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Boundary Work and Water Resources: Towards Improved Management and Research Practice?

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Boundary Work and Water Resources

Towards Improved Management and Research Practice?

Esther I. Dörendahl

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Abstract

This paper explores the potential of 'boundary work' perspectives for enhancing current approaches in water resources management and research with a focus on developing countries[1].

Boundary work thinking is analysed in the context of three currently leading approaches for water and natural resources management, i.e. Integrated Water Resources Management, Adaptive Management, and the Ecosystem Approach. Given the political dimension of water resources management, questions of governance are merged into the boundary work perspective. The paper introduces the Boundary Work framework as developed by Mollinga (2010a), discusses the potential of the framework for enhancing water resources management and research practice and proposes amendments to the framework.

Based on the analyses and following the rationale of Mollinga's boundary work framework, the paper is meant to spark the discussion on a generic 'boundary concept' to communicate about problems in water resources management, to reflect upon a general protocol to develop suitable 'boundary objects' and to cogitate on 'boundary settings' to understand limitations and limits to change towards sustainable water resources management.

This serves the development of operational guidance how to approach complex water resources management problems, aiming for:

- increased sustainability of current water resources management systems,
- improved research and management approaches under uncertainty,
- increased adaptive capacity,
- enhanced resilience to changes, such as climate change.

Further, fields for future research in the context of boundary work and water resources management are outlined.

Keywords: boundary work, water, natural resources management, IWRM, adaptive management, Ecosystem Approach, governance, transdisciplinarity, sustainability science, methodology

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[1] The distinction between ‚developing countries' and ‚developed countries' reflects a biased thinking in perceiving the world. Due the lack of an appropriate and impartial terminology for differentiation of nations, depending on their specific local, political, social, economic and environmental properties, the patter will be used in this paper, being aware of the respective limitations.

1 Introduction

It is a common understanding that water problems in most regions of the world are rather based on poor water governance and management practice than on actual water scarcity. Especially in the developing world the water sector is often characterised by fragmentation, inadequate institutional and administrative structures with unclear roles and responsibilities, inadequate regulatory mechanisms and last but not least lack of continuity in qualified staff. In addition, the range of conflicting actors or stakeholders with no or low interest in cooperation is specifically high in the water sector, as water is a highly politicised and contested natural resource. Further, water systems are complex systems, characterized by uncertainty and knowledge on system behaviour is limited. This holds especially true for the developing world, were lack of data and information often add to the difficulties, when working on sustainable solutions. The above mentioned deficiencies ask for a holistic management approach that incorporates knowledge generation and integrates policy, science and civil society into problem solving.

Diverse approaches have been developed for working in the field of water and other natural resources management and research, i.e. Integrated Water Resources Management (IWRM), Adaptive Management (AM) and the Ecosystem Approach (EA). However, definitions of these approaches vary and while each approach provides important - rather complementing than contradicting - principles and methods, coherence is not given. Complexity of principles, methods and tools makes it difficult for the user to find a way through the jungle of options when trying to approach complex and contested water management problems that involve multiple actors. Thus to achieve sustainable water resources management, an approach is required that does not only foster reduction of complexity while focusing on developing practical solutions in contested water issues, but also focuses on knowledge generation to reduce uncertainties and to facilitate mediation between different, probably conflicting stakeholders. This can be facilitated through the process mode of Transdisciplinary Research (TR). TR provides a methodology on how to define, structure and approach complex and contested problems that require knowledge generation. It integrates multiple actors with their diverse interests and puts a strong focus on action-orientation and concrete problem solving.

However, all these concepts can only be implemented, if cooperation and communication between different actors with their individual perceptions, interests and underlying schools of thought functions in the local context. Distinct barriers in the water sector often exist between political and scientific actors, public utility managers and civil society or between representatives from different sectors such as water, environment, industry and agriculture with their diverse interest and responsibilities. In the context of the developing world more actors add to this already complex situation: the variety of international organisations, ranging from multilateral funding organisations to state-driven donor organisations and non-governmental organisations with their individual objectives, motives and agendas. It is one of the most challenging but most important requirements for the development of sustainable solutions for water and other natural resources management to first acknowledge and second deal with and try to blurry the barriers between the different actors and institutions concerned by a specific problem.

Reflections on this complex task may be facilitated by the meta-theoretical perspective of 'Boundary Work', which is a relatively new stream of science. Boundary Work is a concept that focuses on societal boundaries between actors and institutions and ideally supports bridging them by adequate knowledge production: problem specific knowledge and information are generated, distributed and communicated through different tools and products, or even through tailored institutions - so called 'boundary objects'. So far the literature on boundary work has mostly focused on retrospective analysis, how barriers have been blurred in single cases; a generic methodology to facilitate boundary work from scratch is still missing. A first framework to systematise boundary work processes has recently been developed by Mollinga (2008a, b, 2010a, b). It supports the structured reflection of complex problems by defining boundary concepts – the language to communicate a problem, boundary objects – the tools to approach the issue, and boundary settings – the framework conditions that shape the problem. Or else, it supports the 'rationale organisation of dissent' in complex and contested resources management problems (see also Mollinga, 2008a).

I hypothesise that this framework can add to approach complex water and natural resources management problems. However, it has so far never been used to systematically reflect about water resources management. Research is required to structurally evolve the boundary work framework to the characteristics of the water and natural resources sector and further to the specifics and needs of developing countries, acknowledging principles and methods from IWRM, AM, EA and TR. Case-specific research is then needed to investigate how the boundary work framework can locally be used to support the structured development of concrete solutions to real-life problems by developing the 'instrumental work for action' for enhanced water management.

2 Water Resources Management

Various approaches have been developed to address water and other natural resources management problems worldwide, based on different schools of thought. While some put a stronger focus on research and knowledge generation in a process-oriented way, to better understand the local resources management problem at hand as well as the ecological and socio-economic consequences of management action, other approaches rather focus on the development of specific management action. Uncertainties in water resources management are high. This is often based on the lack of adequate ecological as well as socio-economic data and information on catchment scale especially in the developing world, as well as on very limited knowledge on the behaviour of complex socio-ecological systems in principal. Approaching water management challenges in the developing world thus requires merging process-oriented research models that focus on knowledge generation with management concepts that focus on aspects of practical implementation. To further implement sustainable approaches for water resources management that integrate knowledge generation and structured research into the management perspective, the establishment of flexible management mechanisms is required that allow changing the course of action if new knowledge is gained.

Three leading approaches have emerged in parallel in different scientific and political spheres in the field of water and natural resources management and research: 'Integrated Water Resources Management' (IWRM), Adaptive Management (AM) and the Ecosystem Approach (EA). Each concept is based upon different, rather complementary than contradictive, principles and tools. This chapter briefly introduces the three approaches. In chapter 6 the approaches will be reflected in the context of the boundary work framework and be presented in more detail.

2.1 Integrated Water Resources Management (IWRM)

During the last decades, the concept of Integrated Water Resources Management has emerged as the leading approach towards sustainable water resources management for both, the developed and the developing world. While in the past, water resources management was characterized by defined operational problems, which where individually addressed and solved through techno-centric solutions, such as water quality improvement through water treatment, flood control through dam construction etc., this concept did not embrace the complexity of the eco-systems, here the water systems and related natural resources. In acknowledgement of this complexity, further holistic approaches of IWRM have been developed and brought forward through several international organisations (Global Water Partnership - GWP, International Water Management Institute - IWMI, Food and Agricultural Organisation – FAO et al).

IWRM is meanwhile the accepted 'leitmotif' for sustainable water resources management. However, it still lacks success in practical implementation for several reasons. The natural resources management model provides an ample range of principles and tools to develop localised solutions, but lacks a structured methodology on how to proceed to address a concrete problem. It does furthermore not systematically incorporate the necessity of structured knowledge generation and the integration of research activities into the development of management solutions. And it does not in enough detail acknowledge the required integration of the local governance perspectives (see also chapter 3). As leitmotif, IWRM has the potential to serve as a boundary concept for WRM. However, it has been interpreted in so many different ways that it would first require a harmonised understanding of what IWRM actually implies in order to function as a boundary concept for WRM. The multiple and diverse approaches can be structured within three categories, reflecting different schools of thought (Neubert et al, 2005).

The first set of definitions of IWRM covers intra- or mono-sectoral approaches, focusing on the water-sector only. This 'limited' view integrates groundwater and surface water in its quality and quantity, but does not consider other natural resources, like land and biosphere. It further excludes all water-related sectors, such as agriculture, industry or energy. An example for this perspective is given by the EU Water Framework Directive.

The second set of definitions is slightly more comprehensive and covers inter-sectoral approaches. In the foreground are allocation problems through competing forms of water use, which shall be solved through coordinated action between different sectors, such as water and agriculture. An additional focus may be set on protection of the natural resources. Examples cover e.g. the integration of the agricultural perspective into water management (see e.g. www.iwmi.cgiar.org/), or analysis of ecosystem services and their interrelations with different forms of water use (see e.g. www.riverbasin.org; www.iucn.org, Dehnhardt and Petschow, 2008).

The third set reflects a holistic approach, as defined by GWP (2000): *'IWRM is a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.'* This holistic definition requires integration of different water-related spheres and aspects, i.e. merging a) natural and human system interaction, b) freshwater and coastal zone management, c) land and water management, d) 'green' and 'blue' water, e) surface water and groundwater management, f) quantity and quality in water resources management, and g) upstream and downstream water-related interests. Different interest groups shall jointly develop and manage the water resources in a participatory and catchments based approach, involving knowledge and actors from different sectors (water, agriculture, industry, energy et al), different disciplines (natural science, social science) and experts as well as laypersons. This new catchments based approach acknowledges that from a natural ecosystem perspective, river basins - rather than administrative borders - are the logical planning units for water management. This holistic approach is further based on the four Dublin principles, which have commonly been agreed upon by the international community as guiding principles for water resources management (GWP, 2000):

I) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

II) Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.

III) Women play a central part in the provision, management and safeguarding of water.

IV) Water has an economic value in all its competing uses and should be recognized as an economic good.

While the approaches of the first and second set of definitions imply a certain interest in specific outcomes (e.g. improved water quality, flood control or protection of the natural resources), the third category does not focus on one concrete issue of concern, but leaves it to the actors to identify the prevailing problem by themselves. In this openness and universal perspective it is suitable as 'leitmotif' for water resources management, but so far it lacks a protocol for approaching concrete problems and thus success in practical implementation. The analysis in this paper is based on this third and holistic understanding of IWRM.

2.2 Adaptive Management (AM)

To address deficiencies of IWRM, current research is focusing on merging relevant aspects of Adaptive Management (AM) into IWRM approaches for concept improvement (Pahl-Wostl et al 2007, Medema, McIntosh, Jeffrey, 2008; Medema and Jeffrey, 2005). The origins of the Adaptive Management approach are under dispute: according to some authors the concept of Adaptive Management (AM) has its sources in systems and complexity theory, was launched in the 1970's and was originally meant to improve understanding of complex ecosystems and functioning. Following other authors, the origin may be claimed in the decision analysis field, aiming at supporting structured decision making in complex decision situations in natural resources management (Walters 1986).

The AM approach focuses on two conceptual weaknesses of IWRM: a) it acknowledges uncertainty in understanding human-ecosystem behaviour, the effects of management action and impacts of large scale environmental changes, e.g. through climate change, and b) the inherent capacity of natural systems to self-adapt to changes in their environment. (Medema and Jeffrey, 2005; Pahl-Wostl and Sendzimir, 2005). Human-ecosystems - here water resources systems (WRM systems) - are characterised by a high level of complexity and change, which makes it difficult, if not impossible, to fully understand the system and its interrelations. Complexity in human-ecosystems or socio-ecological systems refers a) to the array and variety of components (ecological, physical, technical and human) forming the ecosystems as well as b) to the multiple and diverse relations (ecological, economic, social, political and physical) interlinking these components. The system is constantly in revision and modification, reacting on changes or anticipating future changes and contains many niches, which can be filled by agents adapting to them. Due to this complexity and mostly non-linear behaviour of ecosystems, performance and developments are mostly unpredictable.

The very limited human knowledge on functioning of complex ecosystems leads to management-decisions which are based on high levels of uncertainty and which hardly allow to overlook and understand the consequences of the decisions in the long term. There are different types of uncertainty which need to be acknowledged in water resources management, e.g. lack of knowledge based on limited data availability in quantity and quality, limited understanding of current systems' behaviour (agents and their interactions) as well as uncertainty in anticipating the ecosystem's reaction on management action and unpredictability of large-scale environmental changes, e.g. through climate change and their consequences for the local social-ecological systems. Furthermore the diversity of stakeholders can create uncertainties, based on different even contradicting interpretations of the same data and information due to different perceptions and values of the stakeholders.

Considering uncertainties in water resources management requires the development of flexible management systems and innovative and robust management strategies, which incorporate knowledge generation, are suitable for different possible scenarios and further allow changing the course of action if new knowledge is gained. Management systems need to be flexible to react on new knowledge, as new information may require a total shift in the management approach and can even contradict previous management action. New knowledge can cover environmental, socio-economic or technological fields, e.g. through better understanding of the systems behaviour in general; improved knowledge on (large scale) environmental changes such as climate change or an increased awareness of socio-economic and demographic changes. A central element in AM is the perception that complex management systems should not aim at reaching a state of equilibrium, but rather be able to integrate past management experiences and increasing knowledge in the current management approach.

Acknowledging complexity and uncertainty leads to four major principles for AM (Ohlson 1999): It requires continuous and deliberate learning; it supports knowledge generation through field science and formal experimentation; it is based on a systems approach; it integrates management and research (for further information see Annex 1). In this aspect AM is en evolvement to IWRM. Acknowledging uncertainties, it goes beyond a pure management approach and requires to base management decision on structured learning processes and research. The principle of integrating management and research into a single concept can add to the IWRM perspective, which so far does not include structured approaches for knowledge generation.

While AM from a conceptual perspective provides important principles, tools, planning frameworks and experiences, its practical value still needs further elaboration. Success in implementation of this participatory 'soft systems approach' is so far limited and depends on scale and issue under dispute. Some tools are too resource intensive and sophisticated to be of practical use for water resources management, however, some generic processes and less sophisticated tools may add to developing suitable boundary objects and support the structured reflection of boundary settings that hamper or limit potential change. Examples for AM approaches mostly refer to small-scale application and modelling rather than experimentation. Success in implementation also depends on the specific local political and cultural conditions: AM requires flexible political and social systems, open to deal with a qualitative and inclusive process rather than focussing on quantitative results. As discussed in the context of IWRM, this may provide difficulties in state-centric or (semi-) authoritarian political regimes as often encountered in the developing world (Mollinga, 2009; Padt, 2009).

Further challenges occur during the implementation phase of AM. To cite just a few of the noted problems, the range covers: *'failure to define what is meant by AM ad how it will be implemented; an absence of strategic thinking of the end-points of scientific inquiry; tendency for AM processes to evolve into continuous and costly modelling exercises; fear on the part of individuals in management agencies that acknowledging uncertainty will compromise public confidence in the agency; failure of the scientists to understand management priorities and to recognize the need to provide information that can directly be uses by managers in decision making; lack of emphasis or attention to the processes required for shared understanding or shared decision making among diverse stakeholders'* (Ohlson, 1999, following Walters, 1997; McLain and Lee, 1996; Rogers, 1998 and Halbert, 1993). In general AM adds to a comprehensive reflection of boundary work and IWRM, while IWRM still remains the 'leitmotiv' for WRM.

2.3 The Ecosystem Approach (EA)

The Ecosystem Approach (EA) is considered as one of the leading concepts for sustainable management of natural resources and reflects a paradigm shift from protected area management to a holistic management perspective, acknowledging that ecosystems, apart from their intrinsic value, provide goods and services to the people. The approach has been developed under the Convention on Biological Diversity (CBD) and is meant to provide operational guidance on implementation and balancing its three core objectives, namely '*the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.*' (Article 1 of the CBD, see www.cbd.int) and is defined as '*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.*' (CBD Dec. V/6 Annex A, section 1). It shall provide operational guidance to balance the three objectives, acknowledge the complex interconnections between ecological, social-cultural, economic and institutional factors and take into account that humans with their cultural diversity are integral parts of many ecosystems.

It further intends to approach environmental degradation including climate change mitigation and adaptation with the aim to increase human well-being and contribute to poverty alleviation. For its application to a concrete project or issue, it provides a framework in terms of twelve principles, operational guidance in five steps and an ample range of specific tools[2].Through its holistic approach and operational guidance it may add to the IWRM perspective. However, on a conceptual basis only first attempts have been made to merge EA with IWRM or to convey ideas of one concept into the other (Dehnhardt and Petschow, 2007). EA may further provide approaches for the development of boundary objects and the analysis of boundary settings in complex water resources management issues.[3]

EA defines twelve principles that form the conceptual basis of the approach (see Annex 5) that all may also apply for IWRM. The ecosystem approach does not specify a spatial unit or scale to be addressed, but focuses on functional ecological units at any scale. IWRM requires water resources management to be oriented at catchment boundaries, which would here define the spatial unit to be addressed. It is further based on the understanding that apart from their intrinsic value, ecosystems provide goods and services to the people; these can be divided into goods, or else 'provisioning services' such as water, fibre and food, regulating services, e.g. emissions sinks or flood control, cultural services, e.g. recreational, spiritual, religious benefits and supporting services, e.g. soil formation and nutrient cycling. There exist substantial linkages between the sustainable provision of ecosystem services and human well being: '*Human well being and progress toward sustainable development are vitally dependant upon improving the management of Earth's ecosystems to ensure their conservation and sustainable use*' (Millennium Ecosystem Assessment, 2005)[4]. The linkages revealed between ecosystem services and human well-being are briefly presented below:

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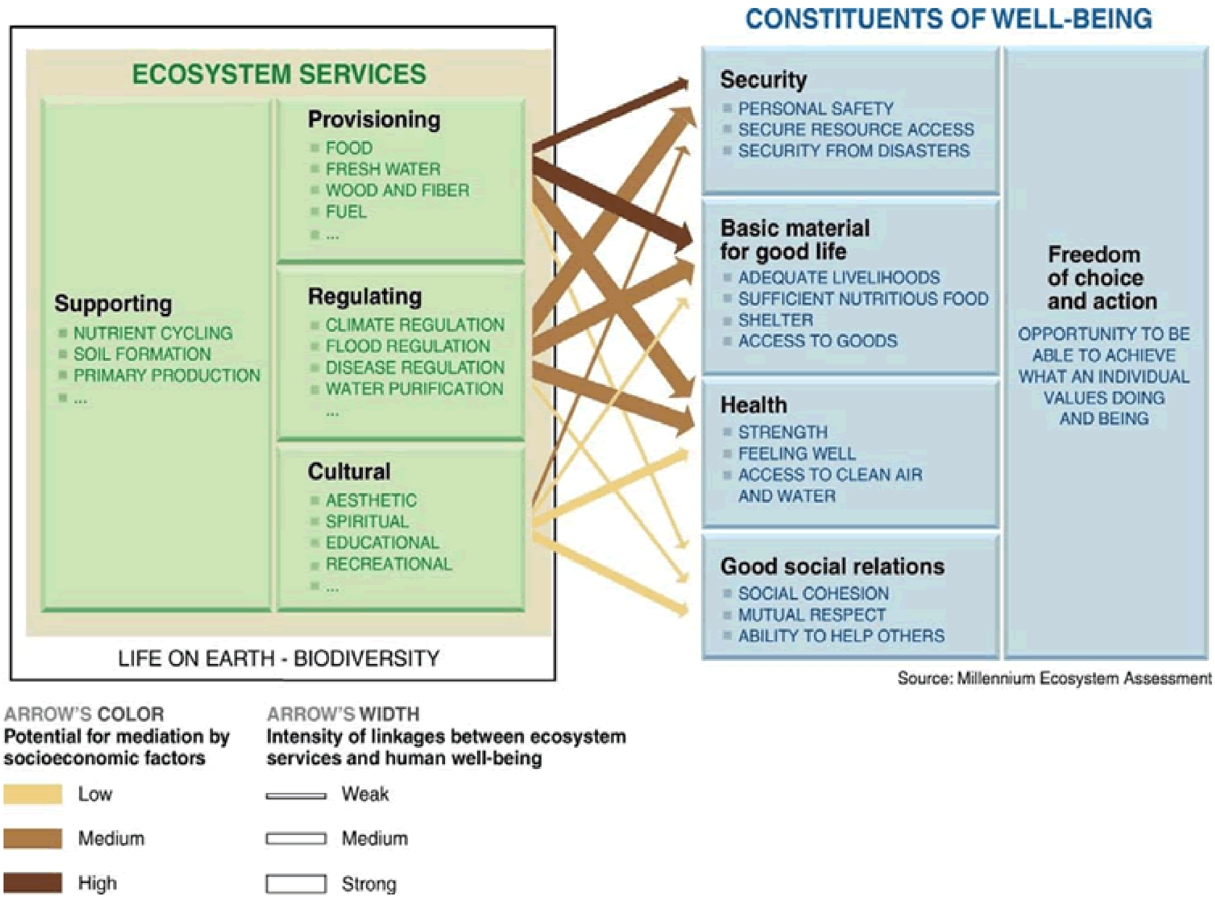
[2] For an introduction to the Ecosystem Approach, please refer to: http://www.cbd.int/ecosystem/; for an overview on how to apply the EA, see the beginner guide on: http://www.cbd.int/ecosystem/sourcebook/beginner-guide/. For more details on the application of the EA see the advanced user guide: http://www.cbd.int/ecosystem/sourcebook/advanced-guide/ and for information on specific tools and approaches, please check: http://www.cbd.int/ecosystem/sourcebook/tools/. (all accessed on 08/08/2010)

[3] For EA and its applicability to water resources management see also Dehnhardt and Petschow (2007)

[4] According to the Millennium Ecosystem Assessment (MA), human well-being has various constituents, covering: basic material for good life (adequate livelihoods, sufficient nutritious food, shelter, access to goods; security (personal safety, secure resource access, security from disasters); health and physical well-being (strength, feeling well, access to clean air and water), good social relations (social cohesion, mutual respect and ability to help others) and freedom of choice and action (opportunity to be able to achieve what an individual values doing and being). Well-being is strongly context specific and dependant on geography, culture and ecological framework conditions.

Figure 1: Linkages between ecosystem services and human well-being



Source: Millennium Ecosystem Assessment (2005:4)

Human well-being has been considered as central focus for the assessment. This will be taken as overarching principle and objective when reflecting on boundary work for sustainable water resources management.

3 Water Governance

Water in sufficient quality and quantity provides a fundamental basis for human and ecosystem well-being as well as human development. Water resources management is an inherently political process that affects civil society by dealing with questions of allocation, regulation, administration, policy, politics et al. This requires including questions of (good) water governance into the perspective of water resources management. While the introduction of the concept of IWRM already reflected a paradigm shift from technocentric approaches of 'infrastructure operation' to a holistic management approach, it goes acknowledged that failures in implementing IWRM may be assigned to the fact that governance aspects have not been incorporated in enough detail: *'There is an emerging consensus that this failure (of implementing IWRM) could be due to inadequate attention being paid to ensuring that appropriate governance systems are in place; and this appears to be due to very varied understandings as to what constitutes good governance*. (Turton et al 2007, following WWC 2000).

Governance is inherently different from government; definitions of governance may but do not have to relate to government. Governance is a complex process that incorporates all kinds of relationships within and beyond the state; besides governmental institutions it covers also relationships between science, civil society, the private sector, formal and informal organisations etc.. In general, it '*describes the relationships between people, the ways they interact with each other in the context of their environment, and the systems of principles, rules and norms that are set up to guide these interactions'* (Turton et al 2007). 'Good governance' further implies that relationships and processes are transparent and all parties are accountable for their behaviour. A more comprehensive definition thus would be: Governance is '*the process of informed decision-making that enables trade-offs between competing users of a given resource so as to balance protection with beneficial use in such a way as to mitigate conflict, enhance equity, ensure sustainability and hold officials accountable.'* (Turton et al 2007).

If governance focuses on water as central element of concern, it is considered as 'water governance'. GWP defined water governance as '*the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels in society'* (Rogers and Hall, 2003). However, a commonly accepted definition of 'water governance' still has to be developed. The prevailing way of local governance strongly depends on norms and values of the society in which it is applied. Thus experience in water governance from democratic countries, as mostly found in the 'developed world', may not be transferred to 'developing countries', which rather imply (semi)-authoritarian regimes to what can be considered 'fledgling democracies'. When dealing with water governance issues in the context of water resources management, the prevailing norms and values of different stakeholders and the norms and values founding the legal system need to be revealed and considered in the local context.

An interesting concept for reflecting upon water governance has been developed by Turton et al (2007); it is considered as *'The Trialogue Model of Governance'*. It will briefly be presented here, as it contains elements which considerably add to developing the boundary work perspective to water resources management and research in the developing world. The model bases (water) governance on interactions between three main clusters of actors: The cluster of government actors, society actors and science actors. The classification in clusters shall embrace the large variety of actors within each cluster:

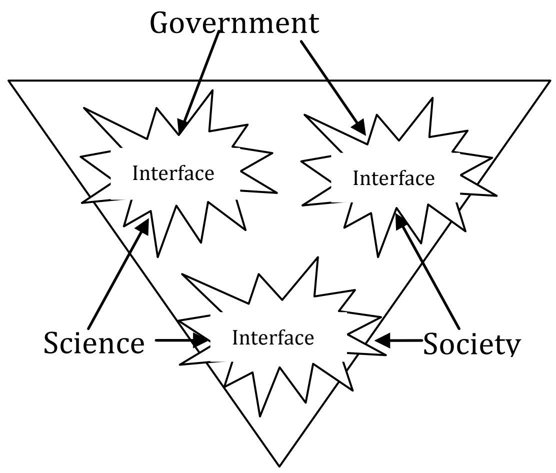
The governance cluster - reflecting the ‘trias politicas’ of political science - consists of three elements: the legislative branch of the government, engaged in rule making; the executive branch of the government, applying these rules; and the judicial branch, adjudicating on these rules. Policy and politics are in an ideal situation based on the needs of society.

The cluster of society actors embraces three sub-elements: civil society, including all individuals or groups of people that have an interest in engaging in areas of concern, such as non-governmental organisations, community based organisations, private entities, industry et al; the second sub-element is the economy, with own interests and formal and informal channels of communication; the third element refers to the environment that encompasses society and economy.

The cluster of science actors focuses on knowledge generation. It is classified according to three subcomponents: ‘basic research’ (also considered as Mode 1 or Type A research) that focuses on analysing and understanding problems without the objective to develop solutions to solve them. Knowledge generation is strictly organised along academic disciplines; ‘applied research’ (also considered as Mode 2 or Type B research) focuses on solving real-life problems in a transdisciplinary manner; knowledge generation is contextualised and oriented at solving complex problems of societal concern (see also chapter 4); apart from scientists with different academic backgrounds, also lay-persons are involved in knowledge generation; Type C research refers to specialist services and technology transfer; services imply feasibility studies, consultancy reports, pilot projects etc. knowledge may be generated through a variety of actors from academia, private companies or civil society groups. Complementing this perspective, a fourth type of research can be added: ‘use inspired basic research’ (Clark, 2007). This is a curiosity driven type of research involving various disciplines and that draws upon basic as well as applied research. The field of Sustainability Science’ fits into this category. Also research on Boundary Work is an example of this fourth type.

These actor-clusters are all somehow in relation to each other, which can best be reflected in the form of a triangle. Communication and relation between the actor-clusters is referred to as trialogue.

Figure 2: Governance as trialogue



Source: Turton et al (2007:18)

Successful governance depends on effective communication and cooperation within and between the three groups of actors from government, society and science. Cooperation occurs along interfaces between government and science, government and society and science and society.

The concept provides important insights that support developing the boundary work perspective according to the needs of water management in developing countries (see chapter 6.1 and 6.5). It supports the structured reflection of boundaries in water resources management according to the three links of cooperation. It further gives insights into 'boundary settings', thus, the framework conditions that shape a project and define limits and limitations to change. Here the concept provides also a basis for reflections upon different types of governance regimes and the respective implications for cooperation between government, science and society (see chapter 6.5). As water resources management problems are complex problems that require knowledge generation based on a functioning cooperation between these three actor-clusters, the prevailing governance type is crucial when reflecting upon limits for change in a local setting.

4 An inter- and transdisciplinary approach

While the ample range of processes and tools provided by IWRM, AM and EA may overstrain the user, be it the policy maker, scientist, or representative of civil society, in their search for decision support in water resources management, the research approach of Transdisciplinary Research (TR) may help to structure the management problem(s) to be addressed, define specific knowledge needs and support target oriented knowledge generation and problem solving. The Transdisciplinary Research approach provides operational guidance how to go over complex and contested natural resources management problems that require knowledge generation. As research model it supports the better understanding of real-life problems in a structured manner and aims at developing practical solutions. Combining elements of IWRM, AM and EA through the methodology of transdisciplinary research acknowledges not only the complexity of the systems, but also supports problem and objective-oriented knowledge generation to foster decision making under uncertainty.

Approaching solutions for complex natural resources management problems requires inherently inter- and transdisciplinary research. Inter- and transdisciplinarity have been defined in multiple ways. In this paper interdisciplinarity is understood as 'cooperation across different academic disciplines', whereas transdisciplinarity implies 'incorporating knowledge from different actors, professionals as well as lay persons, to develop practical solutions to real-world problems.'

While interdisciplinarity tries to overcome barriers between academic disciplines, transdisciplinarity is inherently different. It addresses complex environmental and societal 'real-world' problems, aims for practical solutions and is based on the understanding that these problems can not be solved by science alone. In addition to scientific knowledge it requires the integration of knowledge and perceptions of society. Natural resources management problems are furthermore not only 'environmental or technical problems' but 'societal problems', dealing with questions on resources allocation and thus touching questions of fairness and equity. Research towards sustainable water resources management - as a highly contested arena - requires an approach that integrates society in problem and target definition as well as in the following transformation process and that supports mediation between conflicting stakeholders and interests. Transdisciplinary Research can be defined as research that (Mollinga, 2008a; Lawrence and Després, 2004; Pohl, 2005):

- Addresses problems characterised by complexity and heterogeneity;
- Is action – oriented;
- Tackles complexity in science and challenges knowledge fragmentation in disciplines; it sets aside the idealised context of science in order to produce practically relevant knowledge, transcending any academic disciplinary structure;

- Addresses both science's and society's diverse perceptions of a problem; it accepts local contexts and uncertainty; it is context specific negotiation of knowledge and requires close and continuous cooperation between experts and laypersons during all phases of a research project;

- Addresses possible improvements of the status quo through balancing the diverse interests and inputs of individual stakeholders and disciplines.

Transdisciplinary Research can be regarded as an approach to study, promote and implement sustainable resources management and is oriented towards the common interest. A three-step methodology for implementation has been developed by transdisciplinarity net (td-net), (Pohl and Hirsch Hadorn, 2007). It is briefly presented in chapter 6.6, when reflecting upon an approach to design boundary work processes in real-life cases. Whereas IWRM, AM and EA provide major principles for WRM, the TR methodology may add operational guidance not to get lost in the ample range of proposed processes and tools from the three approaches when tackling a local WRM issue. It also provides support for the development of appropriate boundary objects as well as the reflection of boundary settings.

5 The Boundary Work Perspective

'Boundary work' as meta-theoretical perspective is a relatively new field of science. It tackles the reflection of societal and cultural boundaries, means boundaries between different actors and institutions. These often hamper joint problem solving in complex and contested problems. Boundary work has been defined in multiple ways (Gieryn, 1983; Clark et al 2010; Thompson Klein 1996; Guston, 2001; White, et al, 2008; Cash, 2001; Cash et al, 2002; Cash et al, 2003; Miller, 2001; Keating, 2001; Star and Griesemer, 1989; Agrawala et al, 2001). The original focus was on the analysis of barriers and the respective demarcation between scientific and non-scientific actors, which among others implies political actors. In this context a lot has been written about science-policy relationships, dependencies and independencies between scientists and political decision-makers, of which a nice summary of reflections is represented in Hoppe (2005). The science-policy relationship is further in detail reflected in principal – agent theory (see e.g. Braun and Guston, 2003). Another type of literature on boundary work covers the analysis of institutional arrangements that help to blurry the barriers between science and policy through so called boundary organizations and that support scientists to conduct research that is required by politicians for their actual decision making and also accepted by these politicians.

Up to now research mostly focused on reflections on science-policy boundaries, reasons for their existence and potential ways for their demarcation. Alternatively boundary work studies focused on retrospective analyses how boundary management had developed in a concrete case and the study of supporting and hindering factors for the process. Until recently, a structured framework for clustering and approaching boundary work has been missing and boundary work has not been applied in a systematic approach. However, the common objective of all attempts in boundary work seems to reflect upon and ideally demarcate societal barriers between multiple stakeholders, be it politicians, scientist, private entities or local interest groups and to foster joint problem solving in complex and contested problems.

The first generic framework to systematically reflect upon boundary work processes in complex and contested problems, with a sectoral focus on management of natural resources, has been developed by Mollinga (2008a, b and 2010a, b). It supports the structured reflection of complex problems, reveals different ways to go about them and fosters the analysis of hindering factors that may confine change. In its generality it may serve as the suitable organisational model to merge principles, methods and tools of the research and management approaches of IWRM, AM, EA and TR. In the light of these concepts it is further developed according to the specificities of water management in developing countries (see chapter 6.5). As generic model it may further provide support for the development of a standard approach to go over, discuss and process contested water resources management issues of any kind (see chapter 6.6). The framework bases boundary work on three devices: concepts, objects and settings:

Boundary concepts are referred to as the analytical work for understanding a problem, as well as the development of a common terminology for all actors, to foster communication and cooperation across sectors, disciplines and between professionals and lay-persons. Depending on the different academic or working background and the cultural context a person is settled in, different perspectives are revealed though using the same wording. An example can be given by the concept of 'water control', which has considerably different notions depending on the background of the people using it. While e.g. engineers will primarily associate 'technical control' with 'water control', thus flood control, irrigation channels, etc., representatives from public administrative bodies rather understand it in the context of 'organisational control'. To political scientists it has the connotation of 'political control' of water resources. Different notions according to different academic disciplines are summarised in the following table:

Tab 1: Three dimensions of water control

Dimension	*Association/meaning*	*Disciplines*	*Example references*
Technical control	Guiding-manipulating-mastering of physical processes	(Civil) engineering, soil mechanics, hydraulics, hydrology, agronomy, meteorology, agro-ecology	Plusquellec, Burt and Wolter (1994:35)
Organisational control	Commanding-managing of people's behaviour	Management science, extension science, public administration, organisation sociology	Hunt (199:144), Huppert (1998:35), Lowdermilk (1990:155)
Socio-economic and political control	Domination of people('s labour) Regulation of social processes	Political economy, economics, rural sociology, political science, social and cultural anthropology, gender studies, agrarian history	Stonde (1984:202), Boyce (1987:198-199, 229, 233), Enge and Whiteford (1989:5-7)

Source: Mollinga (2010a:5)

Boundary concepts support the development of a common understanding by associating similar meanings to the same words. This is understood as basis to enable communication between scientists from different disciplines, politicians and other actors that are involved in inter- and transdisciplinary research.

Boundary objects are considered the 'instrumental work for action'. They generally refer to all types of devices, methods, products and tools that facilitate communication between different actors about issues under dispute. One definition of boundary objects is as follows: they are scientific objects '*which both inhabit several intersecting social worlds (…)* and *satisfy the informational requirements of each of them. (…) Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weekly structured in common use, and become strongly structured in individual-site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds'* (Star and Griesemer, 1989). Though considered as important tools to facilitate communication and cooperation across boundaries, the concept of boundary objects still remains vague.

A first classification of boundary objects is presented in Mollinga's framework. It has been developed with a focus on scientific knowledge production to support political decision making in the field of complex and contested problems in natural resources management. Mollinga distinguishes three types of boundary objects, depending on their route of development: the **analytical route** leading to models as mediators, the **assessment route** with frameworks, matrices and flowcharts as outputs and the **participatory route**. In the analytical route modelling of complex system's behaviour is used to develop extensive 'decision support systems' (DSS) as one example of a boundary object. These shall support decision making under uncertainty. However, in short the success story especially for the developing world is described as limited, as *'many modelling and DSS development efforts are science driven not 'user driven'.* (Mollinga 2008 b). They miss to reflect the local cultural and political realities. In the assessment route, frameworks, matrices and flowcharts are used to communicate a problem and potential solutions – a path favoured by practitioners. Foreign organizations in the context of international development cooperation often follow a participatory route, for which an ample range of well developed methodologies and experiences exists. In the context of water resources management in the developing world this classification of boundary objects needs further development which is reflected in the following chapters.

Boundary settings refer to the structural conditions that shape the problem and the project. Mollinga puts a focus on research projects. The **internal boundary settings** relate to the dynamics and framework conditions in the direct context of a research project: how is the research project organised, how is research work distributed and knowledge shared among research partners? **External boundary settings** refer to the wider framework conditions in which the project is situated, e.g. the political regime, legal regulations, power divisions, underfunded governmental bodies, corruption, availability of skilled staff, staff continuity in public organisations etc.. By designing suitable boundary objects to approach a problem, the internal settings may moderately be influenced, however, the external settings are considered as almost unchangeable in the time-frame of a research project.

This classification into concepts, objects and settings may provide a suitable framework to systematically reflect upon and possibly merge prominent principles and elements of the leading approaches for water and natural resources management, to make them more coherent and feasible for implementation. The following analyses and reflections serve the development of a boundary framework for water resources management in the developing world.

6 Developing the Boundary Work Perspective for Water Resources Management and Research

6.1 Boundaries and Water Resources

Water is the basic resource for life and ecosystem health which leads to competition in water use, not only between humans and nature, but also between humans of different interest groups. Problems in water availability, allocation as well as quality are prevailing primarily in the developing world and, as stated before, water is a highly contested and politicised resource. The water sector is characterised by social barriers between multiple actors, which need to be blurred to allow for integrated management and research in a holistic manner. Water management and research has to deal with boundaries of scale: catchments do not confine themselves to administrative borders of states or nations. Promoting management and research that is oriented at catchment boundaries may ask for approaches that cover two to multiple nations in need to coordinate their efforts. Here barriers between political systems, cultures and power-relationships shape the arena. If a catchment fully lies within national boundaries, the approach may still have to deal with different states, their respective administrative bodies and interests.

Within a nation, cultural, cognitive or institutional boundaries further exist within and between the different actor-clusters of government, civil-society or non-state actors and science that all actively involve in water issues of all kinds (see also chapter 3). The action-cluster of government is characterised by a vertical structure, reflecting governmental bodies on national, regional and local scale that may or may not cooperate well with each other. On a horizontal structure barriers exist between public agencies on the same scale of governance, but of different sectors. Many sectors apart from water are involved in water management and use. This covers environment, agriculture, industry and private households. Ministries or departments of the same level of governance but from different sectors may not be willing to cooperate with each other on water issues.

Society in this definition encompasses civil society[5] - here understood as non-governmental organisations, private entities, community based organisations and individuals, as well as the economy and the environment. As boundary work is dealing with societal barriers, the focus is on barriers between the different interest groups; the economy and the environment need to be considered in the context of framework conditions – thus boundary settings – that hamper or support project implementation. Each group or organisation of civil society has its own perceptions, values, cultures, objectives

[5] While society in a general interpretation actually includes science and government, it is here used in a simplified understanding, referring to 'non-state' and 'non-scientific' actors.

and norms and barriers may be strong, as experienced especially between industry and civil society organisations.

In science multiple barriers exist between disciplines and sub-disciplines: The scientific world is organised in disciplines (e.g. biology, geology, chemistry, economics, history etc.), structured along the three categories of natural science, social science and life science.[6] Within these disciplines further sub-division takes place into different fields of specialisation, e.g. botany, zoology, hydrogeology, soil science etc. Specialisation goes on and on, and sub-sequent specialisation can e.g. cover subjects like 'irrigation practice in the sub-tropics' or 'spatial planning in rural areas in Indonesia'. Interdisciplinarity now refers to 'working across barriers of different disciplines', which according to the categorisation above can occur on different levels: blurring barriers between a) the three main categories, (e.g. social scientists and natural scientists), b) different disciplines within these categories (e.g. geologists and botanists) and c) different fields of specialisation within these disciplines (e.g. hydrogeologists and soil scientists) (following Mollinga, 2008a).

While specific barriers are encountered within each actor-cluster, major boundaries also exist between the clusters, thus between government and science, government and society and science and society. Government ideally should base governance on the needs of the society. In a democratic system, society in turn critically reflects government action and legitimates or denies it. Science, ideally, supports political decision-making by providing salient, credible and legitimate knowledge (see also chapter 6.7). These barriers – or interfaces – are reflected by Turton et al (2007:17) and shall here be cited in full length:

'The Government-Society interface determines the needs and requirements of society, the legitimacy of the political process, and the permeability of government to new ideas from civil society and the corporate world. The interface also represents the degree to which the needs of society are satisfied by government;

The Government-Science interface determines the extent to which science and technology form the basis of the political economy, and the extent to which scientific knowledge informs the decision-making processes that are a core function and output of the government actor-cluster. Government facilitates and enables the scientific processes through policy initiatives, resource allocations and overall strategic direction. This interface is critical as it has major implications for social stability and economic growth, making it a key issue for effective governance in the developing countries with fledgling democracies; and

The Science-Society interface can be thought of as science in the service of society, consisting of a number of elements, including the way that scientific knowledge is diffused into so-

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[6] Though not all disciplines can be fitted well into that scheme (e.g. law or mathematics), this structure has evolved historically and has not been changed so far.

ciety. In a developed country with a mature democracy this is visible as the technology-base of the economy. In developing countries with fledgling democracies, this is reflected in the effectiveness with which the science and technology-base is harmonised with the overall needs of society, and becomes a key determining factor in the success of the emerging economy as it overcomes historic and structural comparative disadvantages.'

In the developing world another actor-cluster needs to be added: the international (donor) organisations with their individual underlying schools of thought and interests. While ideally they may be 'drivers of change', through facilitating knowledge-generation and transfer as well as finance, they can also considerably disturb the local system by intervening into local political affairs or by non-harmonised action within the donor actor – cluster. Interference or cooperation of international governmental, non-governmental or scientific organisations exists between all before mentioned clusters in the local context: Governmental agencies cooperate with governments, international universities involve with local universities, private companies involve with government and science actors, NGOs with science and society etc.

When approaching complex and contested water problems it is of fundamental importance to reveal the existing barriers in the local context and to classify them into barriers that may be blurred in the framework of a development or research project and barriers that need to be accepted as unchangeable, based on lack of legitimacy to involve and of resources in terms of qualified staff, time and financing of the project.

6.2 The Boundary Work Framework and IWRM

6.2.1 Boundary concepts and IWRM

As outlined in detail in chapter 2.1, the principles of the holistic perspective of IWRM can be summarised as follows: IWRM claims to base management solutions on the integration of all concerned actors and natural resources that are involved in the water cycle in a catchments-based approach. All stakeholders should have the possibility to get actively involved in the decision making process. This shall warrant a greater acceptance and legitimacy of management decisions. IWRM itself could serve as a boundary concept. However, as interpretations of what it implies strongly vary, it is not yet ready to function as boundary concept without further harmonisation of its principle meanings.

6.2.2 Boundary Objects in IWRM

Trying to foster practical implementation of IWRM, GWP has developed a complex toolbox for knowledge sharing and capacity building (http://www.gwptoolbox.org). The toolbox consists of around 50 tools for implementation of IWRM, around 200 case studies illustrating how the tools work in practice and an ample range of reference materials (support documents, annuals, papers, external IWRM databases). Apart from serving as dissemination platform for IWRM, it shall enable decision-makers to make informed and rational choices for sustainable water governance or management. It does not aim for a 'one-size fits all' solution or blueprint for IWRM, but for the development of individual solutions for specific water governance or management problems acknowledging the prevailing local conditions.

The tools are organised within three categories: a) the enabling environment (through policies, legislative framework and financing and incentive structures), b) institutional roles (creation of appropriate organisational frameworks and institutional capacity building) and c) management instruments[7]. Starting from the individual problem - e.g. allocation problems and user conflicts, water scarcity or water quality deterioration - decision makers can chose a suitable mix and sequence of tools addressing their specific problem. Though providing a comprehensive overview on topics that may be considered when analysing and approaching water problems, it requires high-level water experts and resources to be able to process and implement these tools. The 'toolbox' can rather be considered as knowledge base for information sharing among high-level water experts than for enabling decision makers to work with it without external consulting.

However, in the context of boundary work for the water sector, the toolbox provides as a first step a comprehensive overview of areas of concern in water resources management and as a second step many secondary sources and supporting documents to learn how to approach concrete issues. The overview about areas of concern can be used to support problem identification and problem structuring. The secondary literature – varying in its quality and quantity according to the diverse topics – may then support the structured development and implementation of processes and products to approach the problem.

6.2.3 Boundary Settings and IWRM

Two critical aspects of the holistic IWRM perspective shall further be enlightened: the principle idea of a fully participatory approach towards planning and management and the role of the political regime in IWRM. One of the most challenging ideas reflected through IWRM is that an inherently transdisciplinary planning and management approach should in all stages be implemented in a participatory manner, giving all concerned stakeholders the right and possibility to get actively involved in planning and management to jointly develop sustainable solutions in areas of conflicting interests. This idealistic and ideological approach on 'how IWRM should be' - following a Habermasian logic - has often been criticised as not applicable in real-life cases. IWRM can be regarded as 'society centred framework or policy process', assuming the presence of societal groups, which are contesting current water policies and management approaches

[7] Management instruments are categorised as follows: water resources assessment, IWRM planning, demand management, social change instruments, conflict resolution, regulatory instruments, economic instruments and knowledge and information management

and are actively and critically involved in sector-specific policy debates. Whereas Grindle (1999) shows that often developing countries may rather be characterised by 'state centred' policy processes which are characterised by low level or absence of active public engagement, as for instance in (semi-) authoritarian regimes. IWRM is furthermore based on assumptions on an 'ideal speech situation', in which all affected stakeholders have the room and right to participate in the discourse, without being inhibited by prevailing power distribution (Saravanan et all., 2008; Alexander, 2001:313). This as well is not given in state-centric or (semi-) authoritarian regimes.

Whether or not the strictly participatory IWRM approach is instrumental for achieving sustainable water resources management in developing countries strongly depends on the prevailing local political system and culture. Critics of the idealistic IWRM-approach - following a Focouldian logic - emphasise that integration of all stakeholders is diverse and is a political process (Hofwegen and Jaspers, 1999; Allan, 2006, Saravanan et al., 2008). To aim for real-life solutions, this idealistic approach should be combined with 'strategic action' approaches, acknowledging the political dimension of water resources management in the diversity of actors, power-relations and interests. A realistic and contextual analysis of prevailing power dynamics seems to be a pre-condition for appropriate adaptation and application of the concept. Overarching regime aspects and power relations need to be considered when analysing the 'external boundary settings', or else, the framework conditions in which the project and the problem are set. This helps to reveal limitations to change.

In addition to the required consideration of regime aspects, in developing countries deficiencies in what is called 'the enabling environment' are rather typical and the water sector is often characterised by fragmentation, inadequate institutional and administrative structures with unclear roles and responsibilities, inadequate regulatory mechanisms, lack of data and information and last but not least lack of continuity in staff. Competing institutions (ministries, departments, state-, regional and local governments) claim legitimacy for their existence and may not be interested in knowledge sharing and joint management of water resources. This as well may be covered under the concept of 'external boundary settings'. Working on an 'enabling environment', or trying to influence these boundary settings through adapting laws, policies and financing mechanisms provide the framework for successful IWRM. However, these are slow processes that may take many years to decades – generally longer time frames than a projects' lifespan. Depending on the task, scale, objective and duration of a project, they need to be considered as given or 'unchangeable' and limiting conditions. It further needs to be reflected to what extent - if at all – externally financed projects are legitimated to get involved into changing these framework conditions in the local context.

Developing the boundary work perspective for water resources management in the developing world needs to face up to the bias among participatory reform approaches and state-centred realism. The analysis of external boundary settings as described above helps to reveal limitations and limits to change and to design the process of project implementation in a contextualised manner – thus with a higher or lower level of participation, according to the local culture.

6.3 The Boundary Work Framework and AM

6.3.1 Boundary concepts and AM

As outlined in chapter 2.2, the **Adaptive Management** (AM) approach adds important principles to the IWRM perspective: it acknowledges that human-ecosystems are complex systems that are characterized by uncertainty. AM thus acknowledges the need to structurally merge management with research models to enable decision makers to take decisions based on scientific policy advise. Sound management of complex systems requires structured learning and research, which is facilitated through field science as well as experimentation. The principle of integrating management and research into a single approach can add to the IWRM perspective, which so far does not include structured approaches for knowledge generation.

6.3.2 Boundary Objects in AM

AM is an approach, in which in a structured learning process knowledge improvements in environmental, socio-economic or technological fields and learning from previous management actions is taken to improve the next stage of management (Holling, 1978; Walters, 1986). This is based on a participatory and inclusive management approach. Ideally, committing to a joint process of structured learning, reflection and adjustment may even support mediation and cooperation between conflicting stakeholders.

AM can be split into the two streams of passive AM and active AM. Both paths, active and passive AM, reflect 'boundary objects', be it in terms of (participatory) processes that aim for social and institutional learning or through the development and application of products and tools, like models and experiments, that help to communicate problems, bridge perceptions and support common decision making between various actors. Passive AM *'formulates predictive models of ecosystem responses to management actions, bases management decisions on model predictions, and uses monitoring data to revise model parameters'* (Walters and Hilborn, 1978). In Passive AM, historical data is usually used to model trends and propose one single course of action. Outcomes are monitored and evaluated and the course of action is adjusted, if new information is available. It can be considered as 'trial and error' learning, which can not be afforded in water resources management, as the potential 'error' implies serious and irreversible threats for human well-being and the respective ecosystem.

While passive AM sets more on modelling, active AM better reflects the contextualisation of problems through real-life *experiments*. Alternative management options e.g. the implementation of new policies, are proposed and tested in small- to large scale experiments. Monitoring and evaluation of the consequences may allow an interpretation, whether or not the specific policies or approach in the pilot projects are suitable to achieve the desired outcome or if adjustments are needed. It then bases new management decisions and action on the outcomes of these experiments. However, while active AM provides more information on possible outcomes of alternative management decisions, it is - depending on the scale to be addressed - resource intensive in terms of costs and staff involvement. It further requires close cooperation between different actors, willing to jointly learn and act on new knowledge. The approach can be reflected in a structured learning cycle:

Figure 3: The structured learning cycle

Source: Medema, W. and Jeffrey, P., 2005:25, adapted from National Oceanic and Atmospheric Administration Coastal Services Center)

The first proponents of AM as a matter of principle did not want to provide operational guidance how to implement AM, as this was assumed to diminish the intended flexibility. However, in course of time still a generic approach for AM has emerged. The Generic Adaptive Management Process, as describe by Ohlson (1999), can be summarised as follows (for a quotation in full length see Annex 2):

1. Define problem boundaries
2. Identify key uncertainties
3. Choose ecosystem indicators
4. Generate alternate hypothesis
5. Design management experiments
6. Implement and monitor
7. Feedback results

Translating this into more specific action includes the following steps to be continually repeated:

1. *'Establish a stakeholder adaptive management team*
2. *Define the problem(s) to be addressed*
3. *Establish goals and objectives*

4. *Specify a conceptual model that expresses the collective understanding of how the system in question functions, highlighting key uncertainties and acknowledging factors that are outside of the system*
5. *Develop hypotheses about the effects of different management actions that address the uncertainties*
6. *Design management experiments/interventions to test hypotheses while meeting management goals*
7. *Design a monitoring plan to measure the impact(s) of management interventions*
8. *Implement management interventions*
9. *Monitor*
10. *Evaluate the impacts in terms of management goals and hypotheses*
11. *Reassess and adjust the problem statement, goals, conceptual model, interventions, and monitoring plan.'*

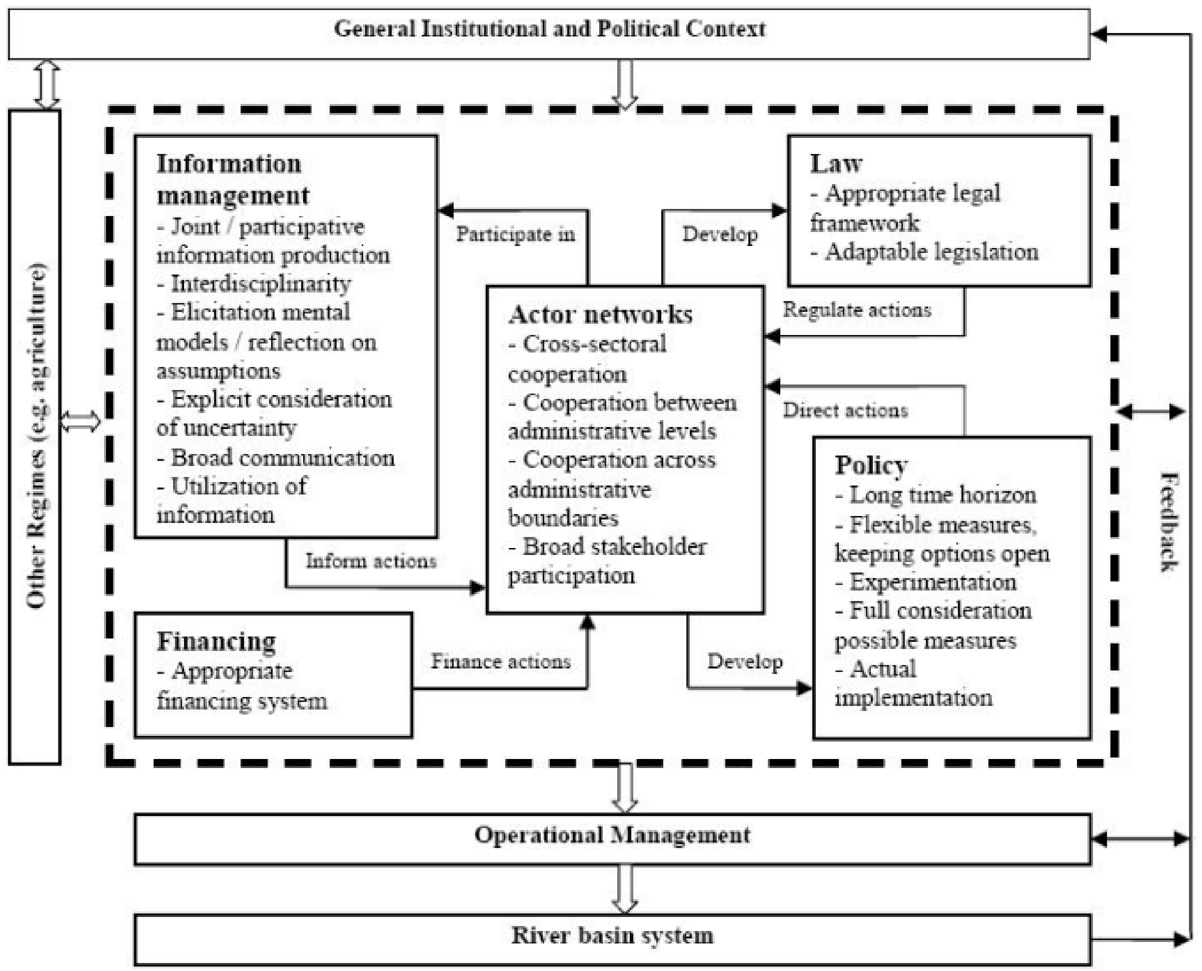
(Source: Medema, W. and Jeffrey, P., 2005:25, following: Levine, 2004; Johnson, 1999; Parma et al., 1998; Walters, 1997). *'As a result of this cyclical learning process, the focus is on response and scenario building based on the monitoring of carefully defined indicators of system state and behaviour rather than on long-term prediction from first principles or past statistics and information'* (Clark and Gardiner, 1994).

For implementation of the processes various tools are available, covering small- to large scale field experimentation, ecosystem modelling and transdisciplinary stakeholder workshops to analyse and reflect upon prevailing problems and outcomes of management experiments, to redefine targets and to jointly adapt the course of action (for details on tools in AM see Annex 3). The generic processes as described above are boundary objects themselves, such as the concrete tools as presented in Annex 3. In a next step, the processes serve as input for the development of a methodology how to approach complex natural resources management problems and develop the instrumental work for action, as proposed in chapter 6.6.

6.3.3 Boundary Settings and AM

Reflections and studies that have been conducted in the field of in AM may be of further support for the structured analysis of conducive or hindering boundary settings. Raadgever et al (2008) have developed a framework for assessing the adaptive capacity of regimes in transboundary river basin management. While the focus is on the international and transboundary level, all elements also apply to national or local scale. Raadgever et all have identified five key features of (adaptive) transboundary management regimes: actor networks, water law, water policy, information management and financing systems. For each element, the authors provide further explanations, examples, criteria and indicators for assessment of the local framework conditions. An overview on relations is given in Figure 4:

Figure 4: River basin management regime and criteria for adaptive management



Source: Raadgever et al, (2008:4)

Without going into further detail now, the framework may serve for reflections on boundary settings for concrete local water issues and a contextual analysis of supporting or hindering factors for the project. A comprehensive overview about the framework is given in Annex 4.

6.4 The Boundary Work Framework and EA

6.4.1 Boundary Concepts and the Ecosystem Approach

The Ecosystem Approach reflects a paradigm shift in natural resources management from protected area management to a holistic management perspective, acknowledging that ecosystems apart from their intrinsic value provide goods and services to the people. It is a general strategy that supports balancing the needs for human development with ecosystem health, based upon principles of fairness and equity. It aims for both: protection of natural resources as well as their sustainable use in an adaptive and flexible way. EA provides twelve principles that outline the theoretical basis of the approach (see Annex 5). They all may apply also for integrated water resources management. For applying the twelve principles, further 'steps' are proposed as operational guidance (Annex 6), however, they rather reflect additional principles themselves. Human well-being is reflected as overarching principle and objective. This shall be adopted to the boundary work framework, when thinking it through in the context of sustainable water resources management.

6.4.2 Boundary Objects in the Ecosystem Approach

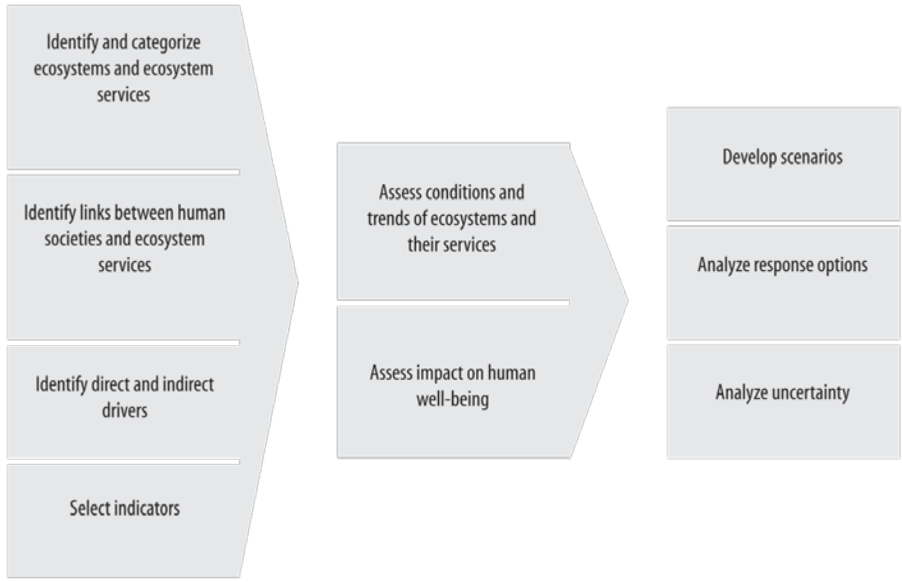
The EA provides not only operational guidance and tools for its application, but also further experience through the process of the Millennium Ecosystem Assessment (MA). When applying the EA, five steps are proposed, which themselves constitute a boundary object in term of a process, but also provide input for the reflection of a generic methodology to develop instrumental work for action in natural resources management problems. The steps cover:

1. Problem definition;
2. Identification of the tasks required to meet the identified problems (the twelve tasks to be reflected are presented in detail Annex 7);
3. Addressing crosscutting issues, such as capacity building and participation; information, research and development; monitoring and review as well as governance;
4. Creating a management plan;
5. Implement the management plan or the project.

The focus is on management and implementation, less on research to adequately address knowledge needs in a transdisciplinary approach. Here approaches from Transdisciplinary Research may considerably add to the Ecosystem Approach and its potential use for boundary work in water resource management.

Additional conceptual work that may support the development of boundary objects and decision-making in complex WRM problems is reflected in the Assessment Framework for the MA (WRI, 2003). The framework shall serve decision makers as mechanism to '*identify options that can better achieve core human development and sustainability goals; better understand the trade offs involved - across sectors and stakeholders in decisions concerning the environment and align response options with the level of governance where they can be most effective.*' The analytical steps to be conducted cover the following:

Figure 5: The analytical approach of the MA



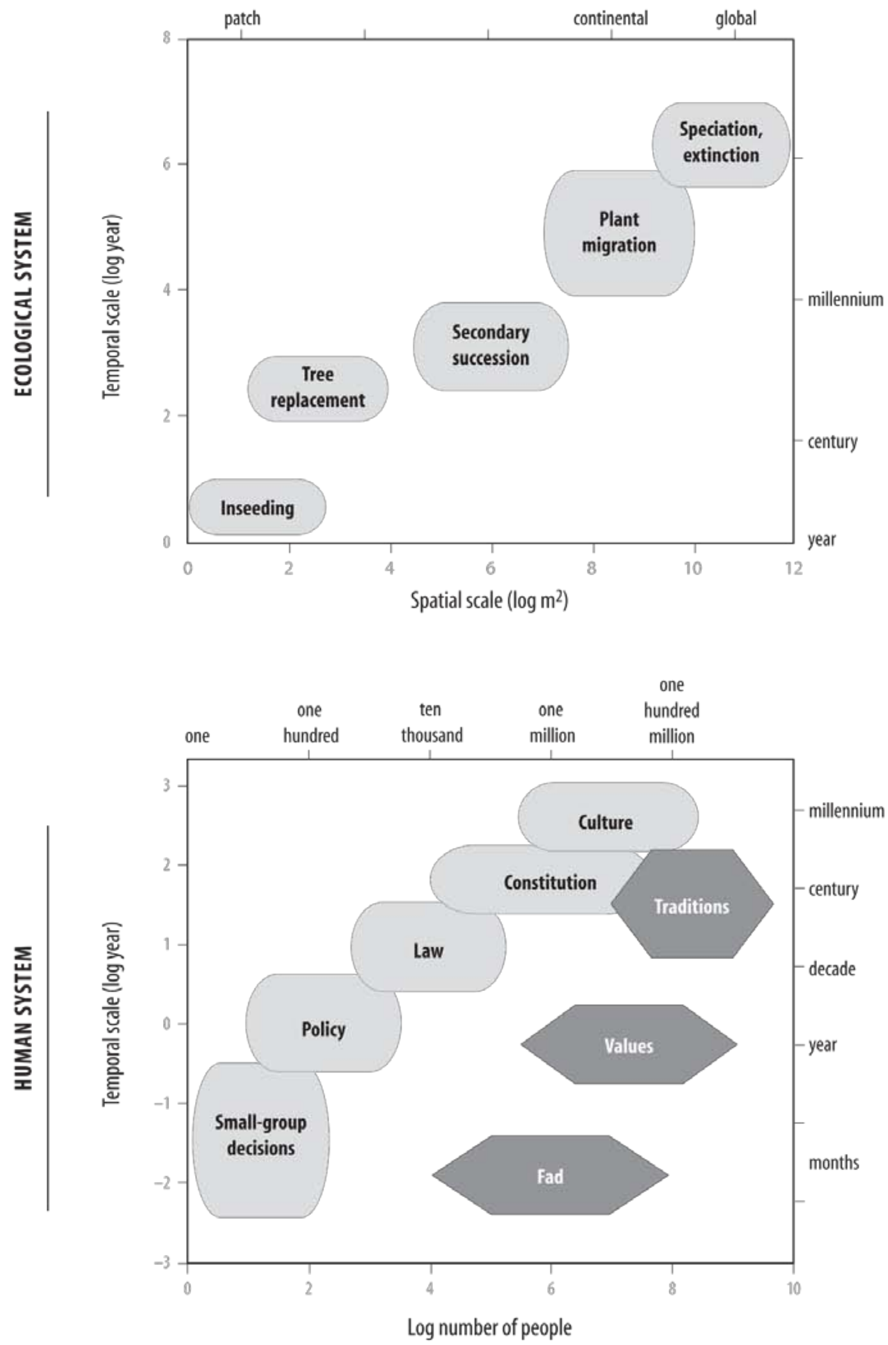
Source: WRI (2003:149)

For details on the nine tasks see ANNEX 8. However, scenario development, analysis of response options and analysis of uncertainty are then approached through extensive modelling exercises in the fields of environmental system modelling and human system modelling. If and to what extent modelling is an appropriate and required boundary object in water resources management strongly depends on the local problem to be addressed and the available resources in terms of staff, time and money and needs to be assessed in the specific local context.

6.4.3 Boundary Settings in the Ecosystem Approach

Some reflections in the context of this framework for assessment may proof to be suitable for the analysis of Boundary Settings. The MA applies a multi-scale approach, whereas 'scale' describes the physical dimension of a process or an issue, in space or time. '*A multiscale approach that simultaneously uses larger- and smaller-scale assessments can help to identify important dynamics of the system that might otherwise be overlooked. Trends that occur at much larger scales, although expressed locally, may go unnoticed in purely local-scale assessments*.' (WRI, 2003). Reflections on space and time scales of ecological and social processes can help to reveal limits for change during a projects' life span. While some processes like small-group decisions can be implemented in relatively short periods of time (according to Figure6 in periods between months and one year), the change of 'the enabling environment' in terms of policies, laws or even culture and traditions may span decades to a millenniums.

Figure 6: Time and space scales for selected ecological and social processes



Source: WRI (2003:116)

It is thus worthwhile to analyse cultural, political, legal and institutional framework conditions in complex water resources management issues in the context of their spatial and time dimension to reveal potential changes during a projects life span. If they lay within spatial or timeframes that are beyond the projects conditions, they need to be acknowledged and reflected as limiting factors for change.

6.5 Developing the Framework

The boundary work framework is a first step to generally structure boundary work processes. Based on principles and methods from selected leading approaches for natural resources management (IWRM, AM and EA), as well as the requirement to merge aspects of water governance, the following subchapter contains reflections and proposals how to further develop the framework according to the needs of water resources management in the developing world.

So far boundary work literature either focuses on the analysis and blurring of policy-science interfaces or in general on the demarcation between 'science and non-science'. It does not systematically incorporate aspects of government-society relationships to reveal political framework conditions that considerably influence the success of a development- or research project. As water is a highly politicised medium, the development of sustainable solutions also needs to consider barriers and interfaces between government and society. According to the reflections of chapter 3 on water governance and chapter 6.1 on barriers in water management, it is thus proposed to develop the framework by discussing barriers and interfaces according to the actor-clusters of government, science *and society*:

Barriers should be analysed on two levels: a) barriers within each actor-cluster and b) barriers between the three actor clusters. Barriers should further be classified according to their societal background: they can be institutional, cognitive, cultural or else.

Revealing **boundaries (and interfaces) between science and government** that sets framework conditions for science **and between science and society** that supports knowledge generation beyond academic limitations helps to analyse preconditions for successful transdisciplinary research. An appropriate process mode for knowledge generation in water management should systematically consider these linkages.

Analysing **barriers (and interfaces) between government and society** supports the understanding of political framework conditions that shape the project and helps to appropriately contextualise it. They define ways, how good governance can be designed and they influence the possible modes of knowledge generation. Revealing these barriers further helps to understand and consider limits to participatory approaches, as they may not be in line with local governance practice and enforcement can hamper successful project implementation. Apart from following a dogmatic 'blind-alley' for participation at any means and without appropriate contextualisation, development and research organisations also need to reflect their legitimacy to involve into local governance practice. Analysing the government-society barriers provides a basis for these reflections.

Considering requirements for transdisciplinary research and conditions that support or hamper project implementation in the context of complex water management problems thus asks for a balanced reflection of boundaries between government, science and society. The boundary work processes that follow this analysis should then support a balanced trialogue between these actor-groups.

6.5.1 *Boundary Concepts and WRM*

In the boundary work framework, 'Boundary Concepts' refer to the requirement of a common understanding as well as a commonly used terminology to solve problems in an inter- and transdisciplinary way. Reflecting the idea on 'boundary concepts' in the context of water resources management reveals two different types of required boundary concepts: a common understanding of **principles** that apply for sustainable water resources management as well as a common interpretation of the **terminology** used. Only if actors apply the same principles and associate the same meaning with the same words, communication and joint problem solving can be possible. The scope of boundary concepts for water resources management should thus be twofold:

Boundary Concept on Principles: As described in detail in chapter 2, there exist multiple attempts to define principles for sustainable water resources management. Though IWRM can be considered as leitmotiv for WRM, also this concept has many different notions. It can thus not be assumed that even the basic principles are commonly shared by the different stakeholders when discussing, what IWRM or 'sustainable water resources management' implies. Further, even the holistic understanding of IWRM as reflected through GWP has shortcomings in terms of relevant principles: this requires in the first place conceptual tuning on *principles.* A proposal for a concept for WRM is made in the following:

- According to the holistic understanding of IWRM, water resources planning and management should be based on an *integration of water, land and all related resources.* Their development and management shall *integrate all concerned actors and sectors* – be it experts or laypersons – and shall be based on *catchment boundaries* rather than administrative borders (see chapter 2.1).

- AM adds the following principles: *Uncertainty* in understanding human-ecosystem behaviour needs to be considered when developing sound management solutions. Acknowledging uncertainty and knowledge needs requires *merging management with research approaches* and modes of 'structured learning'. These combined approaches need to be flexible enough to allow changing the course of action, if new knowledge is gained in the research process (see chapter 2.2).

- Sustainable management of natural resources implies balancing the needs for *human development* with *ecosystem health* - or the *use of natural resources* with the *protection of natural resources,* based upon principles of *fairness and equity* (see chapter 2.3).

- Following the EA, the *overarching principle* for management of water and other natural resources is the aim for *human well-being.* (see chapter 2.3)

Boundary Concept on Terminology: When tackling a local issue, common interpretation of the core terminology needs to be assured. Which concrete wording this implies depends on the prevailing problem; apart from 'water control' other examples for concepts are e.g. 'value' or 'fairness and equity' in the context of water pricing, 'risk and vulnerability' in the context of water supply, 'efficiency' in the context of water use, 'sufficiency' regarding water quantity etc.

6.5.2 Boundary Objects and WRM

As described above, Mollinga's classification differentiates between three types of boundary objects. Depending on their route of development, this covers models as mediators (analytical route), frameworks, matrices, flowcharts (assessment route) or participatory approaches (participatory route). However, boundary objects in their general definition cover more than what is classified according to this framework. Boundary objects are all tools, devices and methods that *'sit between two different social worlds, such as science and non-science, and they can be used by individuals within each for specific purposes without loosing their own identity'* (Guston, 2001).

Reflecting the type of boundary objects that are comprised in the selected three chore approaches for natural resources management as well as discussed in literature on boundary work, a new classification system for boundary objects is proposed here. Boundary objects can be categorized in terms of organisations, processes, tools and products:

Organisations: Much of the literature on boundary work and boundary objects actually focuses on entire *organisations or institutions* that serve as bridge, mostly between science and policy or government (see e.g. Guston, 2001; White et al, 2008; Miller, 2001; Agrawala et al, 2001; Cash, 2001; Keating, 2001; Huitema and Turnhout, 2009). However, boundary organisations may also bridge between other social worlds, such as science and society or policy and society, which has so far not been reflected in the context of boundary work. These organisations are then called 'boundary organisations' or 'boundary institutions'.

Most case studies retrospectively analyse, how boundary organisations have evolved and what were supporting and hindering factors. Examples for boundary organisations are e.g. the Netherlands Environmental Assessment Agency (MNP), working on scientifically valid policy assessments and evaluations for policy and politics in environmental fields (Huitema and Turnhout, 2009) or the U.S. American Health Effects Institute (HEI) that is meant to bridge between air quality debates and health effect debates. Its origin stems from conflicts between the automobile industry and the U.S. Environmental Protection Agency (EPA) on the technical feasibility of emission standards for automobiles as well as the scientific basis for the National Ambient Air Quality Standards (NAAQ) (Keating 2001). While boundary organisations in these analyses mostly just link policy and science, it is of question, how the public or civil society could stronger be involved. This is required when reflecting an approach of a critical and **public** sociology of water resources management (see also Mollinga 2008c, d). While some authors rather focus on the historical evolvement of boundary organisations, others focus on different types of boundaries, such as institutional, ideological or cultural boundaries and analyse how to reflect and approach them (see Paulsen and Hernes, 2003). Here experience from the field of management science may also add to the boundary work perspective.

Apart from entire organisations, also *groups and individuals* can serve as boundary objects. There was no literature found analysing the role of groups or individuals in the context of boundary work, however, in practical experience many processes on bridging barriers between different actors are initiated by one or more individuals that are technically and culturally respected by the different sides.

Processes: Boundary objects can also refer to entire *processes* of project planning, development, management and / or implementation, be it in fully participatory manner or else. Processes can serve as mediators between the actors involved, reveal diverging interests, support mediation but may also increase barriers, if not all actors of concern are included. Here the original classification of boundary objects in Mollinga's framework fits: different processes (analytical, assessment, participatory) lead to different outputs or products – which themselves serve as boundary object. Adaptive Management or Transdisciplinary Research are boundary objects in terms of processes that support knowledge generation.

Especially with regard to participatory processes an ample range of literature exists on experiences, methods and tools. As described previously, the appropriateness of process solutions has to be considered in the light of the political regime and governance practice of the specific country.

Tools: Tools are devices that help to carry out a particular task. There exist an uncountable number of tools to approach water problems. Classification can be oriented along the structure of the GWP toolbox for IWRM (see chapter 2.1) and be linked to the boundary work framework: tools to support the development of an enabling environment can be used to supporting the 'stretching' of external boundary settings; tools to create appropriate organisational frameworks can support the design of internal boundary settings or the structured development of boundary organisations; the tools proposed under 'management instruments' cover a broad range of aspects of assessment, planning and management of water resources.

Products: Institutions and / or individuals generate *products* to communicate about a problem or a situation. These products present knowledge and information in words, figures or graphics, e.g. through models, indicators, pictures, articles, reports, flowcharts, diagrams etc. They may reflect and picture the current state, ongoing developments, perceptions of different stakeholders, framework conditions, management options or possible outcomes of management action. These products help all parties to better understand an issue; they support communication and facilitate the discussion.

Conjunction of organisations, processes, tools and products: None of the above categories implies boundary objects that can stand-alone. They always are, have been or will be related to one or more of the above categories of boundary objects in the process of approaching a complex problem. E.i. every boundary organisation has a history – a process that brought conflicting parties together and ended up in the decision of setting up this institution, agreeing on funding schemes, lines of responsibility etc. Often these processes were initiated by individuals that started to bridge between different social worlds. Communication was most probably facilitated through the development products, in terms of presentations, reports, models etc. that served as basis for discussion and mediation. Products are developed through the application of tools.

6.5.3 *Boundary settings and WRM*

In the boundary work framework 'boundary settings' are analysed in the context of research projects: internal boundary settings refer to the set-up between the involved research groups, external settings to the outer framework conditions of the project. Water resources management problems require combined research and management approaches, thus it is required to convey the idea of boundary settings not only to research but also to development projects.

While the shaping of internal boundary settings are of utmost importance for the effective implementation of development and research projects, the focus of this reflection lies on the analysis of external boundary settings in water resources management. Internal boundary settings can still be influenced during project implementation, while the analysis of external boundary settings helps to reflect limitations for change at the early stage of project design, as these are considered as unchangeable in the given time.

The necessity to think political regime aspects through when designing management and research projects has been discussed in detail in chapter 3. In this context the structuring of barriers according to the actor-clusters of government, society and science helps to identify, where limits and limitations to change may be encountered during the course of project implementation. Some reflections on the connection between regime aspects and their limitations for effectively bridging the barriers between government, science and society in a development context have been made by Linda Gofrey in Turton et al (2007): The 'strength of engagement' between the three actor clusters is presented in three models, differentiating between an 'undemocratic society' (model 1), a 'young democracy' (model 2) and a 'maturing democracy' (model 3).

In an 'undemocratic society' the interrelationship between government and society as well as between government and science are usually weak. Engagement with the government shows little success and governance is strongly ruled by the government only. In a 'young democracy' government and society strongly interact, as the new government needs to assure transparency and accountability to maintain acceptance and legitimacy. However, it is noted that the connection between government and science as well as between science and society are not equally strong. The reasons for this can only be hypothesised and may vary between different countries. Depending on the role that science had played in the previous non-democratic regime, there may be no trust in the scientific community by society. To claim legitimacy, the government thus may not like to be associated with science. This is just one hypothesis of several that try to give hints for the reason of the week role of science in young democracies. However, in a 'maturing democracy' the interaction between government and society is getting weaker, while the acceptance of scientific actors by government and society is increasing. This is just a brief overview on the influence of regime aspects to the quality of engagement between different actor clusters.

It terms of practical guidance for the analysis of external boundary settings in water resources management I propose to orient along the 'framework for the assessment of the adaptiveness of management regimes in river basin management' as developed by Raadgever et al (2008). The criteria provided require the analysis of actor networks, legal frameworks, policy, information management and financing mechanisms (for details see chapter 6.3 and Annex 4). To illustrate limits to change, the results can also be brought into context with spatial and time scales of socio-ecological dynamics, as presented in Figure 6.

6.6 Designing a Boundary Work Process

Having discussed the boundary work framework in the context of water resources management, the question is now: How can the boundary work framework be used to design boundary work processes from scratch for enhanced water and other natural resources management problems in the local context? And further: How can 'instrumental work for action' - thus contextualised boundary objects - be developed for a specific case?

Here the approach of transdisciplinary research (TR) as proposed by Pohl and Hirsch Hadorn (2007) may support the structured reduction of complexity and the development of tailored solutions (see also Mollinga 2010b, who exemplary thinks the approach through in the context of a water pollution and health research project in India). TR has four underlying principles that shall support reduction of complexity:

1. Reduce complexity by specifying knowledge needs and the actors involved
2. Achieve effectiveness through contextualisation
3. Achieve integration through open encounters
4. Develop reflexivity through recursiveness

Transdisciplinary Research is conducted in an inherently recursive procedure, i.e. it is based on an iterative process in which concepts and methods are repeatedly tested. This allows to test underlying principles, assumptions and approaches in 'real-life- experiments' and to adapt them, if it is found that they do not further reflect reality or are not anymore target oriented. So far these principles are also in line with the requirements of adaptive management, as described in chapter 2.2. The transdisciplinary research process consists of three phases to be repeated over time:

Phase 1: problem identification and problem structuring. It aims at reducing complexity by identifying the relevant actors, the prevailing problem and the corresponding framework conditions. To structure the problem, the main question has to be divided into sub-questions.

Phase 2 (problem analysis) the sub-questions will be handled and answered in a reflexive procedure.

Phase 3 (bringing results to fruition) is implemented during the course of the research process through continuous implementation of outcomes from Phase 2. Monitoring and evaluating the impacts of these activities allows for an interpretation, whether or not the research community is still on track to solve the prevailing problem.

And three kinds of knowledge are necessary to design the process (Hirsch Hadorn et al, 2007): 1) Systems knowledge - knowledge about the genesis and possible development of a problem and about interpretations of the problem in the life-world; 2) Target knowledge - knowledge to determine and explain the need for change, desired objectives or improved practices; 3) Transformation knowledge - knowledge about technical, social, legal, cultural and other possible means of acting to transform existing practices and introduce desired ones.

Pohl and Hirsch Hadorn suggest different tools to put the four principles into practice. In the following, I reflect these in the context of the boundary work framework and complement them by insights, processes and tools from IWRM, AM and EA. Preconditions or principles for TR are given by Pohl and Hirsch-Hadorn. They state that '[*t*]*here is a need for TR when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them.'* This holds true for almost all problems in water resources management (see also Mollinga 2010b). It can be assumed that this is encountered, if different stakeholders are actively (and controversially) engaged in a certain issue.

Phase 1: Approach Boundary Concepts and Boundary Settings – Analysis for the 'real-life case'

I refer to boundary concepts in terms of principles and terminology. Boundary settings are considered the internal and external framework conditions that shape the project and the problem. Revealing underlying principles of core actors and identifying the wording that requires a harmonised interpretation in the context of the specific boundary settings is directly linked to the first phases of development- and research projects. As suggested in TR, this covers **problem identification and problem structuring** as well as **problem analysis**.

Complexity shall be reduced by identifying the relevant actors, the core problem and knowledge needs as reflected by principle 1 (*'reduce complexity by specifying knowledge needs and the actors involved').* By working on the development of a boundary concept for the local problem, the core problem will be concretised. To allow implementation of principle 2 (*achieve effectiveness through contextualisation)* the corresponding framework conditions, thus the boundary settings, need to be analysed. The knowledge needs for this first step cover generation of **system knowledge** as well as **target knowledge**. Three tools suggested by TR can be used to support this first step:

Tab 2: Tool 1-Indentifying the actors involved with regard to TR requirements:

Actors involved Requirements for TR	Actor A	Actor B	Actor…	Discipline A	Discipline B	Discipline…
Complexity of problems						
Diversity of perceptions						
Abstract and case-specific knowledge						
Knowledge and practices that promote what is perceived to be the common good						

Source: Pohl and Hirsch Hadorn (2007:30)

As TR deals with problems that require knowledge generation, there will always be a 'research question'. This may be a new thought for the design of development projects that hardly merge implementation with research approaches. There may be a specific reluctance to acknowledge knowledge needs and uncertainty in the context of development projects that - depending on the philosophy of the funding agency – may be obliged to guarantee achieving pre-defined results and impacts. Three guiding questions are given by Pohl and Hirsch-Hadorn to reveal assumptions that guide the research:

1. To what understanding of the genesis and possible development of a problem and life-world interpretations of it does the research question refer?

2. To what kind of need for change, desired goals and better practices does the research question refer?

3. To what technical, social, cultural and other possible means of acting does the research question refer?

Tab 3: Tool 2-Positioning the need for knowledge with regard to the three forms of knowledge

	Research Questions	Particular challenge	Questions to help with positioning
Systems knowledge	Questions about the genesis and possible development of a problem and about life-world interpretations of a problem	Reflecting on and dealing with uncertainties with the help of real-world experiments	2,3
Target knowledge	Questions related to determining and explaining the need for change, desired goals and better practices	Clarifying and prioritising diverse perceptions of targets and values, taking into account the common good as a regulatory principle	1,3
Transformation Knowledge	Questions about technical, social, cultural, legal and other possible means of acting to transform existing practices and introduce desired ones	Learning how to make existing technologies, regulations, and practices and power relations more flexible	1,2

Source: Pohl and Hirsch Hadorn (2007:40)

This tool is originally meant to classify the type of TR according to the focus of knowledge needs. In the context of the boundary work framework – and aiming at developing instrumental work for action, thus boundary objects – I aim for developing of transformation knowledge. However, to be able to develop tailor made boundary objects that support the transformation, first systems and target knowledge needs to be generated to 'achieve effectiveness through contextualisation'.

Tab 4: Tool 4-Embedding TR in the life-world

Questions about the impact model	Area of impact		
	Private sector	Civil society	Public agencies
What impact is intended?			
What existing needs, interest, technologies, regulations, practices and power relations need to be taken into account?			
What causal relationships are initially assumed?			
In what form and at what point in time can results be introduced in a way tailored for the target group?			
What are likely unintended impacts, and what 'probes' may reveal them?			

Source: Pohl and Hirsch Hadorn (2007:65)

Some further guiding questions to reveal systems knowledge could be: What is the concrete resources management problem to be addressed and how is it interpreted ('problem mapping')? Who are the main actors involved ('actor mapping')? What are the relationships, roles, responsibilities and power dynamics alike ('network mapping')? What are their perceptions and interests ('perception mapping')? What knowledge needs to be generated to approach the problem ('abstract and case-specific knowledge identification'). What generates the problem ('perception mapping')? What are the external and internal boundary settings (technical, social, legal, cultural, political)? Which modes of cooperation between different actors, thus boundary work processes, already exist? Which specific boundaries hamper problem solving?

Some further guiding questions to reveal target knowledge may be: What should be changed about the problem? Why should this be changed? What are the desired objectives?

An ample range of specific tools for these type of qualitative analyses is provided through the academic fields of social and political science and compiled at td-net[8] as well as complemented through IWRM, AM and EA. However, to be of effective use, the tools for analysis in the concrete case need to be selected and compiled according to a) the capacities and experiences of the staff involved in the project and b) the culture of the local people and their hierarchical and educational level. While e.g. 'actor mapping' and 'network mapping' are activities to identify the actors and their relationships, there are many different ways how to do this in the local context. In some cultures 'drawing and picturing exercises' in group work give a good insight about actors and relation-

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[8] See: www.transdisciplianrity.ch

ships, however these exercises may be totally inappropriate in other cultures or at higher hierarchical levels that 'do not want to fool around by playing games' and prefer to give their perspectives and perceptions through one-by-one expert interviews. The above reflections are meant to provide general guidance, but the specific tools of use in the specific context need to be identified based on the culture, educational and hierarchical level of the interviewees.

Phase 2: Develop suitable Boundary Objects

The development of boundary objects is closely linked to what in TR is considered as 'transformation knowledge'. Suitability of boundary objects needs to be considered in light of principle 2 ('*achieve effectiveness through contextualisation*') and principle 3: ('*achieve integration through open encounters*'). Two tools suggested by TR can be assigned to be of use for this task:

Tab 5: Tool 5-Embedding TR in the scientific environment

Strategic elements	Project phase		
	Problem identification and structuring	Problem analysis	Bringing results to fruition
Goals (scientific/science policy)			
Contents State of the art in relevant disciplines/ state of the art in transdisciplinary research/ future research areas/ need for institutional action)			
Addresses (disciplines/ transdisciplinary groups/ science policy actors)			
Forms (publications/organisations of conferences/ initiation of research programmes/ development of networks/ writing of official statements)			

Source: Pohl and Hirsch Hadorn (2007)

Tab 6: Tool3-Forms of collaboration and modes of integration

Modes of integration	Forms of collaboration		
	Common group learning (search for some-thing new)	Negotiation among experts (give and take)	Integration by a leader (give or take)
Boundary object			
Glossary			
Everyday language			
Models			
Mutual adaptation of concepts			
Transfer of concepts			
Bridge concepts			

Source: Pohl and Hirsch Hadorn (2007:59)

This distinguishes different forms of collaboration (common group learning, negotiation among experts and integration by leader), which supports the identification of suitable boundary objects according to the encountered form of collaboration in the specific context. However, the proposed 'modes of integration' cover a colourful mix of different ideas that could all be interpreted as boundary objects. It is proposed to structure the 'modes of integration' according to organisations, processes, tools and products, as discussed in chapter 6.5. The identification of appropriate boundary objects needs to develop in a joint approach with the involved stakeholders. It is about prioritisation of possibilities that require different resources in terms of expertise and money. Some guiding questions to reveal transformation knowledge and define suitable boundary objects could be: Which devices and instruments are suitable to facilitate the desired transformation process? Which boundary objects are required and suitable to facilitate maximum change in a given time-frame and with limited financial resources?

Principle 4 (*'develop reflexivity through recursiveness'*) characterizes an ideal for the process of TR (and thus boundary object itself) and also a precondition for adaptive management. It means the TR should be understood as iterative process in which in a structured learning cycle questions are asked and answered in a repeating procedure. There is no guidance given how to do this in practical terms. Of course, 'recursiveness' can not be endlessly repeated and repetition will be limited by 'real-life' constraints in terms of budget and time. To apply this principle in boundary work processes requires further reflections.

However, merging the steps of TR with proposed steps from AM and EA I propose that a process to be followed when actively approaching Boundary Work could be:

1. Identify core actors and set-up a stakeholder team (ideally this comprises researchers, political decision makers and representatives from society, i.e. civil society and the private sector);
2. Jointly identify, structure and analyse the problem to be addressed in the context of the different stakeholder perceptions;
3. Define problem boundaries;
4. Define objectives and intended impacts;
5. Identify key uncertainties;
6. Develop a conceptual model that reflects a shared perception of the problem, the system in question within the identified boundaries including ecosystem goods and services and their importance for human well-being. Incorporate the reflection of key uncertainties. Specify a common perception of the 'external boundary settings' and how they may limit change or risk the successful implementation.
7. Develop hypotheses about the impacts of different management actions in a) the light of different key uncertainties and b) their influence on ecosystem goods and services; choose ecosystem indicators;
8. Identify knowledge needs; identify the boundary objects suitable to generate and communicate that developed knowledge. Boundary objects could also be 'management experiments/interventions' to test the hypotheses, as proposed in the adaptive management approach.
9. Implement the research and management interventions and develop a monitoring plan to measure the short to medium to long term impact(s) of management interventions;
10. Evaluate the impacts in terms of management goals and hypotheses – if impacts can be noted within the project's life span.
11. Review results;
12. Reassess and adjust the problem definition, problem structuring and problem analysis, problem boundaries, objectives and intended impacts, the underlying conceptual model, the suitability of chosen boundary objects, planned interventions, and the monitoring plan.

6.7 Boundary Work and Sustainability Science

The field of 'Sustainability Science' has emerged in the last decade and gains continuously growing attention. While meanwhile being an accepted field of science, it can still not be considered an established discipline in terms of common principals and methods. However, one common objective of the multiple sciences working in sustainability science is to facilitate transformations of human-ecological systems towards sustainability. In my understanding, Sustainability science is action-oriented in approaching complex and contested problems of unsustainable resource use; it aims at developing sustainable solutions for real-life problems that are developed based upon principles of fairness and equity. It structurally considers uncertainties and the need for knowledge generation in developing sustainable management solutions.

I consider the boundary work framework as one potential conceptual and methodological piece of the puzzle to implement sustainability science. Reverse, experiences and reflections from sustainability science can considerably contribute to the effectiveness of boundary work processes (see also Clark et al, 2010). In sustainability science the term 'boundary work' is mostly used to refer to the boundary between science and policy (only).

Following the outcomes of sustainability science (Cash et al, 2003; Cash et al, 2002; Clark et al 2007, Clark et al 2010), certain success factors can be identified that foster boundary work processes. Any knowledge and information needs to fulfil three properties to be accepted and used by different actors in the decision making process: it needs to be credible, salient and legitimate: credibility refers to the source and content of information: it needs to be trustworthy and / or believable; while salience implies the relevance and timely provision of knowledge to approach a specific problem, legitimacy addresses fairness in the information gathering process. Trade-offs between salience, credibility and legitimacy have to be taken into account, but to approach a right balance, investment is required into communication (which should be active, iterative, inclusive), translation (which requires a common terminology, as addressed through Boundary Concepts) and mediation because of trade-offs between credibility, salience, legitimacy of knowledge, which may lead to conflicts among stakeholders (Cash et al, 2003). Furthermore, boundaries between stakeholders need to be actively dissolved and managed, these mechanisms do not happen without external support but require a strong driving force reflecting visionary leadership and the conscious design of structures and procedures, through which the processes can happen effectively.

6.8 Future Research

The previous analysis and reflections of this paper have covered:

- The presentation of three leading approaches in water and natural resources management (IWRM, AM and EA) in terms of principles, methods and tools and the need to merge management with research approaches when dealing with water problems (chapter 2).
- The requirement to incorporate governance perspectives into reflections on sustainable water resources management (chapter 3).
- The presentation of the transdisciplinary research approach that supports to go over complex 'real-life' problems in a structured manner and that aims for the development of practical solutions (chapters 4 and 6.6).
- A presentation of the boundary work framework (concepts- objects- settings framework) as developed by Mollinga. The framework was further used as organ-

isational model to merge elements of the different management and research approaches. A proposal was made for development and amendment of the framework according to the needs of the water sector in the developing world. Based on the latter reflections, an interactive methodology for boundary work in water resources management and planning was drafted (chapter 6.6).

Further research is now required to apply and reflect upon the interactive methodology and the framework for its suitability to approach 'real-life-problems' and to develop it further. This is best done through intensive case study research in different contexts. The common guiding questions could be:

- Is the framework in its current form helpful to reflect and communicate about complex problems in water resources management and research in the developing world?
- How can it be improved?
- How can it be used to develop 'instrumental work for action', means boundary objects, to approach 'real-life problems' in the local context?

Case studies are conducted in many different disciplines, such as environmental science, civil engineering, anthropology, management studies, psychology, medicine to list only a few. They are designed in multiple ways with different focuses, methods and perceptions. The only common understanding is that they are '*an empirical inquiry that investigates a contemporary problem within its real-life context. Understanding the problem and its solution requires integrating a myriad of mutually dependant variables or pieces of evidence that are likely to be gathered at least partially by personal observation.'* (Scholz and Tietje, 2002). Scholz and Tietje classify various types of case studies, depending on their design (holistic or embedded; single case or multiple cases), the motivation (intrinsic or instrumental), the epistemological status (exploratory, descriptive or explanatory), the purpose (research, teaching or action / application), the data used (quantitative or qualitative), the format (highly structured, short vignettes, unstructured or ground-breaking) and the synthesis (informal, empathic, intuitive, formative or method driven).

Following this classification, the case studies required in future research for testing and developing the interactive methodology and framework should be:

Exploratory / experimental / interactive: Case and methodology are not specified in advance but are evolving during research in order to support the development of framework and methodology.

Embedded: The case covers several units or objects of analysis, as required in complex and contested problems. The analysis incorporates qualitative as well as quantitative data.

Single (intensive case study research): In order to scrutinize and develop the interactive methodology and framework, intensive case study research of single cases is appropriate. Analysis at this stage should not focus on multiple cases or comparative studies. Single cases - intensively studied - can reveal in greater detail the strengths and weaknesses of the proposed approach.

Instrumental: The situation shall not be studied due to intrinsic motivation of the researcher in a specific case; it shall serve as medium to reflect upon usefulness and suitability of the boundary work framework in its current state.

Unstructured or groundbreaking cases: Due to the difficult framework conditions as often encountered in developing countries, such as a fragmented water sector, unclear roles and responsibilities of often competing institutions, lack of data, high fluctuation of staff, etc, cases studies in the developing world can often be considered as either unstructured or groundbreaking. ‘Unstructured’ means that problems are not well ordered or defined and information is not available in a written or condensed manner. The problem is mostly contested and no ‘best solution’ is obvious. ‘Groundbreaking’ implies that little to nothing is known about the current situation and the boundary settings and no structured research has been done on this issue.

Further research is required in deriving success factors for boundary work from other fields of science. This implies developing the link between boundary work and sustainability science, through identifying how the boundary work framework can add to develop and approach projects towards sustainable development and through learning from the experiences of sustainability science for effective design and implementation of boundary work processes.

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ANNEX 1: Adaptive Management Principles

Principles and Description:

Continuous and Deliberate Learning: Ecosystems are inherently complex and continually evolving as a result of natural and anthropogenic processes. Uncertainty is the key issue that underlies all major resource and environmental management problems. A formal and structured approach to learning about the functional relationships that drive these evolutionary processes is central to the adaptive management approach (Holling et al., 1978)

Field Science and Formal Experimentation: Adaptive Management is field science. Functional knowledge of ecosystem behaviours can only be developed by carrying out formal experiments that test hypothesis (Dorcey, 1986). Adaptive management advocates the use of experimental management techniques for developing and testing hypotheses (Walters and Holling, 1990). These hypotheses usually take the form of predictions about how one or more important ecosystem indicators will respond to management interventions.

Systems Approach: Adaptive management is based on a formal application of systems theory, which focuses on i) wholes and their emergent properties, ii) internal and external hierarchical arrangements of wholes, and iii) functional interactions between component parts of wholes (Checkland, 1981)

Integration of Management and Research: Adaptive management calls for the integration of management and research into a single activity, with resource managers actively involved in the process of defining problems, generating and testing hypotheses, and evaluating outcomes (Holling, 1978; ESSA, 1982). An implicit assumption is that information gained in the process of implementation will be used to meet management objectives.

Source: Ohlson, (1999:14-15)

ANNEX 2: The Generic Adaptive Management Process

Steps and Description:

Define Problem Boundaries: Most environmental management problems are fraught with uncertainty and complexity. To make them tractable, boundaries oif the management problem are clearly defined. Walters (1986) suggests bounding the problem the problem in four dimensions: 1) the breadth of factors considered, 2) the depth of details, 3) the spatial scale, and 4) the time scale and resolution

Indentify Key Uncertainties: Explicitly identify what is unknown about the ecosystem being managed. More specifically, identify which of these unknowns are most important to resolve in order to increase confidence in management interventions and policy directions (Walters, 1986).

Chose Ecosystem Indicators: Appropriate ecosystem indicators are established based directly on the key uncertainties that need to be resolved. A commitment to thorough monitoring is made up front, and sufficient resources are allocated. Marcot (1998) identifies that for AM studies an indicator should: 1) respond rapidly to changes, 2) signal changes n other variables of interest, 3) be monitored efficiently, and 4) be causally linked to changes of interest.

Generate Alternate Hypotheses: Alternate hypotheses are generated that centre on the key uncertainties. These hypotheses guide the design of management experiments.

Design Management Experiments: Experiments are designed in conjunction with ongoing management activities. Both qualitative and quantitative aspects of good experiment design are addressed to test alternative hypotheses (Lee, 1993)

Implement and Monitor: Managers, researchers and technicians collaborate to meet both management and research goals. Data collection activities focus on previously chosen ecosystem indicators – in most cases these will be consistent with ongoing management data requirement (e.g., water quality measures) (Taylor et al., 1997)

Feedback results: Experimental Results are applied toward the ongoing improvement of management activities. Results are used to improve understanding of ecosystem functioning and to update original hypotheses.

Source: Ohlson, (1999:13-14)

ANNEX 3: Adaptive Management Tools

Tools and Description:

1. **Modelling:** Adaptive management makes use of all sorts of modelling, including:

   a) Conceptual Modelling: Conceptual models synthesize current understanding of ecosystem functioning or describe hypotheses of ecosystem response to management intervention. They can be presented with a combination of words, symbols or mathematical expressions. (Walker, 1996)

   b) Simulation modelling: Simulation models use one or more algorithms to transfer a set of input data into output data. Their use is primarily predictive, helping to test a particular theory or propose a particular management action. Models serve for important functions: i) as a means of organising thought, ii) as a mean of structuring large amount of data, iii) as a tool for comparison and simulations, and iv) as a means of facilitating collaborative problem solving. Adaptive management proponents stress that it is the process of model building rather than the model simulation that are most important in terms of gaining improved overall understanding of resource management situations (Walters, 1986).

2. **Interdisciplinary workshops:** In an effective adaptive management process, government resource management professionals, scientists and other stakeholders enter into a partnership to regularly redefine objectives and redirect management actions. A unique interdisciplinary approach to this is fund in the **Adaptive Environmental Assessment and Management (AEAM) Workshop** process developed by the early practitioners of adaptive management (Holling et al. 1978). These workshops have three general goals: i) to include all stakeholder interests, ii) to work across jurisdictional boundaries, and iii) to bound conflict.

3. **Experimental Design:** Adaptive management requires large scale experimentation at the scale of ecosystems. Effective experimental management requires rigorous attention to the details of experimental design (McAllister and Petermann, 1992). Specific considerations include:

   a) The Fundamentals: Well designed experiments are often structured around the use of **controls** (against which to compare one or more experimental treatments).

   b) Statistical Power Analysis: Classical approaches to experimental design focus on the avoidance of Type I and Type II errors. Statistical power analysis is a well established body of classical statistics theory that is sued to design experimental and monitoring programs or evaluate their results (Peterman and M'Gonigle, 1992). The 'statistical power' of an experiment is simply a measure of the probability of correctly accepting as true an hypothesis that is true; that is, it I an inverse measure of the chance of making Type II error. Calculating the statistical power as part of a formal adaptive management program enables researchers and managers to judge how much confidence to place in their monitoring results. Further, statistical power analysis can be used to design new experiments, monitoring systems and data analysis programs that have a higher chance of delivering valid results, and even to rank alternative designs.

c) Bayesian Statistics: Bayesian statistical analysis is an approach that has been developed for cases where a lack of existing data sets or a lack of controls and replicates occurs. The approach allows experimenters to assess impacts by assessing a **prior probability** that a hypothesis is correct (based on expert opinion), and then uses data collected during experimentation to update the assigned probability (Berger and Berry, 1988). Although the task is computationally intensive, it allows experimental management to proceed in a structured manner.

d) Qualitative Tests of Validity: The validity of experimental results can also be tested for validity by qualitative means. Internal threats to validity are those that led to questions of whether something else really caused the observed effect in an experiment. Examples include **Hawthorne effects** where the act of experimentation itself actually caused the effect, and **maturation effects** where the effect would have occurred anyway as a result of forces already in effect. External threats to validity are those that question whether the experimental result can be applied to other circumstances. Examples here include **cumulative effects** where it is difficult to determine which of several simultaneous interventions actually caused the effect, and **complexity effects** where it is difficult to even identify the relationships between cause and effect. Understanding the possible qualitative threats is vital to the experimental management design process (Lee, 1993).

Source: Ohlson, (1999:15-17)

ANNEX 4: Overview over Framework for assessment of management regimes

CRITERIA	INDICATORS
A. Actor networks	
1. Cross-sectoral co-operation	• Sectoral governments actively involve other government sectors • Cooperation structures include government bodies from different sectors; many contacts generally • Conflicts are dealt with constructively, resulting in inclusive agreements to which the parties are committed
2. Cooperation between administrative levels	• Lower-level governments are involved in decision making by higher-level governments • Cooperation structures include government bodies from different hierarchical levels; many contacts generally • Conflicts are dealt with constructively, resulting in inclusive agreements to which the parties are committed
3. Cooperation across administrative boundaries	• Downstream governments are involved in decision making by upstream governments • International/ transboundary cooperation structures exist (e.g., river basin commissions); many contacts generally • Conflicts are dealt with constructively, resulting in inclusive agreements to which the parties are committed
4. Broad stakeholder participation	• Legal provisions concerning access to information, participation in decision making (e.g., consultation requirements) and access to courts • Cooperation structures include non-governmental stakeholders • Non-governmental stakeholders actually contribute to agenda setting, analyzing problems, developing solutions, and taking decisions ("co-production") • Non-governmental stakeholders undertake parts of river basin management themselves, e.g., through water users' associations • Governments take stakeholder input seriously

(con'd)

B. Legal framework	
5. Appropriate legal framework	• A complete and clear legal framework for water management exists (with sufficient detail) • Policies have to be reviewed and changed periodically
6. Adaptable legislation	• Laws and regulations can easily be changed • Water (use) rights can easily be changed / are not permanent
C. Policy	
7. Long time horizon	• Solutions for short-term problems do not cause more problems in the (far) future (20 years or more) • Preparations are already being made for the (far) future (20 years or more)
8. Flexible measures, keeping options open	• Measures taken now or proposed for the near future do not limit the range of possible measures that can be taken in the far future and are preferably reversible
9. Experimentation	• Small-scale policy experiments take place / are financially supported
10. Full consideration of possible measures	• Several alternatives and scenarios are discussed • Alternatives include small- and large-scale and structural and non-structural measures
11. Actual implementation of policies	• Plans and policies are actually implemented • Policies are not dogmatically stuck to when there are good reasons not to implement them, e.g., new and unforeseen circumstances and new insights
D. Information management	
12. Joint or participative information production	• Different government bodies are involved in setting the terms of reference and supervising the search, or are at least consulted (interviews, surveys etc.) • The same for non-governmental stakeholders
13. Interdisciplinarity	• Different disciplines are involved in defining and executing the research: in addition to technical and engineering sciences, also, e.g., ecology and the social sciences

(con'd)

14. Elicitation of mental models / critical self-reflection about assumptions	• Researchers allow their research to be challenged by stakeholders and present their own assumptions in as far as they are aware of them • Research results are not presented in an authoritative way, but in a facilitative way, to stimulate reflection by stakeholders about what is possible and what it is they want
15. Explicit consideration of uncertainty	• Uncertainties are not glossed over, but communicated (in final reports, orally)
16. Broad communication	• Governments exchange information and data with other governments • Governments actively disseminate information and data to the public: on the internet, and also by producing leaflets, through the media, etc.
17. Use of information	• New information is used in public debates (and is not distorted) • New information influences policy

As to the issues for which information should be produced, communicated, and used, see under C.

E. Financing

18. Appropriate financing system	• Sufficient (public and private) resources are available • Costs are recovered from the users by public and private financial instruments (charges, prices, insurance, etc.) • Decision making and financing under the same control • Authorities can take loans and depreciate their assets to facilitate efficient use of resources and replacement of assets

Source: Raadgever et al, (2008:6-8)

ANNEX 5: 12 Principles of the Ecosystem Approach

Principle 1: The objectives of management of land, water and living resources are a matter of societal choices.

Different sectors of society view ecosystems in terms of their own economic, cultural and society needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2: Management should be decentralized to the lowest appropriate level.

Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

a) Reduce those market distortions that adversely affect biological diversity
b) Align incentives to promote biodiversity conservation and sustainable use;
c) Internalize costs and benefits in the given ecosystem to the extent feasible.

The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems.

Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: Ecosystem must be managed within the limits of their functioning.

In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable of artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9: Management must recognize the change is inevitable.

Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential "surprises" in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems.

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, taking into account, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

Source: http://www.cbd.int/ecosystem/principles.shtml accessed on 01/10/2010

ANNEX 6: Operational guidance for application of the ecosystem approach

1. Focus on the relationships and processes within ecosystem.

The many components of biodiversity control the stores and flows of energy, water and nutrients within ecosystems, and provide resistance to major perturbations. A much better knowledge of ecosystem functions and structure, and the roles of the components of biological diversity in ecosystems, is required, especially to understand:

i. ecosystem resilience and the effects to biodiversity loss (species and genetic levels) and habitat fragmentation; and
ii. underlying causes of biodiversity loss; and
iii. determinants of local biological diversity in management decisions.

Functional biodiversity in ecosystems provides many goods and services of economic and social importance. While there is a need to accelerate efforts to gain new knowledge about functional biodiversity, ecosystem management has to be carried out even in the absence of such knowledge. The ecosystem approach can facilitate practical management by ecosystem managers (whether local communities or national policy makers).

2. Enhance benefit-sharing.

Benefits that flow from the array of functions provided by biological diversity at the ecosystem level provide the basis of human environmental security and sustainability. The ecosystem approach seeks that the benefits derived from these functions are maintained or restored. In particular, these functions should benefit the stakeholders responsible for their production and management. This requires, inter alia: capacity building, especially at the level of local communities managing biological diversity in ecosystems; the proper valuation of ecosystem goods and services; the removal of perverse incentives that devalue ecosystem goods and services; and, consistent with the provisions of the Convention on Biological Diversity, where appropriate, their replacement with local incentives for good management practices.

3. Use adaptive management practices.

Ecosystem processes and functions are complex and variable. Their level of uncertainty is increased by the interaction with social constructs, which need to be better understood. Therefore, ecosystem management must involve a learning process, which helps to adapt methodologies and practices to the ways in which these systems are being managed and monitored. Implementation programmes should be designed to adjust to the unexpected, rather than to act on the basis of a belief in certainties. Ecosystem management needs to recognize the diversity of social and cultural factors affecting natural-resource use. Similarly, there is a need for flexibility in policy-making and implementation. Long-term, inflexible decisions are likely to be inadequate or even destructive. Ecosystem management should be envisaged as a long-term experiment that builds on its results as it progresses. This "learning-by-doing" will also serve as an important source of information to gain knowledge of how best to monitor the results of management and evaluate whether established goals are being attained. In this respect, it would be desirable to establish or strengthen capacities of Parties for monitoring.

4. Carry out management actions at the scale appropriate for the issue being addressed, with decentralization to lowest level, as appropriate.

As noted in the description of the ecosystem approach, an ecosystem is a functioning unit that can operate at any scale, depending upon the problem or issue being addressed. This understanding should define the appropriate level for management decisions and actions. Often, this approach will imply decentralization to the level of local communities. Effective decentralization requires proper empowerment, which implies that the stakeholder both has the opportunity to assume responsibility and the capacity to carry out the appropriate action, and needs to be supported by enabling policy and legislative frameworks. Where common property resources are involved, the most appropriate scale for management decisions and actions would necessarily be large enough to encompass the effects of practices by all relevant stakeholders. Appropriate institutions would be required for such decision-making and, where necessary, for conflict resolution. Some problems and issues may require action at still higher levels, through, for example, transboundary cooperation, or even cooperation at global levels.

5. Ensure intersectoral cooperation.

As the primary framework of action to be taken under the Convention, the ecosystem approach should be fully taken into account in developing and reviewing national biodiversity strategies and action plans. There is also a need to integrate the ecosystem approach into agriculture, fisheries, forestry and other production systems that have an effect on biodiversity. Management of natural resources, according to the ecosystem approach, calls for increased intersectoral communication and cooperation at a range of levels (government ministries, management agencies, etc.). This might be promoted through, for example, the formation of inter-ministerial bodies within the Government or the creation of networks for sharing information and experience.

Source: http://www.cbd.int/ecosystem/operational.shtml accessed on 01/10/2010

ANNEX 7: 12 tasks to be considered when applying the EA

Task 1: Involving all members of society in decisions associated with the management of land, water and living resources

Task 2. Ensuring management is decentralised to the lowest appropriate level

Task 4: Ensuring the economic context can be understood

Task 6: Considering what measures can be taken to ensure ecosystems are managed within the limits of their functioning

Task 9: Using adaptive management to address the problem(s) identified

Task 10: Seeking an appropriate balance between, and integration of, conservation and use of biological diversity

Task 11: Ensuring all forms of relevant knowledge including, scientific, indigenous and local knowledge, innovations and practices are included

Task 12: Facilitating the involvement of all stakeholders including all sectors of society and scientific disciplines

Source: The Ecosystem Approach Advanced User Guide; accessed on 01/10/2010:
http://www.cbd.int/ecosystem/sourcebook/advanced-guide/?steps

ANNEX 8: The analytical approach of the MA

1) **Identify and categorize ecosystems and their attendant services.** To facilitate the assessment of complex ecosystems, the MA will classify them into a limited number of categories as a basis for assessing the services they provide. Ecosystem services are identified and grouped into **functional** categories: provisioning, regulating, cultural, and supporting.

2) **Identify links between services and human societies.** Here the links are de- scribed between human societies and the particular ecosystem services that they use or benefit from. This includes defining the components of human well-being that are affected by the services (such as health, livelihood, culture, and equity), as well as the human activities that in turn affect ecosystems and the supply of services (such as population growth, consumption, and governance).

3) **Identify indirect and direct drivers.** In this task a list of indirect and direct drivers of the state of ecosystems and their services is drafted. Indirect and direct drivers affect not only ecosystems and their services but also each other. For example, demographic changes (an indirect driver) can affect ecosystems though land use change (a direct driver) but also can influence other indirect drivers such as social values and institutions.

4) **Select indicators of ecosystem conditions, services, human well-being, and drivers.** A set of indicators is selected to assess the state of ecosystems, ecosystem services, human well-being, and drivers. As an example, if the ecosystem service is food provision, then a potential indicator for the ecosystem state would be area under cultivation; for the service, quantity of food produced; for human well-being, rates of malnutrition; and for drivers, population growth. Next, these indicators are quantified or otherwise evaluated for use in the other analytical tasks.

5) **Assess historical trends and the current state of ecosystems and their services and drivers.** The current state of ecosystems and their services is assessed by assembling and analyzing data on the indicators selected. The details of how these data will be analyzed have not been completely worked out, but some considerations are discussed in Chapter 2. Since ecosystems are dynamic, an important issue to be addressed is the meaning of "current conditions." In some cases this will refer to the most recent data collected, but for most ecosystems it must take into account year-to-year and perhaps inter-decadal variability. (For example, it is not useful to refer to the availability of fresh water for a particular year because of its strong year-to-year variability.)

6) **Evaluate impact on human well-being.** This is among the most challenging tasks in the MA, since it involves the translation of information largely from the natural sciences (such as the state of fresh water, soil, and forests) into variables of concern to society (health, livelihoods, wealth, and security, for instance). One challenge is that a given service can affect several components of human well-being. Another challenge lies in sorting out the many possible trade-offs among services. Finally, the distribution of service benefits among societal groups will need careful consideration.

7) **Develop scenarios.** The MA is concerned not only with the historical, present, and short-term future trends of ecosystems, but also with future trends over the medium and longer term. This information is needed to anticipate critical changes in ecosystems and to develop response strategies. The aim of this task is to identify a set of plausible futures or "scenarios" for ecosystems, services, and drivers.

8) **Evaluate possible responses.** In this task the many possible "response options" are identified for preventing the deterioration of ecosystem ser- vices or recovering lost services. This includes evaluating the success of past response options and developing guiding principles for designing needed policies. Consistency is needed between the response strategies identified here and those used in the scenarios.

9) **Analyze and communicate uncertainty.** Since the MA is concerned with a new and rapidly changing body of knowledge, it is clear that many of the findings will be uncertain. Assessing and communicating the level of certainty in a clear and consistent manner is therefore a central task of the MA.

Source: WRI (2003)

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