity

1 Introduction

Water development projects are important in allowing urban areas to adapt to changing circumstances, such as population growth or socio-cultural changes. These types of changes are currently occurring at a rapid rate in Pacific island nations due to an increasing demand for urban services, and potentially in response to population movements that could occur as a consequence of climate change. At the other end of the spectrum failure in such projects is often related to health problems, increased environmental vulnerability and limited opportunities for economic and agricultural growth. Unfortunately many water development projects do fail, and in the United Nation's Water Development Report from 2006, a number of observations were made regarding the state of water service delivery around the world (United Nations 2006):

- "20% of the world's population still lacks access to safe drinking water"
- "Good governance is essential for managing our increasingly stretched supplies of freshwater, and indispensable for tackling poverty."
- "There is no blueprint… but we know it must include adequate institutions – nationally, regionally and locally – strong effective legal frameworks and sufficient human and financial resources."
- "… a bottom-up approach is needed."
- "It is inability to learn from local people on the ground that is at the root of this problem."

These statements make clear that there is surprisingly little progress in providing water and sanitation services to the world's poor. It also seems clear that there are no single solutions that will solve the problem in isolation. There are considerable barriers on the ground, in terms of involving local people and developing appropriate institutions. But why is this so difficult? Some of the reasons may relate to the fact that providing water and sanitation services suitable for the particular socio-cultural context is in fact a complex task where traditional approaches are often unsuitable. This is despite the fact that such traditional approaches appear to be suitable in urban areas in developed nations with considerable resources and where market mechanisms are well established.

The aim of this study is to understand why water development projects tend to fail. For this purpose, the Cynefin framework (to be further explained below) is applied on a case study basis using multiple perspectives, narrative information and complex systems tools such as (Bayesian) network diagrams. The chosen case study is the small atoll town of Tarawa in the Republic of Kiribati.

2 Background: Case study

Kiribati is a Small Island Developing State in the Equatorial Pacific (see Figure 1), and also classified as a Least Developed Country. Tarawa, the capital of Kiribati, is an atoll town, with a population around 50,000 people (Kiribati National Statistics Office 2006). The unemployment rates varies but is often reported as high as 60%, with paid jobs primarily within government and a large percentage of the population survives through subsistence livelihoods. A strong demand for urban services has generated rapid influx of families from outer islands and the traditional culture and customs remain influential.

Tarawa is severely polluted due to a high population density, virtually non-existent garbage collection, deficient sewerage disposal and sanitation, and poor environmental management practices. This has negative impacts on environmental resources such as freshwater lenses and the lagoon. Based on many previous efforts to improve water services in Tarawa, there is much available on social, technical and environmental issues Tarawa also represents a community with socio-cultural tensions, due to the high demand for modern services, but a limited ability to take up practices such as centralised infrastructure systems; or market-based incentives.

Tarawa has traditionally relied on groundwater for water supply. This groundwater occurs as freshwater lenses, with sizes varying depending on the width of each island. Groundwater was traditionally extracted from shallow open wells, and initially the supply was not a major problem. This changed during the 1900s as the population increased. To meet an increasing demand, the British colonial government decided to install groundwater infiltration galleries, and establish water reserves to protect the catchments. This meant displacement of traditional land owners who were disenfranchised by losing control over symbolically and practically important land. The process was then repeated until recent times, with water reserves successively being added along the urban periphery.

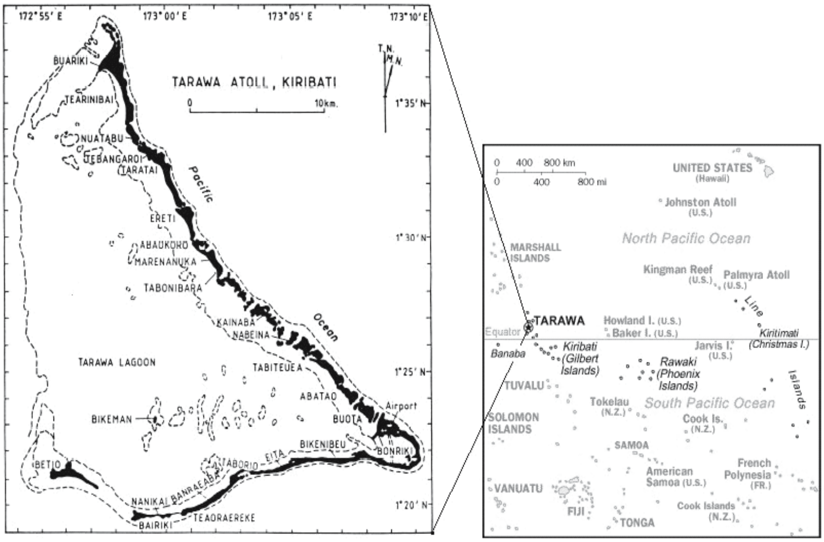

Fig. 1 Map of the Tarawa atoll and its location in the Equatorial Pacific

In the current situation, water reserves are established on the islands of Buota and Bonriki, providing a daily sustainable yield of approximately 1,700 m^3 (Falkland 2003). However, as the population is still increasing, demand now outstrips supply, with tap water often available for only 3 hours per day. In an attempt to increase the supply and reduce demand, a number of strategies have been attempted (Asian Development Bank 2004), such as:

- Installing three desalination plants with a total capacity of about 200 m^3 per day – all of which are currently inactive
- Introducing legislation meaning that each new house needs to be fitted with a rainwater tank – a legislation which is not widely followed
- Adding another two water reserves and infiltration galleries– extensions that have stalled due to a stalemate between the public utility and land-owners
- Installation of slow-flow tanks as a way to reduce demand – with only a handful of trial tanks installed due to reported household ownership concerns

3 Method: Participatory assessment

The reasons for failure or success in water developments in Tarawa have been explored using a Participatory Assessment technique. The answers are generally not straightforward, but multi-faceted, strongly contextual and often surprising. This could be expected as water management is a complex task dependent on the socio-cultural context (Jakeman 2007, Moberg and Galaz 2005, Pahl-Wostl 2002a, 2002b). Moglia *et al* (2007b) lists the following types of complexities in water systems:

- Adaptive features due to adaptive human behavior
- Social complexity in relation to participants' decision making
- Non-linear features related to environmental systems
- Uncertainty due to socio-political constraints, organizational limitations and climate variability
- Distributed features due to the ecology of socio-technical settings

As shown in Figure 2 (based on Kurtz and Snowden 2003), there are four types of system domains ranging from Complex to Complicated, Chaotic and Routine. In the ordered routine domain, cause and effect relationships are repeatable and predictable, and here, standards and best practices are applicable. In the Complicated ordered domain, cause and effect relationships are knowable but usually not immediately obvious, such as is the case in many physical systems. In this domain, reductionist thinking and scenario planning is applicable. In the un-ordered chaotic domain on the other hand, there are no visible cause and effect relationships and the system is turbulent. In this domain, acting decisively may reduce uncertainty, and hence increase the potential for control in the system. This may allow it to be transferred into the complex domain. In the complex domain, cause and effect relationships are dynamically changing and difficult to discover. This is also the domain of complexity science which explores how local interactions lead to emergent system behaviour.

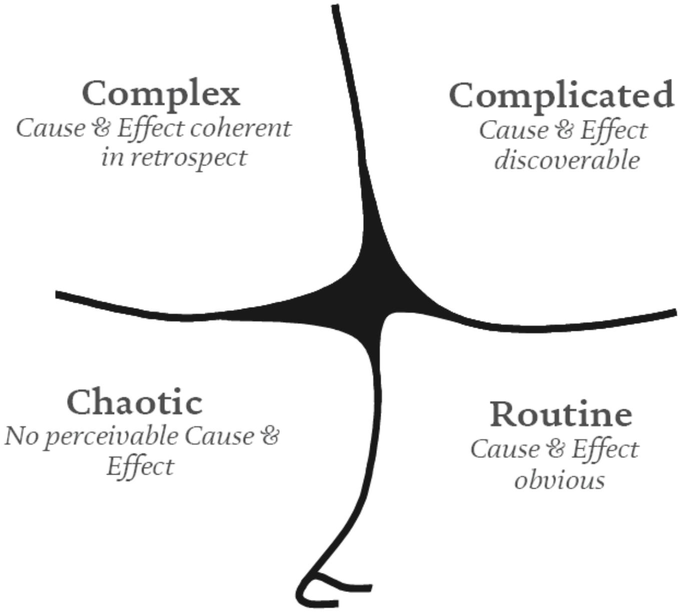

Fig. 2 Four system domains in the Cynefin sense making framework

Fortunately, the Cynefin framework (Kurtz and Snowden 2003) also suggests that there are some general guidelines for how to operate in the complex domain. It prescribes:

- Analysis of history as a way to understand systemic properties; but this is insufficient in itself as a complex system is evolutionary and dynamic
- Exploratory analysis in order to temporarily move from the complex domain, where cause and effect relationships are only coherent in retrospect, to the complicated sphere where cause and effect relationships are discoverable
- Use of a Probe, Sense and Respond approach, where
    - A Probe (an intentional disturbance to the system) can make patterns of behavior in the system apparent or more visible
    - Sense in the meaning of finding behavioral patterns by inductive reasoning
    - Respond, in the sense of stabilizing desirable patterns and vice versa destabilizing undesirable patterns
- Use of Multiple perspectives on the nature of the system; because no single perspective is sufficient to fully understand it

- Use of Narrative techniques, as these are able to capture and convey complexities without necessarily being bound by formalism and simplifying assumptions

In acknowledging that water management is in the complex unordered domain, and applying the Cynefin framework, the methodology of the participatory assessment described in this paper is to carry out the following steps:

1. Reviewing the case study
    a. Reviewing literature and context
    b. Interviews with stakeholders based on stakeholder map
    c. Field observations
2. Historical probing: previous strategies and implementations are seen as probes
    a. Mapping the factors and conditions that lead to success or failure of each strategy
    b. Developing network representations that describe these factors and conditions
3. Sensing: based on the analysis of the strategies (i.e. probes), inductive reasoning is used to attempt to understand the patterns of behaviour
4. Social validation. This creates a circular process by feeding back into the review (i.e. step 1) and typically leads to:
    a. Further interviews
    b. Modified network representations
    c. Modified conclusions

As is clear, this is not a linear process, but one of iterative learning and repeated social validation. The output of the process is a combination of stakeholder maps, artifacts (i.e. models), and conclusions based on inductive reasoning. However the social validation is likely to challenge review outputs, hence completing a negative feedback loop (see Figure 3). As in most learning processes, there is no clear stopping criterion, but as per the Probe-Sense-Respond framework the next step is to attempt at stabilizing desirable patterns and destabilize undesirable patterns.

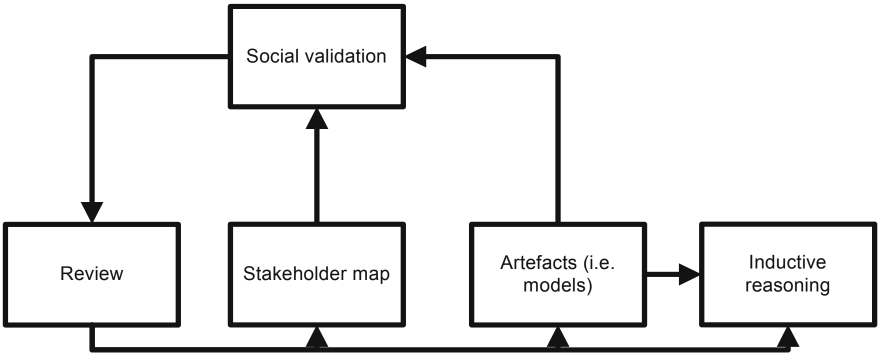

Fig. 3 Participatory assessment as an iterative process of learning and social validation

In terms of information collection a number of sources are used:

- Written material
- Interviews with stakeholders
- Field inspections

4 Reviewing literature and context

Based on previous projects and experiences, there is a much written material in relation to the water system in Tarawa, and some of these sources are described in Table 1.

It is also noted that unconventional sources such as web sites, travel reports or documentaries can be useful in order to generate an understanding of the socio-cultural situation, which is critical in making the most out of stakeholder interviews and field observations. For this purpose, a useful introduction to the situation in Tarawa is provided by a Troost (2004), and Appendix E of an Asian Development Bank report (Asian Development Bank 2004) written to help consultants understand the context of water supply in Kiribati, and the cultural factors that will impact on their work.

Table 1. Key written sources of information on the water management situation in Tarawa

Reference	Description
Crennan, 1998	UNICEF report describing the socio-economic analysis of the situation on the water reserves.
Dray et al, 2006	Journal article describing the development, using Participatory modelling, of a co-management framework for reserves.
Falkland, 2003	Evaluation of water systems and sustainable yields from freshwater lenses in South and North Tarawa.
Kiribati National Statistics Office, 2006	Census for Tarawa and Kiribati
Asian Development Bank, 2004	Report for a major project in Tarawa.
Asian Development Bank, 2000	Community survey.
White et al, 1999, 2005a, and 2005b	Journal and conference articles describing the water management challenges in Tarawa.
WHO, 2006	Compiled data on performance and health indicators for countries, including Kiribati.

4.1 Interviews with stakeholders

Because of practical difficulties in accessing stakeholders, the researchers have had to be pragmatic and flexible in their approach to stakeholder interviews. The following basic approach to interviews, loosely based on convergent interviewing (Dick 2002), was taken:

1. Create an initial map of relevant stakeholder perspectives based on the researcher's understanding of the issues; and supported by existing literature
2. Carry out interviews with individuals that represents relevant stakeholder groups
    a. Introduction
    b. Initiate questions by using open-ended non-specific language to allow the informant to decide what is important
    c. Use probing questions either based on earlier interviews, or pre-prepared to focus in on critical issues
    d. If disagreements are found between informants' statements, explore these further, or challenge disagreements in order to develop a deeper understanding

3. Evaluate and update map of stakeholder perspectives
    a. What other type of stakeholder have been mentioned in interviews?
    b. What are the agreements?
    c. What are the disagreements?
4. Evaluate completeness of the perspectives, and whether understanding of agreements and disagreements has been achieved for a particular perspective. If not, return to 2).
5. Approach a stakeholder with the representation of the issues at hand as developed by the researcher, in order to socially validate the representation

Table 2. Stakeholder perspectives explored

Wide category	Sub-category	Examples
Interventionists	Funding agencies	AusAID, NZaid, Asian Development Bank, European Commission
	Overseas experts	Academics, consultants, health professionals
	Foreign governments	Australia, New Zeeland, China, Taiwan
Community	Landowners	Reserve land owners
	Business owners	Hotel and restaurant owners Industrial company owners
	Households	Squatter households, semi-urban households
	Community leaders	Religious leaders, Traditional leaders
	Community groups	Sports teams, Religious groups
Local capacity	NGOs	FSP, KANGO, Women's Federation
	Water utility and related organizations	Public Utility Board Water Engineering Unit
	Ministries	Ministry of Health Ministry of Environment
	Operators & staff members	Treatment plant operators Community education staff members
	Regional organizations	South Pacific Applied Geoscience Commission

Table 2 shows a map of stakeholders that was used to identify the relevant perspectives.

5 Field observations

Field observations provide current and contextual information that is sometimes necessary for understanding the context. Such field observations involve visiting locations, recording conditions and inspecting technology. For instance, when visiting the existing water reserves in Tarawa, a number of observations could be made such as the presence of burial grounds on the reserves, as well as torn down fences and sand mining.

5.1 Bayesian network diagrams

Factors that impact on the chances of success for developments can be illustrated using networks, where each factor is represented by a node, and an inter-relation between factors is represented by a directed arc between the nodes. If all factors can be in only one of two possible states, i.e. on or off, and if the inter-relations between factors can be described using logical formalism, then the network is a Boolean network. If on the other hand, the causal relationships between factors can be described using a probabilistic formalism, then it is usually a Bayesian network.

In the illustrations of development strategies that are described below, there is not yet a defined quantitative formalism describing inter-relations. A logical formalism is considered too simplistic, but a probabilistic formalism is more appropriate due to the uncertain nature of cause and effect relationships. Consequently, the illustrated networks are referred to as Bayesian networks.

Nodes and arcs have been identified using the convergent interviewing method rather than through analysis of transcripts. This is because recording of interviews was deemed to have a potentially negative impact. At a later stage, the networks themselves can be presented to stakeholders, to support social validation. In this way, whilst due to the equifinality principle in complex systems (Richardson 2002) there are several possible representations, the identified representation is at least agreed upon. As per Gershenson (2002), this combines the two methods of dealing with the equifinality problem: 1) use of logical arguments to dismiss theories incompatible with human knowledge, and 2) social validation.

In reality, the causal relationships are dynamically changing, and the networks of conditions that are described in this paper are in fact localized systems with boundary conditions that are part of a larger and more complex network (and this is further explored in a related study).

6 Results: Bayesian networks and Inductive reasoning

As an output of the participatory assessment, networks of relevant factors for different strategies were identified. Figures 4 – 6 show Bayesian network diagrams representing the conditions necessary for successful implementation and operation of three investigated strategies: “Chlorination”, “Desalination” and “Reserves extensions”. These diagrams ought to be read in the following manner:

- Each circle represents a condition or a strategy
- An arrow represents a causal relationship between two circles. These causal relationships can not always be easily described using logical formalism (i.e. using AND, OR, etc)
- The color of circles represent the extent to which these conditions have been achieved
  - Yellow circles represent success
  - Red circles indicate failure
  - Grey circles indicate an uncertain outcome

These strategies / probes are now described below.

6.1 Chlorination

Because of considerable contamination of the freshwater being pumped to urban Tarawa, this water needs to be adequately treated before distribution to customers. For this purpose, two Chlorination plants have been operated efficiently and usually with a high reliability, and as such, this is an example of a relatively successful centralized solution. Figure 4 shows a network diagram describing the conditions for operation of the Chlorination plants.

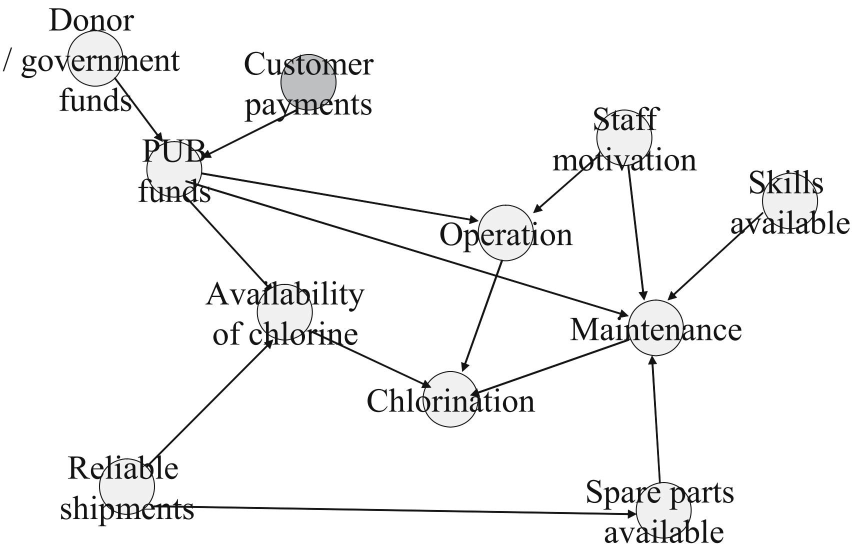

Fig. 4 Network of conditions necessary for Chlorination of water in Tarawa

6.2 Desalination

Three desalination plants have been installed in Tarawa with a total capacity of about 200 m^3 per day. This marginal but significant contribution would provide a supply not reliant on rainfall. A disadvantage of desalination is that it is relatively expensive due to costly maintenance and reliance on fossil fuels for energy supply. Figure 5 describes the required conditions for successful desalination:

- Availability of fuel typically imported via shipments and paid for by the water utility.
- Customer acceptance of the water provided to them. It is believed that customers will accept drinking desalinated water despite an unusual taste, but the cost of water is higher and customers may not be willing to pay a higher price for their water services.
- Maintenance of the desalination plant, which in turn requires availability of:
    - Skilled and motivated staff. The required skill levels are higher than for operating a chlorination treatment plant. However, as desalination is not a core activity of the water utility, the commitment is not consistently given highest priority.

- Specialized spare parts. In Tarawa, this was a critical vulnerability because of difficulties in sourcing spare parts from the supplier.

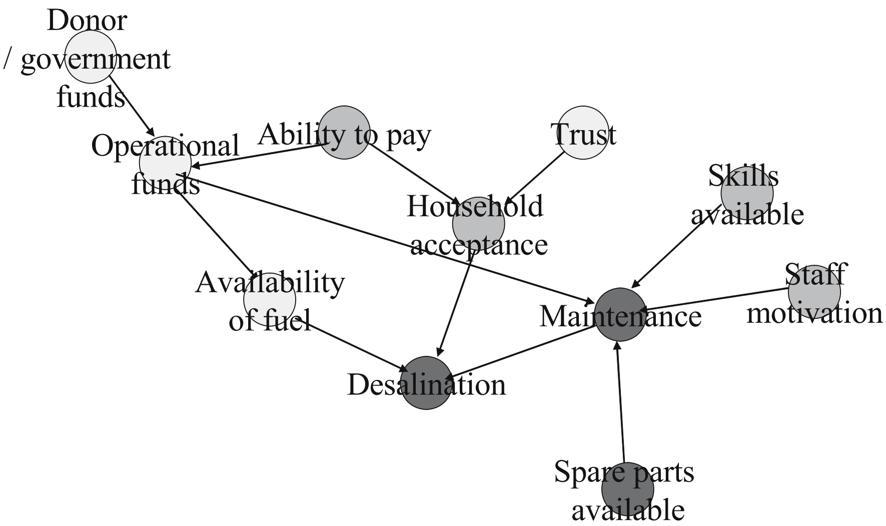

Fig. 5 Network of conditions necessary for Desalination of water in Tarawa

As indicated in the diagram, this project failed mainly because of the difficult maintenance, and perhaps because of limited organizational capacity.

6.3 Reserves management

The primary freshwater source for Tarawa is the groundwater pumped from the urban periphery where water reserves have been established. With population increases, Tarawa faces the need to further increase the supply, and work has initiated to set up another two major water reserves. This was done despite the considerable concerns with the existing water reserves, including:

- Disgruntled land-owners and expensive land-lease payments. In addition to the important symbolic cultural value of land, land-owners have reduced opportunities for subsistence living
- Severe pollution on the reserves related to blurred land-ownership. The government response of fencing reserves has repeatedly failed

In the spirit of Ostrom (1990, 2004) and Berkes (1989) a co-management framework was established for the water reserves through the AtollScape (Perez *et al* 2003) and AtollGame (Dray *et al* 2006) projects. However, for political reasons, the water utility (the PUB), and the parliament have decided not to follow this path and consequently land-owners are not accepting further reserves extensions. In other words, this project is in a political stale-mate despite already having installed most of the infrastructure.

Figure 6 describes the required conditions for successful reserves extension:

- Installation and operation of infrastructure. This can be achieved given sufficient funds and skills. Skills are already available because the strategy is already applied in Tarawa.
- Landowners' acceptance, which would put the strategy in a much better light, and would avoid making the same mistakes as in the past. For landowners to accept, their situation and demands must be considered in terms of:
    - Space to house relatives moving in from outer islands
    - Funds as compensation, but this is perhaps not a necessary demand
    - Being allowed to collect sufficient amounts of coconuts, firewood and other essentials from their land
- Water utility acceptance of the co-management framework. This requires a cultural change at the water utility to start to work more closely with the community and share responsibility with landowners

In summary, the limited success of this project was primarily due to the inability to understand and accept the socio-cultural situation; dichotomy between traditional and political decision processes, and a preference by the water utility not to work with the community.

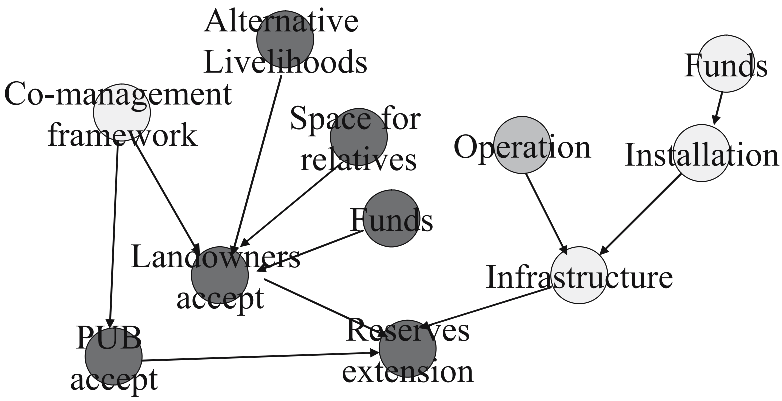

Fig. 6 Network of conditions necessary for Reserves extension in Tarawa

7 Lessons

The lessons based on inductive reasoning are outputs from the participatory process. Identified failures of the described strategies (as well as other strategies that are not described here), were generally agreed by stakeholders. Based on this, two key lessons emerge that reflect the observations made in the United Nations Water Development report (2006) previously referred to; i.e. lack of consideration of:

- Social and cultural issues. Developments need to consider the local socio-cultural context but there is often limited capacity for this locally, and outsiders can only facilitate. This was the case within the Reserves extensions project.
- Local organisational capacity for engagement, maintenance and operation. Developments need to consider and foster local organisational capacity. This was the key concern within the Desalination project.

It appears that there is a need for integrated analysis and wide stakeholder engagement, rather than decision making by specialist and experts in isolation; in particular in the early design stages. Unfortunately, there is a serious capacity gap here, because:

- The water utility tends to prefer not to work with the community, and outsiders can only really participate as facilitators, while local NGOs tend to not have a sufficient capacity. There is a critical need for capacity building at local NGOs, and for cultural change at the level of the water utility

- Knowledge and analysis capacities are inadequate due to poor information, system complexity, inadequate knowledge management and vulnerability to staff movements

Another observation relates to the process of project selection, which tends to be political rather than based on practical reasoning. In other words, if projects are to be developed in a participatory manner, what good does that make if they are restructured as part of the political process. Hence, there is a case for handing some decision power to the community, in combination with participatory and transparent processes for project development and selection.

Additionally, there needs to be a flexible project management approach that will allow for adapting decisions in response to surprises and unexpected failures that occur throughout a project implementation. This is in contrast to having strict deadlines, and definite objectives stated in the initial project plan. In particular, the process needs to be stepwise where necessary requirements are in place before making major investments. Such necessary requirements can be mapped as part of the project risk analysis, and Bayesian networks have been identified as particularly suitable for this (Boulanger and Brechet 2005).

8 Respond / Further research

Based in part on this participatory assessment, Moglia (2007b) has suggested a framework of capacity building; modelling to improve knowledge management and decision making; and dialogue, involving wide community representation. To explore how this could be applied in reality, a participatory modelling exercise is prepared based on Agent-based simulation.

Participatory modeling and integrated assessment using Agent-based simulation has been applied in a large number of water related contexts, such as in Jakeman and Letcher (2003), Abrami et al (2002), Barreteau et al (2000), Dray et al (2006), Perez et al (2002), Janssen and Carpenter (1999), Pahl-Wostl (2002c) and Tillman et al (2005). Additionally, it has been identified as a suitable modelling methodology for supporting policy-making in the water area because of its combination of features (Boulanger and Brechet 2005):

- Supporting inter-disciplinary modelling; and not requiring prior mathematical translation

- Allowing for an intuitive representation of agents within their spatial and natural setting; and hence supporting participatory decision making
- Allowing an adequate representation of micro-macro scale relationships; and its ability for taking into account heterogeneity in spatial conditions and agent populations

In line with this, a model called Townscape has been developed based on the UML (Unified Modelling Language) class diagram in Figure 7 which provides a standardized representation for object oriented modelling. This diagram represents key stakeholders and features of the water system in Tarawa and it is to be socially validated by local stakeholders.

Each of the boxes in the diagram represent an object class, such as “Landowner”, “Water utility”, “Water reserve”, “Pipe”, or “Customer” etc. Links represent logical connections between class types, such as association, composition or aggregation. Strategies that are being explored relate in particular to demand management, co-management as well as non-monetary methods for maintaining and operating the system.

More research is also needed in terms of quantifying the probabilistic relationships in the Bayesian networks. By achieving this, the current framework could provide risk assessment tools to be used in planning and evaluation of project implementations.

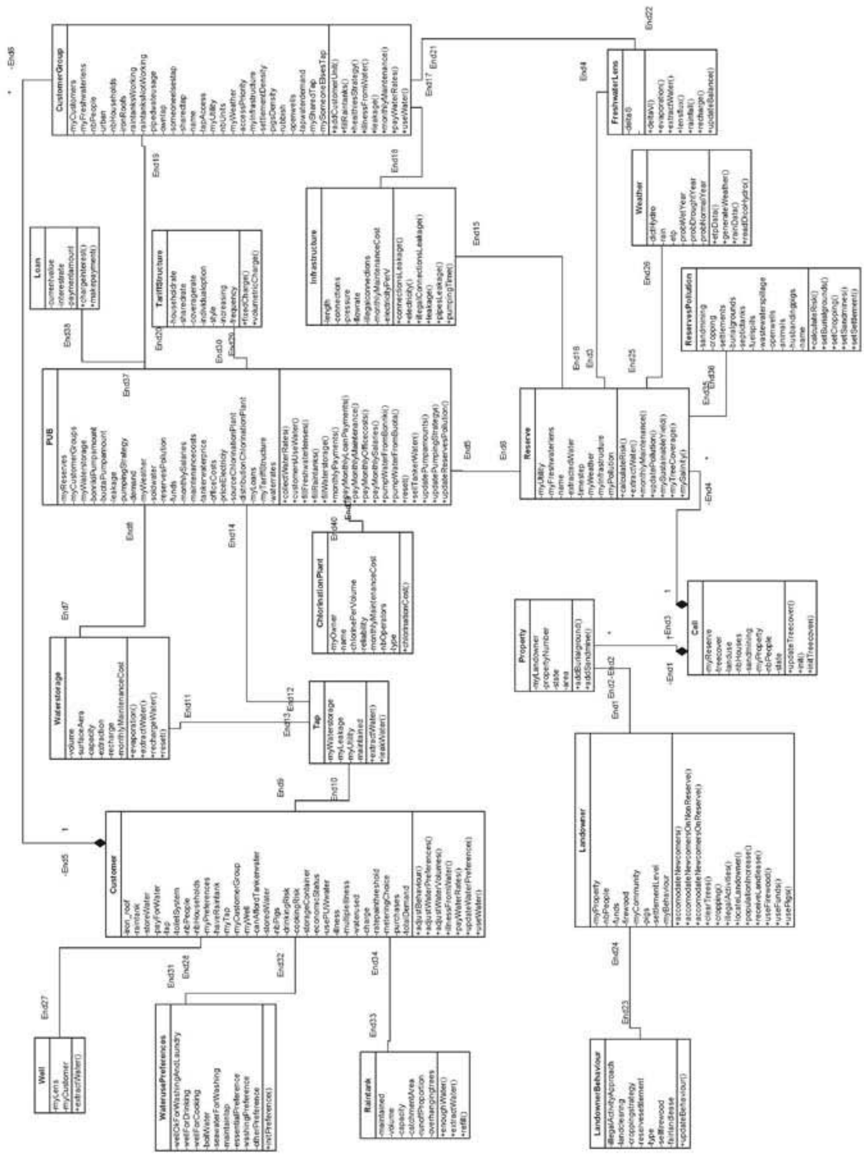

Fig. 7 UML class diagram for the Townscape Agent-based model

9 Conclusions

Based on a review of water development projects in a field study, the findings in this paper reinforce what was identified in a recent United Nations water development report. It is observed that water development projects often fail for lack of consideration of social issues and local organisational capacity. The reasons for insufficient consideration of such issues relate to a combination of compartmentalized thinking and poor capacity for engaging with the community.

In particular there is inadequate community participation in the design stages of projects. However such community participation is often difficult to achieve due to project management constraints, and a complex socio-cultural situation which is almost impossible for an outsider to understand; combined with a limited capacity from the NGOs

Bayesian networks have been identified as a way to describe key factors in implementation and operation of projects. While these are localized networks showing the interactions in a sub-set of the water management system, it also indicates the complexity of the full task. Such diagrams could be used during early design stages to identify and address key vulnerabilities and requirements. Ideally, this would serve to support more adaptive project management, and would tend to highlight the need for stakeholder engagement and consideration of local capacity problems.

It is also argued that because the water management system is in a complex domain of cause and effect, as per the Cynefin framework (Kurtz and Snowden 2003), the approach of probe, sense and respond, learning from history, is suitable and would achieve an emergent practice. To extend the approach of probe, sense and respond, a framework of capacity building, system representation, adaptive management and dialogue is suggested, supported by Agent-based simulation and Bayesian networks.

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Criteria for the Assessment of Planning Processes for Sustainable River Basin Management - Illustration by two cases: the EU Water Framework Directive and ongoing water planning processes in Sweden.

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Abstract

This paper examines a set of criteria for processes that aim to attain sustainable river basin planning at the regional scale. The criteria answer to the lack of deductive methodologies for the assessment and development of participatory approaches to water planning. They are derived from the two concepts and sustainability principles *participation* and *integration*. The criteria are here explained and their use is illustrated by presentation of the results and conclusions from two case studies. The first case concerns an assessment of the EU Water Framework Directive (WFD). - In what ways does the WFD support or obstruct processes for sustainable water management? The second case concerns the ongoing planning processes in Sweden that follow from the implementation of the WFD. The cases show that the criteria work well in achieving their purpose as their use resulted in practicable proposals for taking the studied planning objects closer to meeting the criteria.

1 Introduction

In light of the growing understanding that participation plays an important role in the sustainable planning and management of river basins, new practices and methodologies relating to participation in watershed management are being developed and tested. In the literature on participatory approaches to water management, keys to the promotion of "successful" practice are presented. Such factors include: adequate funding or resources to support the process, the quality of communication and information exchange, team-building (creating trust, respect and honesty between group members), organisation and leadership, and the development of common goals and understanding (e.g. Beierle and Konisky 2000; Leach et al. 2001; Margerum 1999; Schuett et al. 2001; Vari 2004). From these studies it seems that if the group is working well as a group, the broader aims of the collaborative activities will be met as a result. This is not surprising, as participation and co-operation are seen as necessary means for sustainable watershed management (e.g. Barrow 1998; Falkenmark 2003; Loucks and Gladwell 1999 pp 132; Stout 1998; World Water Council 2000). Participation is not however a *sufficient* means for that purpose. Participation is only one of the many principles/dimensions of the sustainability concept needed to steer development in a sustainable direction. In order to judge whether a participatory effort does contribute to a sustainable development or not, the scope must be broadened. More deductive approaches, that go beyond participants' perspectives and objectives, would also be necessary (Conley and Moote 2003).

A set of normative criteria for the assessment of participatory planning processes for river basin management at the regional scale has recently been proposed by the current author (Hedelin 2007a). Instead of focusing on participation alone, the criteria broaden the scope by including one more sustainability principle: integration. In addition to participation, this principle is by far the most referred to by current water professionals, academics, and other experts (e.g. World Water Council 2000; SIWI 2002). In this paper the criteria are explained and their use are illustrated by application to two cases The first case concerns the EU Water Framework Directive (EU 2000), which is currently being put into practice in all member states[1]. The WFD is an important contextual factor that steers planning

[1] The Directive (WFD) is extensive and prescribes not only organisational criteria for water administration, but also the tasks that should be performed and detailed instructions for the work. One such task that follows from the WFD is the development of regional river basin management plans. The WFD points out

processes through out Europe. The second case concerns the ongoing planning processes in Sweden, which result from the implementation of the WFD.

2 Method

In this paper, the proposed assessment criteria will only be summarised very shortly, as a detailed account of the criteria, and of how they are derived, are presented in Hedelin 2007a. The assessment criteria will rather be explained here from a meta-perspective, focusing on the ideas connected to the use and further development of the criteria. The criteria were derived through a synthesis[2] based on a broad literature review. Focus was placed on how, methodologically, to achieve participation and integration in a planning process for regional water management.

Results and conclusions from two case studies are used to illustrate the practical use of the assessment criteria. Thus, the focus is put here on what the cases can tell about the criteria. For a counter-perspective, see Hedelin 2007b and 2007c. As the criteria are thought to be useful both in relation to planning processes and to their contexts (as described in the next section), one case of each type are used to illustrate the use of the criteria. In the first case study – the assessment of the EU´s Water Framework Directive - each criterion were analysed in relation to relevant parts of the legislative document itself (EU 2000). In the second case study – the assessment of ongoing planning processes in Sweden – key persons responsible for the planning in one of the five Swedish Water districts were interviewed. 25 interview questions had been constructed based on the twelve criteria. One question also concerned the planner's view on the criteria. In this way, it was possible to assess if the scope of the criteria matched the scope of the planning process as the interviewed planners perceived it. All together, 13 semi-structured interviews were performed, which each lasted between 1 and 2 hours. This second case study is still ongoing and the results pre-

participation as a key principle for the planning processes that follow from its implementation. For a detailed description of the WFD, see Chave 2001.

[2] The production of a synthesis entails the integration of the relevant areas of a literature into a new whole (Kirkevold 1996). Rather differently from a traditional review however, a synthesis claims to present connections that have not previously been made (*ibid.*).

sented here are preliminary. (Additional results will be presented at the CAIWA conference.)

3 The Assessment Criteria

In this section the criteria are first presented very shortly, as summarised in Table 1. Focus is then put on explaining the ideas behind the use of the proposed criteria. For a full presentation of the criteria and an explanation of how they are derived, see Hedelin 2007a.

Table 1. Outline of the assessment criteria. The criteria are derived from either one of the concepts of integration or participation, which are two key dimensions of sustainable development of rivet basin management.

Criteria Planning methodologies/processes for sustainable river basin management must include, support or promote:	
A	Integration of knowledge from all relevant disciplines.
B	Handling of different views of knowledge (e.g. positivist, relativist).
C	Handling of different kinds of uncertainty.
D	Identification of the most relevant values.
E	Rational argumentation based on the identified values, relating them to alternative choices in the planning process.
F	Inclusion of knowledge owned by relevant actors.
G	Inclusion of the ideological orientations represented by relevant actors.
H	Participation in the most critical phase(s) of the process.
I	A procedure for defining the actors that should be involved.
J	Handling of power asymmetries.
K	Procedures that ensure that ideological orientations are not suppressed (for consensus-based processes).
L	Learning.

Criteria A to E are derived from the concept of Integration. They are based on the idea that integration can be obtained across the areas of disciplines (A to C) and values (D and E), as proposed by Jepson Jr. (2001). Criteria F to L is directly linked to participation. According to Hemmati (2002), Participation mainly relates to two objectives: increasing the quality of decisions and generating commitment, legitimacy or acceptance. Criteria F to G are mainly derived through looking at the first objective while criteria H to L mainly relate to the last objective. The criteria connected to participation are much influenced by current thoughts on deliberative democracy.

The overall aim of the criteria is to act as a tool to relate different water planning processes to the concept of sustainable development (SD). Researchers can use the proposed criteria to analyse existing planning methodologies, or for development. Researchers and practitioners together could, as in action research, use the criteria as theoretical framework for developing specific planning models and efforts. Alternatively, persons responsible for setting up a planning process can use the criteria to check that the most important aspects are considered, or to evaluate a completed process. In addition, the criteria can be used in relation to the context of the planning process at hand (e.g. the national legal system, related organisational settings, civic culture, the professional culture at the responsible authority, and the national democratic system). Participatory processes are highly dependent on the context in which they are embedded, and must be understood in the light of these contexts (Carpini et al. 2004; Lane 2005). For a process to be successful in terms of sustainability, its context must support, or at least not obstruct, certain ways of working.

It is the ability to explicitly relate water planning processes and their contexts to the concept of SD that is the main idea behind the proposed criteria. Systematic ways to relate to the concept are rare both in research and in practice. Expressions of hopes or intentions that a certain activity will contribute to SD, or an explanation of the definition or the view of the concept that are thought to be consistent with the activity are common. If no explicit links between such intentions or definitions and the activity in question are provided, how can one be sure that the activity (e.g. a water planning process or a legislation) actually is congruent with SD? The proposed criteria and the ideas behind their development show a possible way of working for answering to this problem. Presumably, this methodological approach could be applied not only to the area of water planning, but to all areas that one wish to relate to the sustainability concept. The point of departure is the sustainability dimensions or principles that are adopted by the scientific community[3], e.g. the precautionary principle, participation and polluter pays principle. Identification of a system of principles that

[3] By means of a literature survey, I have identified seven dimensions or principles for sustainable development as being recognised by the research community: The use and the distribution of resources, the use of management approaches that are based on participation, that are holistic/integrative and strategic and future-oriented with long time perspectives, and adopting the precautionary principle and the polluter pays principle (e.g. Bellamy et al. 1999; Berke 2000; Costanza et al. 2000; Daly 1990; Gudmundsson and Höjer 1996; Jepson Jr. 2001; Wagner et al. 2002).

should be the basis for the approach can be seen as a first step in using the proposed approach.

In the simplest form of the methodological approach (model), the SD principles are used themselves directly to analyse if a certain sustainability issue is in line with SD. Gudmundsson and Höjer (1996) have done this for the area of transport and Karlsson (2003), has done it for the area of genetically modified organisms. But since the principles are very general, it may be useful to *operationalise* the principles, as in the case with the proposed criteria for water planning. The framework for measurement then gets more easy to use as it provides "indicators" describing the conditions that should be met in order to fulfil a certain principle. (E,g. the criteria C-handling of different kinds of uncertainty – could be seen as an indicator for the principle of integration when the SD issue is planning processes for regional water management.) One could see it as if the accuracy of the measurement increased. But in order to increase the accuracy above the level of what is provided for by the SD principles themselves, the sustainability issue must be more specified. The principles themselves are so general that the issue they are valid for are not even defined at all (the world and everything in it). For developing the proposed water planning criteria, the sustainability issue was defined as processes for regional water planning, as described in the method section.

But the proposed criteria are still relatively general. They provide little help in designing specific water planning processes: –Which are the most important uncertainties, and how should they be handled? -Who are the main actors, and in what ways should they be involved in the process? How should power imbalances be handled? There are two main ways to proceed in getting more specific according to the proposed model. For both ways, the issue must be defined in more detail, e.g. from regional water planning in general to regional water planning in Sweden. The first way is to develop the criteria further. This could generate more detailed guidelines for how to meet the criteria in the Swedish context. These could be established by the newly set up water administrations and used by the planners that are responsible for the practical work. This way of working within the model framework is called a *from above approach* (Fig 1.). The other way of proceeding would be to use the derived criteria to set up a specific planning process. One could imagine planners and researchers working together in a project of action research character, looking at how the criteria could be met in the particular case. This way of working would according to the model be a *from below approach*.

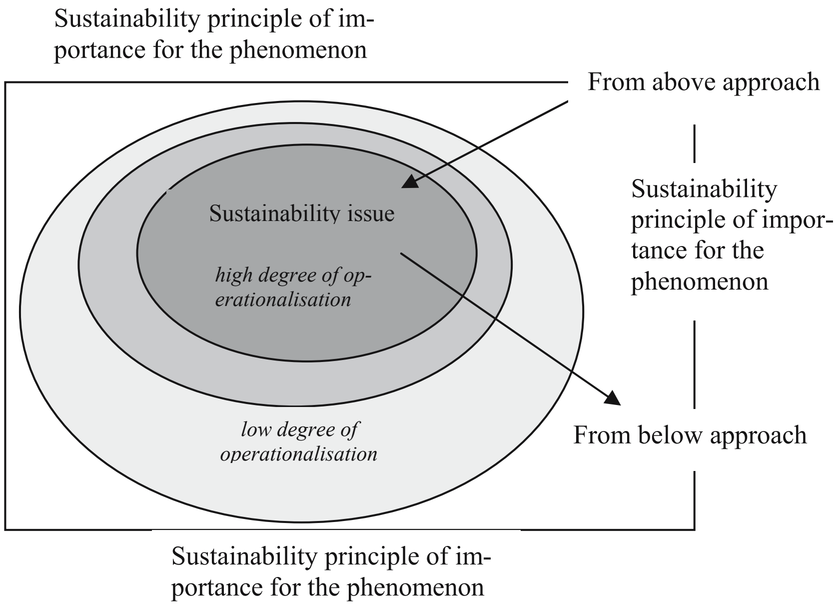

Fig. 1 Model (methodological approach) for the operationalisation of the concept sustainable development in relation to a sustainability issue, e.g. regional water planning. As the framework set up by principles, critera or guidelines gets more specified or applied, the level of operationalisation of the principle increases. Accordingly, the sustainability issue needs to be more specified as the level of operationalisation increases.

The model suggests that there are general SD principles that are more or less relevant for the sustainability issue in focus. It is reasonable that the relevance would vary with the strength of the connections between a certain issue and a principle. In order to be in line with SD it is also reasonable that the issue is not on opposition of any of the SD principles. To make sure that this is the case, it would be necessary to include all the SD principles in the operationalisation in relation to any issue. The reason for not doing so in the development of the proposed criteria is practical. Including all principles would have been an overwhelming task. In order to make the work practicable, two of the seven SD principles were selected as point of departure for the proposed criteria. In general, practical circumstances often limit the scope of research efforts. A very important first step in working according to the model is therefore to carefully select the SD principles that should be the basis for the work. As the work proceeds it must be characterised by openness in relation to knowledge and experiences that point at reassessing the choice of principles. Basing the criteria on only two principles, as in the case of the proposed criteria, it can be expected that the criteria framework will need to be developed further.

The choice to use the principles participation and integration as points of departure for the curernt work is explained in the introduction. One additional argument is that the principles can be divided into either “state”/”what” or “process”/”how” kind of principles. See Table 2. As the SD issue the proposed criteria are aimed for is in fact itself a process, it seemed rational to choose from the principles of process character. The proposed model rests on the assumption that a process that answers to the criteria derived from the process principles could (and in the long run would) result in a plan that answers to the state principles. It would be highly problematic if that would turn out not to be the case. That would indicate that the generally adopted sustainability principles are inconsistent. Some might also draw the conclusion that the state principles must be favoured in relation to the process principles in such a situation. One could agree that long term access to drinking water (which is consistent with sustainable use of resources) is more important than for example democracy (which is consistent with participation). However, the methodological model rests on the assumption that it is possible to live in a world that does not conflict with any of the sustainability principles.

Table 2. The identified sustainability principles. The principles can be devided into either “state”/“what” principles or “process”/“how” principles.

Principles of “state” or “what” character	Sustainable use of resources Distribution of resources globally and over generations
Principles of “process” or “how” character	Long time perspective, strategic Holistic, integrative Participation Polluter pays principle Precautionary principle

4 The WFD – support or obstacle for processes for sustainable water management?

The general aim of the EU Water Framework Directive is to achieve “good water status”, which is defined as “a state where the deviation from a water’s pristine state is small”. The WFD also claims however to provide new tools for sustainable water use. In order to render these ideas operational, the WFD provides detailed instructions in relation to the carrying out of several tasks. In short, the main tasks include a characterisation of the river basin district including an economic analysis. Based on the characterisation, environmental objectives should be defined for each water body and a Programme of measures should be established, including the actions needed to attain the objectives. A thorough prescription of monitoring activities is also given. Finally, a River basin management plan should be drawn up for each district, in relation to the documentation and presentation of the work undertaken. These tasks are part of a cyclical process on a six-year basis, with the first Programme of measures established before the end of 2009.

In a recent study the current author used the proposed criteria for assessing the WFD. The aim was to understand in what ways the WFD - as a context that strongly influences national water planning - supports or obstructs planning processes for sustainable water management. In this paper the results and conclusions from that study are described for the sake of illustrating the use of the criteria. There is not however room here for a detailed presentation of the analysis that supports those findings. The reader who is interested in that analysis is directed to the article that presents the assessment study itself, see Hedelin 2007b.

The result from the assessment of the WFD i summarised in Table 3. The results show significant deviations between the WFD and the assessment criteria, covering the entire criteria spectrum. In fact, the WFD does not deliver unbridled support to any of the twelve criteria outlined above. The analysis undertaken has even revealed the existence of a potential barrier to effective participation (H), as the participants have little influence on the environbmental objectives that will steer the work.

Table 3. Summary of results from the assessment of the WFD.

	Criteria	Treatment in the WFD	Comment
A	Integration of knowledge from all relevant disciplines	Partial support, no formal barrier	New and existing knowledge will be gathered and collated. Mainly natural sciences are requested.
B	The handling of different views of knowledge	No support, no formal barrier	The issue is not handled.
C	The handling of different kinds of uncertainty	Partial support, no formal barrier	Precautionary principle mentioned and applied in part. Implicit strategy to collect information.
D	Identification of the most relevant values.	Partial support, no formal barrier	Economic valuation is encouraged.
E	Rational argumentation based on the identified values, relating them to alternative choices in the planning process.	Partial support, no formal barrier	The use of economic tools for decision support is encouraged. No other methodologies are encouraged.
F	The inclusion of knowledge owned by relevant actors.	Weak support, no formal barrier	Vague pronounced intention. Nothing on how. Focus on publication procedures.
G	The inclusion of the ideological orientations represented by relevant actors.	Weak support, no formal barrier	Vague pronounced intention. Nothing on how. Focus on publication procedures.
H	Participation in the most critical phase(s) of the process.	Weak support, partial barrier	First publication three years before final plan. Focus on publication procedures, i.e. reacting to proposals. General objectives already set.
I	A procedure for defining the actors that should be involved.	Weak support, no formal barrier	Prescribes that all concerned should be encouraged to participate. The river basin as administrative border. No procedure for identification of actors. Nothing on non-human species or future generations.
J	The handling of power asymmetries.	No support, no formal barrier	The issue is not handled
K	Procedures that ensure that ideological orientations are not suppressed (for consensus based processes).	No support, no formal barrier	The issue is not handled
L	Learning.	No support, no formal barrier	The issue is not handled

The table shows how each criterion from is handled in the WFD. The WFD neither provides much support for processes of sustainable river nasin management, nor puts up any formal barriers to such processes.

It is obvious that stronger support for the twelve criteria would have been desirable. The analysis can provide a number of hints both as to how such support could have been provided, and what kinds of formulations that are lacking. Some important examples include, the request for the better use of knowledge from within the social sciences and the humanities (A), the request for a procedure to identify the main values connected to water in the specific district (D), and a formulation that highlights the importance of how best to engage the concerned parties in respect of democracy (I-L). One way to make up for the missing formulations pointed out would be to develop a supplementary directive to the WFD. Parts of the CIS guidance documents, e.g. the one conterning participation, could be important constituents of such a directive. Grimeaud (2001) also points to the fact that further specifications would have strengthened the possibility to put in place an efficient and sustainable water policy in the EU. An attempt to complete the legal framework would probably now be the most effective way forward as all member states would be affected.

Moreover, the analysis also revealed that no formal barriers to processes of sustainable water management are put in place by the WFD (except for that already mentioned above). Therefore a genuine possibility to design water management processes that answer the basic sustainability intentions of the WFD remains. Through focusing on the areas identified in the assessment (described in detail in Hedelin 2007b), it is possible to design the planning process so that the lack of support and the potential barrier can be successfully negotiated. Thus, in order to compensate for the problem related to participation and goals that are set in advance, concerned actors could be engaged in a systematic process that undertakes to identify the exceptions to the general objectives. The WFD allows for such exceptions under certain circumstances. This raises an opportunity to influence the process agenda.

Furthermore, while the WFD focuses on the natural sciences (A), and the natural science approach to handling knowledge (B and C), a responsible authority can also choose to engage experts from the humanities and social sciences in the process. While the WFD focuses on neo-classical economic ways of handling values (D and E), other methods for integrating all relevant values into the planning process can be used in parallel. The WFD focuses on publication procedures though the water authorities are free to use other methods to engage the concerned parties such that their perspectives and knowledge can be better integrated (F, G, H). And finally, it is of course possible for a responsible water authority to make an effort to design a democratic participatory process (I, J, K, L), taking advantage of the vast literature in this field (e.g. Hemmati 2002; Forester 1989, 1999).

5 Ongoing planning processes in Sweden – processes for sustainable water management?

Water administration in Sweden is strongly affected by the WFD, which has been under implementation for some years now. According to the WFD, geographical boundaries for administration should be based on river basins. In Sweden, there are now five large Water districts, each draining into one of the major sea basins around Sweden. A Competent Authority responsible for putting the regulations into practice has been appointed for each District. These authorities are called the Water authorities. The practical planning tasks however are carried out at the sub regional county administrations, generally by persons within the environmental offices. Most of the work so far has been focused on mapping and classification of all waters. For further description and discussions on the new water administration in Sweden, see Hedelin 2005, and Emmelin and Lerman 2004.

Although the regulations of the WFD affects the work much, there is still large room for each member state, responsible authority or individual planner to influence how the prescribed tasks are carried out, as pointed out in the first case study. The assessment of the ongoing planning processes in Sweden shows how the planners - who hold both the responsibility of carrying out the tasks of the WFD and the possibilities that follows with it, in their hands - look upon their work in relation to the criteria. Both managers of the Water authorities and planners at the sub regional county administrations were interviewd. Here, results from a preliminary examination of the interview data are presented, with a preliminary over all conclusion. For a detailed account of the asalysis and results, see Hedelin 2007c.

The preliminary examination points at important differences between the criteria and the studied planning processes. One likely reason, limiting the fulfilment of the criteria, is the unbalanced handling of criterion A (integration of disciplinary knowledge) as it can be expected to influence the relation to many of the other criteria. Currently, disciplinary knowledge from natural sciences is clearly dominating the process. In terms of the employee’s educational background, there is an evident predominance of the natural sciences over the social sciences and the humanities. This fact has a great influence on how the water planning mission is understood and performed. Knowledge on theories and methodologies in relation to participation is limited to personal and professional experience, since such knowledge is not a part of the employee's scientific background. In the political process that the work actually represents, the importance of scientific knowledge on how to work with values[4] (criteria D to F) and how to create forms and ways for participation and collaboration (criteria F to L) is clearly underestimated. Lack of this kind of knowledge is evident according to data. As a consequence, the main objectives behind participation –contributing with knowledge and perspectives t the process, and creating legitimacy, acceptance or engagement – are actually at risk.

One reason for the total dominance of the natural sciences experts could be that the main tasks at this early stage of the planning process (characterisation and classification), mainly require different kinds of natural sciences expertise. To employ more personnel require more resources, and to change personnel is practically difficult. It might therefore be difficult to adjust the competence at staff level to what is most needed at the different stages of the process. All occasions for employment should be seen as chances to adjust the competence of the engaged personnel to fit the competence required for *all* stages of the planning process.

During the interviews however, many highlighted the importance of knowledge connected to participation (mainly concerning how to communicate with concerned actors). Many of the employees had taken a short course on environmental communication. Further, some co-operation projects with researchers within different areas of the social sciences and the humanities are running. Such researchers are also involved in reference groups that advice and support the planners, mainly at the super-regional level. This is evidence of the fact that the planners, despite their academic background, take an interest in both knowledge from other disciplines and in issues of participation.

Another positive sign, connected to the issue of knowledge, is the general approach to uncertainty (C). Various kinds of uncertainty are being recognised as important issues by the respondents. It seems that the way to handle this problem is to see the first, or even the two first, planning cycles as test cycles. As regional administrations are given great freedom to shape the practical work, a large bank of examples to learn from will evolve over time. Even if the water administrators generally lack the scientific knowledge on many of the fields that are relevant for their work, learning by doing could be an important strategy. This strategy need to be complemented however with the development of systematic communication with re-

[4] Besides the knowledge required for the cost-benefit analysis requested by the WFD.

searchers or other experts that cover the whole spectrum of needed knowledge, in order to create robust feedback mechanisms.

Concerning the respondent's perceptions of the scope of the criteria, the main part of the respondents said that they thought that the interview covered the most important issues of their work. A few respondents mentioned that issues connected to the function of the organisational system had not been covered. Two respondents thought that the interview had not dealt with the issue of sustainability (!).

6 Conclusion and discussion

In order to assess the usefulness of the assessment criteria, their ability to measure the relationship between the criteria and the studied planning process/context is important (- Does the planning process/context work in line with the criteria or does it fail to meet some of them? – Which?). To be of more practical use, the assessment should also lay the ground for suggestions and proposals on measures that would improve the management effort.

6.1 Deviations from the criteria and suggestions for improvement

The result from the case studies shows that one could surely wish for more from both the WFD and the ongoing planning processes in Sweden, concerning their fulfilment of the proposed criteria. Even if that conclusion is important, it is not very supportive and it might not be very constructive. When making an over all assessment it is therefore useful to make a comparison. E.g. how has the legislation or the process evolved over time? - Does the WFD and its implementation, however far from meeting the criteria, represent an improvement? (Many has found that the WFD actually represent progress in different ways (see Flynn and Kröger 2003; Grimeaud 2001; Hedelin 2005; Howe and White 2002; Kallis and Butler; 2001).)

To set up processes that meet all the criteria is, even in theory, difficult. In reality, many factors make such ways of working nearly utopian. E.g. as Flyvbjerg argues: rationality and power are generally in opposition, and unbalanced power relations will always exist in a planning situation (Flyvbjerg 1998). Thus full rationality, which is a basis for deliberative (and participatory) processes according to Habermas, is almost impossible to obtain. In practice, all participants neither have the full, or the same level of, understanding of the issue. They also have varying monetary resources and only some have administrative power. Under these circumstances, equality in terms of power is not a small issue.

It is thus very difficult to set up processes that meet all the normative criteria (as supported by the findings in the case studies). - What does this say about the criteria then? Well, that depends on the ability of the criteria to work as a tool to for developing planning efforts to come closer to meeting the criteria. If they can not, the criteria is mainly useful as an indicator that can be used to assess trends and changes. If they can, the criteria have a potential to be more constructive. The results from these case studies imply that they indeed can be useful for identifying important and practicable measures. In the first case, a number of measures covering the whole criteria spectrum were suggested. If these measures would be performed with some enthusiasm and with some addition of resources, one would come a long way closer to meeting the criteria. Adding some formulations to the legislation is not impossible. Engaging experts from all relevant disciplines in the work should be feasible. Using complementary methods for handling values (e.g. Multi-criteria methodologies) and carefully selecting forms and methods for engaging concerned actors is not unreachable.

The second case generated an over-all advice: to balance the competence base for the work by engaging experts from relevant areas of the social sciences/humanities. Either by employment or by creating a learning system, where the current staff (which mainly represents the natural science part of the needed competence) can learn from the experience of the ongoing work, and from input by social sciences/humanities experts engaged from outside. If this advice, which is certainly practicable, is taken seriously, the work would do better in relation to many of the criteria. The two cases thus shows that the criteria are not only useful for indicating the relationship between the criteria and the planning process/context, but also as a tool for developing these in the right (sustainable) direction.

6.2 Planner’s view of the criteria

A remaining question concerns the development of the criteria themselves. The interview study provided an ”outside” perspective on the criteria. Asking the respondents directly about their view of the criteria makes it possible to assess important issues: - Are the criteria based on the most important sustainability principles (in relation to the current phenomenon)? - Do the criteria need to be complemented with issues that fall within the scope of the selected sustainability principles? - Are some of the criteria less relevant?

The main part of the respondents thought that the most important issues in relation to their work had been covered during the interview. This suggests that the criteria actually cover the main aspects. The comments about the organisational system however, suggest that the criteria need to be complemented. During the original derivation of the criteria, organisational aspects were found to fall within the concept of integration, which should be thought of across four dimensions: actors, organisations, values and disciplines (Jepson Jr. 2001). For different reasons, the organisational aspects were given less priority than the others when the criteria were derived. From the interview study however, it seems that further work with development of the criteria must concern how the various organisational aspects of natural resources management can be integrated to the criteria framework.

Two of the respondents thought that the interview had not covered issues of sustainability. This shows that these respondents have a view of what aspects that are relevant for processes for sustainable water management quite different to the view represented by the criteria. - Are the criteria derived from sustainability principles that are inappropriate then? The criteria are based on sustainability principles that are of a process rather than a state character (see Table 2). The respondents might have expected more issues concerning the sustainable use and distribution of water resources, e.g. definition of the sustainable withdraw from a specific water body, or a scheme for allocation of water from an aquifer. The main reason for basing the current criteria on principles that are of a process character however, was that planning/management is in fact a process. The SD principles that characterise a state would, according to this line of thought, be better suited for analysing the resulting plan.

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Portfolio optimisation of water management investments

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Abstract

Typical water management or natural resource management decision problems require decision makers to select a subset of available decision options that return a maximum benefit whilst satisfying limiting constraints, usually a budget constraint. This optimisation problem becomes increasingly difficult to solve if uncertainty aspects are being considered and/or as more decision options are included. To tackle this selection problem the multi-criteria analysis tool (MCAT) which contains both multi-criteria functionality and solution methods was developed. The benefit scores for the decision options are computed with the well known compromise programming technique. To optimise the selection of options subject to the constraints, two heuristics, namely Local Search and Tabu Search were coded. MCAT was primarily developed to optimise water management decision making in Australia. However it can also be used to solve a range of other decision problems in natural resources management as well.

1 Introduction

In natural resources management many decision problems consist of more than just selecting the best management option out of a set of available options. Very frequently an optimal subset of options is sought to return a maximum benefit. However, management options are usually associated with costs and the selection of an option will heavily depend on its benefit cost ratio as well as on the available budget.

In all fields of natural resources management the selection of an optimal portfolio of decision options is of increasing economic significance. Governments all over the world are spending billions of dollars for nature conservation or waterway health improvements and are in need for transparent decision support tools that help to optimally allocate these expenditures.

The problem to select an optimum portfolio of options is comparable to a backpack which has to be filled such that all items being packed in it represent an optimum portfolio where the volume of the backpack is the constraint. In operations research this combinatorial problem is commonly known as the knapsack problem (KP). There are a wide range of applications for the knapsack formulation, including a) selecting a set of projects to produce the highest profitability given a total budget constraint b) selection of skills to maximise output given total salary budget or c) loading cargo onto a ship with a fixed capacity.

Though the mathematical formulation of the KP is simple, such combinatorial problems can be computationally intensive when the number of decision options is high. While the use of complete enumeration methods may turn out to be slow for larger KP problems a quicker solution is the use of algorithms based on meta- heuristics which do not determine a mathematically proven optimum but approach an optimum fairly quickly.

While meta-heuristic algorithms help solve the combinatorial problem with a given (budget) constraint it needs to be combined with Multi Criteria Analysis (MCA) to accommodate the multiple benefits associated with each option. Traditional benefit cost analysis requires the assignment of monetary values to every issue involved in the analysis which is difficult if social, ecological or historical issues are involved (Acreman, 2001). It seems therefore more favourable to use wider decision making approaches such as a MCA framework. To widen its applicability, the multi criteria analysis tool (MCAT) therefore implements a MCA framework. Out of the great variety of available MCA methods it was chosen to use compromise programming (CP) introduced by Zeleny (1973). CP is mathematically not too complex and it has proven its efficiency in a variety of applications across water management and natural resources management problems (e.g. Shiau and Wu, 2006; Abrishamchi et al. 2005; Duckstein and Opricovic, 1980). In this paper we use recent case studies of a natural resource management and a water management problem where optimum portfolios of decision options were derived with MCAT. We show how the proposed multi criteria knapsack can be effectively used to provide a transparent and effective means of overcoming complexity in some decision making problems.

2 Compromise programming

Compromise programming introduced by Zeleny (1973) uses ideal values, both positive and negative ideal values, as reference points. It is assumed that the choice of a decision option depends on its distance to the ideal values for each criterion. Hence the closer a decision option is to the ideal, the higher its utility.

In the conventional compromise programming we define u_j^- as the disutility of option j, which is calculated as:

$$u_j^- = \left[\sum_{i=1}^{m} w_i \left(\frac{f_i^+ - f_{ij}}{f_i^+ - f_i^-} \right)^c \right]^{1/c} \quad (1)$$

where:

f_{ij} = the score of option j against criteria i.

f_i^+ = the best score (or ideal/target score) for criteria i and f_i^- = the worst (or least ideal value) for criteria i. c is a parameter that reflects the importance of maximal deviation from the ideal solution. w_i is the weight for criterion i, m is the number of criteria.

Where possible f_i^+ and f_i^- can be set to ideal and anti-ideal values, and may be threshold values given in legal guidelines. Where no such ideal or anti-ideal exists, they may be drawn from within the evaluation matrix in terms of the minimum and maximum values across the options.

Compromise programming was selected as a suitable approach since it effectively creates scores of criteria within suitable (or expert defined) upper and lower bounds. Compared to the common weighted summation approach, it overcomes the problem of extremely high values of f_{ij} for some criteria, which can create unrealistic biases in the utility score for some options.

We felt there were some necessary changes in adapting the compromise programming method. Firstly, we wanted a utility score where the larger the value, the better. We therefore redefine:

$$g_{ij} = \frac{f_i^+ - f_{ij}}{f_i^+ - f_i^-} \quad (2)$$

where g_{ij} is a value between 0 and 1 with 0 being best and 1 being worst. Eq. 1 can then be rewritten as

$$u_j^- = \left[\sum_{i=1}^{m} w_i * g_{ij}^{\ c} \right]^{1/c}$$	(3)

By substituting g_{ij} with (1- g_{ij}) a value of 1 would best and 0 be worst. Therefore, we define the utility function, u_j where the larger value of u_j the better, as:

$$u_j = \left[\sum_{i=1}^{m} w_i * (1 - g_{ij})^c \right]^{1/c}$$	(4)

We also needed the ability to use non-linear transformations of the raw scores. For a variety of criteria (e.g. biodiversity measures, water quality) the true benefit of an option j against criteria i cannot be reasonably described with a linear function of the raw f_{ij} within the upper and lower limits f_i^+, f_i^- Moreover criteria are likely to be in different units and different orders of magnitude. Transformation is therefore necessary to bring criteria to a common scale. Besides the linear transform, non-linear transforms that show a sigmoidal, convex or concave shape are integrated in MCAT as well.

3 The Knapsack Problem (KP)

The KP is well known in the operations research literature and refers to the situation where a backpack has to be filled with items where each item has a specific volume and value. The items must be packed such that it is best taken advantage of the total volume of the backpack whereby the total value (or benefit) of the packed items must be maximised at the same time. This decision problem is faced by a lot of decision makers who have to identify an optimum portfolio of decision options (projects) while keeping a budget constraint. The general mathematical formulation of the KP is as follows:

$$\text{Maximise} \quad \sum_{j=1}^{n} f_j x_j$$	(5)

$$\text{subject to } \sum_{j=1}^{n} a_j x_j \le b \tag{6}$$

where:

x_j is the decision variable (i.e. x_j =1 if item i is included in the knapsack (= project selected), = 0 otherwise)

f_j is the benefit (or score) of including item j in the knapsack

a_j is weight or cost of item j

b is the capacity of the knapsack (or the budget)

Though the mathematical formulation of the KP is simple it is known to be NP-Hard (Garey and Johnson, 1979) which means the computational complexity to guarantee an optimal solution increases exponentially with the number of decision variables. An extension of the KP that is used is the Multi-Criteria KP, which requires the following modification to eq. 5:

$$\text{Maximise } \sum_{i=1}^{m} w_i \sum_{j=1}^{n} f_{ij} x_j \tag{7}$$

where

w_i is the weight of criterion i

f_{ij} is the score of item (or option) j against criterion i, as defined in Eq. 1.

Multi-criteria KP are not new to the literature though they have primarily focused on problems with only two objectives (Gomes da Silva et al, 2006, Captivo et al, 2003, Erlebach et al 2002). In the case of two objectives, multi-objective programming is a suitable method since it produces a range of trade-off solutions along a Pareto front. Many MCA problems in practice, including the case studies of this paper have several criteria (or objectives), which make multi-objective programming more difficult to adopt by real world decision makers. In MCAT, we used an alternative approach, compromise programming, which is not only an innovative approach to the multi-criteria KP, but overcomes many of the practical shortcomings of multi-objective programming and weighted summation.

4 Solution Methodologies

4.1 The Comparison Process

There is an extensive literature of techniques applied to find optimal and near optimal solutions to the KP problem. An overview of exact solution methods can be found in Martello et al (2000). A range of meta-heuristics have also been applied such as Simulated Annealing (Drexl, 1988), Ant Colony Optimisation (Higgins, 2003) and Tabu Search (Hanafi and Freville, 1998). Whilst meta heuristics do not guarantee an optimal solution, they can approach an optimum fairly quickly even for hard KP problems with very large *n,* and Higgins et al, (2007) has shown such methods to find the optimal solution to real world case studies on all occasions. We decided to apply heuristics (instead of exact solution methods) to solve the KP problem for two main reasons:

1. we intend to expand the capability of MCAT to handle complementarity and interdependencies between options, which heuristics would be more flexible to accommodate (Higgins et al, 2007);
2. we plan to use MCAT for problems of a spatial nature where some problems may require to access GIS data types like raster datasets on a raster cell basis with raster datasets easily consisting of millions of raster cells.

Two meta-heuristics are used within MCAT, a common local search "hill climbing" heuristic and the Tabu Search (Glover, 1989). The local search method terminates when a local optimal solution is found, whilst the Tabu Search has features to escape from local optimal solutions and search for better local optimal solutions. The next two subsections describe the applications of these methods in further detail.

4.2 Local Search

The local search heuristics is a much faster approach than Tabu search however this comes with the cost of terminating as soon as the first local optimal solution is found. For small problems with $n<60$, it has been shown by Hajkowicz et al, (2007a) to produce solutions within 2% of the optimal. The quality of the local optimal solution is highly dependent on the initial solution though. MCAT generates the initial solution by sorting the options in descending order of benefit to cost ratio, f_j/a_j first. The selection is performed by stepping through the sorted list of options, starting from the highest f_j/a_j options where all options are selected until the sum of costs of the selected options reaches the budget constraint. This is the initial solution. The local search works by iteratively progressing through the list and swapping between selected and unselected options. If a swap produces a better solution and the budget constraint is satisfied, this new solution is kept, otherwise the old solution remains. The process continues until no more swaps yield a better solution.

With this rather simple approach to solving the KP, instances consisting of a larger number of projects can be solved within fractions of a second. Even though the returned solution may be inferior to the Tabu search, local search heuristics may be first choice when the number of decision options is small or an interactive sensitivity analysis is performed where results must be quickly updated because of user changes in analysis boundary conditions.

4.3 Tabu Search (TS)

Tabu search is a meta-heuristic approach which can be used to solve combinatorial optimization problems and is based on flexible memory structures in conjunction with strategic restrictions (Glover et al. 1995). Unlike local search, TS escapes local optimal solutions by allowing non-improving moves to be performed when no improving moves are available. TS starts with a randomly generated initial solution which satisfies the constraint (e.g. the budget constraint).

Next, a variety of candidate moves which are referred to as the neighbourhood are performed. This basically implies the testing of new combinations (solutions) of options and a subsequent check if the sum of benefits is improved whilst the constraint is satisfied. In MCAT, two neighbourhood searches are integrated: 1) add or remove an item from the knapsack; and 2) exchange an item in the knapsack with one that is not. Note that each combinatorial change leading to an improvement is kept in a list in memory which is the Tabu list (TL). A move is tabu if it (or the reverse move) is one of the TL most recent moves applied. After the neighbourhood search the best solution found overrides the current solution if it is better and overrides the current solution if it is worse but not in the tabu list which helps to escape local optimums.

5 The multi criteria analysis tool (MCAT)

MCAT was developed within the eWater CRC, a **c**ooperative **r**esearch **c**entre focussed on the business needs of the Australian water industry.

This CRC develops solutions that integrate environmental aspects in water resources planning and operations, provides education for water managers and delivers a whole range of software tools that will help facilitate and improving sustainable water management. MCAT was assigned to the water management research program which aims to develop analyses, modelling and optimisation tools for water management decision making. MCAT was developed with .Net and is, despite some complexity in the implemented solution methods, an easy to use decision support tool where the user is guided step by step through the whole optimisation process.

6 Test applications of MCAT

6.1 Queensland Nature Assist Program

Whilst developing MCAT, we tested the software along a variety of real world datasets taken from finished natural resource management projects. Here we evaluate a dataset of the Queensland Nature Assist Program (NAP). The NAP is an incentive scheme for landholders and provides financial assistance to protect natural assets on their property. Landholders can bid for financial support through a competitive tender process. In return landholders have to undertake a variety of activities that protect or maintain areas of high conservation value on their properties. Bids will be evaluated regarding their environmental benefit and chosen such that the benefit is greatest with respect to investment. The NAP is coordinated by the Queensland Environmental Protection Agency (QEPA). As our purpose is to illustrate MCAT we use a hypothetical budget ceiling of A$2 million.

To measure the performance of the conservation tenders an environmental benefits index (EBI) was developed (Hajkowicz et al. 2007b). This EBI comprises a hierarchical set of indicators which can be grouped into three main categories: site-suitability, management suitability and contract security. These indicators were then further divided into numerous subcriteria covering hydrologic aspects as well as biodiversity issues and cultural assets. In the end a set of 25 criteria was established on the lowest hierarchy level.

Whilst a variety of criteria values could be retrieved from digitally available data in a GIS, others needed to be assessed by means of field inspections and/or expert judgement. The criteria weighting was performed by a team of experts from the QEPA.

The total dataset cannot be shown in this paper due to its large size. The dataset used for this case study contained 95 tenders across the whole state of Queensland (Figure 1) which is considered small for a KP instance. The total cost of all tenders was around A$3,000,000 which exceeded the available budget of A$ 2,000,000. The problem was then to select those tenders whose summed benefit returned the maximum aggregate EBI whilst not exceeding the A$ 2,000,000 budget constraint.

Fig. 1 Case study locations.

To take into account the land size of the properties for which a tender was submitted, the EBI was adjusted by multiplying it with the size [ha] of the property for which it was computed.

Now that the benefit score of each project was known, the selection process of projects taking into account each project's benefit and cost as well as the total budget constraint was initiated. Local search returned a selected set of 71 tenders whose summed (dimensionless) EBI was 71132.3 with a total cost of A$ 1,998,637. Tabu search slightly outperformed the local search returning a portfolio of 69 tenders with a slightly higher total EBI of 71134.5 at a total cost of A$ 1,999,865. Since both methods are of a heuristics nature differences in results are not surprising since there is never a guarantee that the true optimum or the same results will be reached. However the selections were identical for 93% of all tenders. The differences in results of local search and tabu search are very small in this case study. In most real world problems such a difference may not be meaningful since the returned results are - prior to final approval by the decision makers at QEPA - subject to further discussion and possibly slight changes.

The number of evaluated options in this case study is fairly small and it may be hard to defend the use or even the application of tabu search given the subtle differences in results and the slower computational speed. However, in the medium term we intend to integrate interdependencies between projects where the selection of a project is conditional on the inclusion of another project. It has recently been shown (Higgins et al. 2007) that tabu search will provide up to a 66% improvement over simple heuristics when a large number of project interactions (or interdependencies) are present.

7 Water Quality Investments Perth, Western Australia

In this case study, we demonstrate how an optimal expenditure can be transparently identified. This important functionality is an integral part of MCAT. As with the previous case study MCAT processes the data of a finished project (see Hajkowicz et al. 2007c).

The Swan and Canning river system, located in Perth in Western Australia (Figure 1), is an area with high recreational, cultural, tourism, scenic and ecological value. The river system is under stress with biodiversity loss, algal blooms and seasonal fish deaths resulting from increased nutrients, sediment loads, foreshore erosion and other contaminants. As a response the Western Australian Government is committing new funding of around A$33 million over the next 5 years to improve river health (Swan River Trust, 2006a). One of the programs, funded under the government package, is the Drainage Nutrient Intervention Program (DNIP). The DNIP was established in 2003 to fund projects in the Swan-Canning Catchment to remove nutrients and sediments before they enter the river system.

Here, we evaluate 17 proposed DNIP sites. The criteria and DNIP sites were identified by staff from the Swan River Trust who manage the DNIP. The DNIP evaluation matrix (Table 1) were populated using estimates supplied by engineers as were the project costs. The project costs are not part of the evaluation matrix. This is because the aim of the evaluation is to maximise benefits against costs subject to a budget constraint. “Cost is a constraining factor, but not relevant to the measurement of benefits” (Hajkowicz et al. 2007c). The estimated project costs are given in Table 2.

The application of compromise programming requires that each criterion is assigned a weight, where the weights sum to 100 percent. The weights provide an explicit statement of the relative importance of each criterion. The following criteria weights are used in our analysis:

Nitrogen reduction (30%)	Other site constraints (5%)
Phosphorus reduction (30%)	Ongoing management (2.5%)
Other environmental opportunities (15%)	Societal benefits (10%)
Land availability (5%)	Strategic benefits (2.5%)

Table 1. Evaluation matrix of the Swan River case study (from Hajkowicz et al. 2007c).

	Environmental benefits	Site feasibility (1=worst, 5=best)	Other (1=worst, 5=best)					
	Nitrogen reduction [%]	Phosphorus reduction [%]	Other environmental opportunities	Land availability	Other site constraints	Ongoing mgmt	Societal benefits	Strategic benefits
			Improvement in habitat and water quality, reduction in litter organic carbon etc.	Availability of land required for wetland restoration	access, poor topography, etc.	Extent to which the site will benefit from ongoing management	reduction in odours, noise, positive aesthetics, amenity etc.	Opportunity for research and development to reduce costs in other programs
Site/Project								
Mills St water treatment plant (WTP)	0.625	0.875	1	4	2	2	2	2
Mills St Phoslock	0	0.625	1	4	3	3	2	2
Groundwater treatment trench	0.4	0.05	1	4	3	3	3	4
Mills St outfall	0.2	0.2	4	3	3	4	5	4
Hamilton Way CB	0.05	0.05	2	5	3	4	3	4
Mills St CB	0.4	0.4	3	5	3	3	3	5
Anvil Way CB	0.4	0.4	4	5	4	3	3	4
Division St CB	0.05	0.05	2	1	3	5	4	4
Wharf St MD (Council offices)	0.4	0.4	5	5	5	5	5	5
Charles Treasure Park	0.2	0.2	4	4	4	4	4	5
Liege d/s DUP	0	0	5	5	2	4	5	5
Liege St MD, Grose St	0.2	0.2	3	2	2	4	4	3
Liege St MD, Lake St	0.2	0.2	3	2	2	4	4	3
Railway Pde CB	0.05	0.05	3	1	3	4	3	2
Queens Park Rec Centre	0.2	0.2	4	4	2	4	4	3
Maniana Park CB	0.4	0.4	4	5	4	4	5	3
Bickley Rd CB	0.4	0.4	3	4	4	4	3	4

Table 2. Estimated project costs of the Swan River case study (from Hajkowicz et al. 2007c).

Project/site	Cost (A$000)
Mills St water treatment plant (WTP)	1,751
Anvil Way CB	208
Bickley Rd CB	208
Charles Treasure Park	88
Division St CB	208
Groundwater treatment trench	351
Hamilton Way CB	231
Liege d/s DUP	88
Liege St MD, Grose St	208
Liege St MD, Lake St	88
Maniana Park CB	208
Mills St CB	576
Mills St outfall (both 2 and 3)	576
Mills St Phoslock	1,751
Queens Park Rec Centre	208
Railway Pde CB	88
Wharf St MD (Council offices)	208

In addition to finding an optimal portfolio of project sites for a given budget, we repeated the computation for varying budget constraints where each evaluation may return a different aggregated benefit of the selected options. The budget variation was done within the range of cost of the cheapest project and the sum of cost of all projects. Figure 2 shows the results of this evaluation.

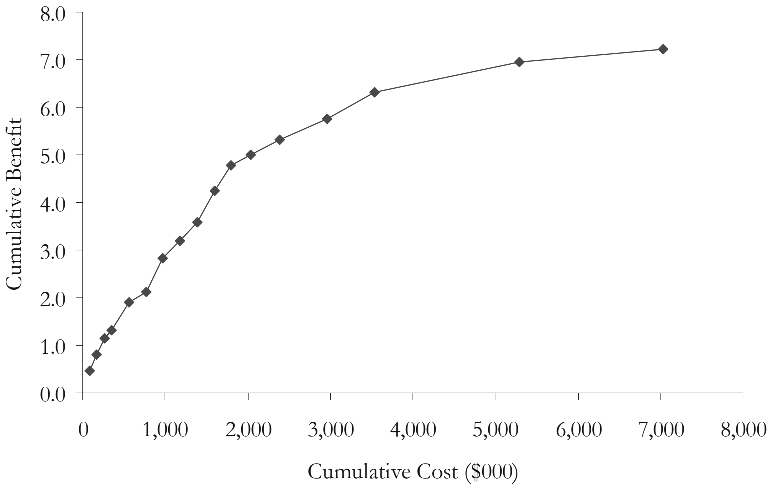

Fig. 2 Costs and cumulative benefits of the Swan River case study (Hajkowicz et al. 2007c).

The cumulative cost-benefit analysis shows the optimised aggregate benefit at each possible level of expenditure. Generally, we expect to see diminishing marginal returns, as found in our study. This can identify "expenditure thresholds" where further expenditure delivers only minor improvements in aggregate benefits and may not be considered worthwhile. In our study such a breakpoint can be identified at the A$3.6 million mark. Expenditure beyond this point, to fund all projects, would increase the cumulative benefits by only 15% whilst costs would double.

The analysis of the cumulative cost-benefit curve is a useful means for decision makers where there is no fixed budget to work with. Whilst exploring this graph, decision makers can more easily identify budget thresholds which return reasonably high benefits. A chosen expenditure can be well defended and not all available funds must necessarily be spent. If future funding rounds can be expected, Hajkowicz et al. (2007c) suggested investing unspent funds in other areas of activity until the upcoming new funding rounds.

8 Future enhancements

Though MCAT already covers a useful set of functions, we are aware that there is need for further improvements. Medium to long terms enhancements of MCAT include the implementation of

- interdependencies between two or more projects,
- group decision making approaches and
- Mont Carlo simulation functionality to take account of uncertainty in input values.

Especially in a spatial context, project interdependencies play an important role in that the selection of two projects A and B with benefits b_A and b_B may give a total benefit which is greater than ($b_A + b_B$) or the contrary, the selection of two projects may lead to a decrease in the overall benefit with ($b_A + b_B < 0$). Other enhancements will include a net based group decision making module which enables the online participation of a variety of stakeholder groups and allows for the aggregation of their weight preferences. An important aspect is the uncertainty of input values which MCAT will be evaluating by means of Mont Carlo Simulation. We therefore intend to integrate interactive functionality which lets the user specify distribution functions for specific criteria of project options. The range of distributions which can be used will be kept to a minimum and will include simple distribution types (e.g. triangular, uniform) that do not require the specification of a variety of parameters.

9 Conclusion

The multi-criteria knapsack which is integrated in the multi-criteria analysis tool (MCAT) has shown to be a useful approach to select an optimum portfolio of projects. Compromise programming, as the implemented multi-criteria analysis (MCA) technique, has the advantage that the user can define ideal and anti-ideal values and is therefore well suited to be applied, once legally provided guidelines or expert defined best and worst values have been taken into account. However, there might be users who prefer using other approaches to derive benefits or consider other MCA approaches more appropriate for a specific decision problem and are in need to specify a defendable optimum portfolio of options. MCAT therefore offers the possibility to bypass the compromise programming interface by directly importing externally computed benefits and costs of a whole set of projects allowing the user to derive an optimum portfolio for any constraint specified. We believe that MCAT offers an intuitive user interface and is – despite some complexity in the applied meta-heuristics – an easy to use tool. It offers a portfolio of functions which will make it attractive for a lot of decision problems not only in water management but in natural resources management and other applications as such. Interested readers are asked to visit eWater CRC's toolkit website (http://www.toolkit.net.au/) for the latest beta version of MCAT.

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