Does the EC Water Framework Directive Build Resilience?

Harnessing Socio-Ecological Complexity in European Water Management

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Foreword

Illustration: Klara Wettre

This is the first policy paper from the *Resilience and Freshwater Initiative*. The ambition of the initiative is to make emerging scientific theories of resilience operational for policy making that concerns integrated water management. The initiative includes a wide scope of network partners such as Stockholm University, Institute for Social and Environmental Transition (ISET), Stockholm Environmental Institute (SEI), Stockholm International Water Institute (SIWI).

As will be discussed and elaborated in this paper, the perspective offered by emerging theories of *resilience* adds important and previously poorly elaborated dimensions to what is usually denoted Integrated Water Resource Management (IWRM). Put bluntly, while

IWRM suggests an approach that "promotes the co-ordinated development and management of water […] in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP 2000:22), a resilience perspective complements this view with an approach that promotes social learning, experimentation and attempts to enhance the ability of actors to tackle uncertainty, complexity and environmental change.

The issue to be discussed in this paper is whether the EC Water Framework Directive (WFD) builds resilience, i.e. the capacity of freshwater systems to deal with change and perturbations. The WFD is of crucial importance for the governance of freshwater resources in the European Union. As will be discussed in detail, the current realization of the WFD in Sweden raises some considerable issues, and might at worst reduce the resilience of nested social-ecological freshwater systems. The results should therefore be of interest to all those concerned with how to secure the bloodstream of both nature and society: water.

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Key Points

Human induced changes, from the local to the global scale, have serious impacts on waterflows and on ecosystems. What's more, our earlier perceptions about the stability of ecosystems, and that change is possible to control, have proven to be false. Today we know that freshwater systems do not respond to change in a smooth way, rather a stressed ecosystem can suddenly shift from a seemingly steady state that is difficult to reverse. As a result, freshwater resources are becoming increasingly complex to manage. Taking this complexity seriously has fundamental consequences for our understanding of what is to be defined as "sustainable" water management and politics.

Adaptive management has been proposed as a way to tackle uncertainty and change, and as a way to enhance the resilience of freshwater systems. As is discussed in detail in this paper, the realization of the EC Water Framework Directive is far from nurturing such an approach. The following key points summarize the findings of this paper.

Key Point 1

Collective Action and Analytical Deliberation is Highly Limited

- Collective action among Swedish water users is seldom ambitious, which implies that the adaptive capacity of key local water stakeholders is highly limited. None of the interviewed water directors have an explicit strategy for how to improve the current situation.
- Learning processes that include the joint analysis of system dynamics – i.e. identifying feedbacks, driving forces, thresholds, possible regime shifts and major uncertainties - is currently a non-issue. Water directors do not have an explicit strategy on how to stimulate learning processes between local stakeholders, academia and managers.

Key Point 2

Water Management Institutions Disregard Complexity and Uncertainty

- There is no preparation for how water managers are to promote stakeholder participation in the face of high social and ecological uncertainty. In addition, the fact that unpredicted changes in social, political and ecological circumstances might seriously change the conditions for stakeholder involvement is not recognized.
- There are currently no plans to actively experiment, *systematically* evaluate local water improvement projects, or to assess the thresholds of freshwater systems to avoid sudden and unwanted state shifts.
- Water authorities seem to try to suppress both institutional and organizational diversity hence risking stalling potentially future efficient social innovation. This might at worst create institutional vulnerability.

Key Point 3

Water Policy is Poorly Prepared to Tackle Global Environmental Change

- Climate change is likely to pose fundamental challenges to Swedish freshwater resources.
- These impacts have received limited attention in both the Common Implementation Strategy documents produced at the EU level, and by key Swedish authorities such as the Swedish EPA.
- Four out of five water directors apply a "wait-and-see" strategy to climate change, and there are no concrete plans to adapt classification scales and river basin plans taking into account the effects of climate change.
- The models expected to provide an important basis for the activities assumed by water authorities is not able to handle nonlinear interactions and feedbacks across scales. This implies that future river basin plans are likely to misinterpret potential negative impacts of climate change.

I. Introduction

Water managers around the world someway or another have to deal with uncertainty and environmental change. Sudden flooding, new national policy, climate change, unexpected nutrient leakage and algae bloom, technological innovations, or unanticipated high levels of toxic pollutants in groundwater resources all indicate the complexity and surprises inherent in freshwater systems. Prominent scientists are now making an important point; surprises and change are the rule, not the exception (e.g. Levin 1999). Unfortunately, water policy makers seldom take these facts seriously.

The ambition of the following paper is to highlight one suggested way to tackle uncertainty and complexity in freshwater resource management: *adaptive management*. Adaptive management is as will be discussed in detail below, an integrated, multidisciplinary approach for confronting uncertainty in natural resources issues (Holling 1978, Walters 1986, National Research Council 2004). It is "adaptive" because it acknowledges that managed resources such as freshwater will always change as a result of human intervention, that surprises are inevitable, and that new uncertainties will emerge. Adaptive management acknowledges that policies must be continually modified and flexible for adaptation to these changes. As this paper discusses, taking this complexity seriously has fundamental consequences for our understanding of what is to be defined as "sustainable" water management and politics. And in addition, for how we evaluate not only the potentials, but also some of the possible problems in what often is denoted Integrated Water Resource Management (IWRM).

This policy paper discusses and evaluates the present implementation of the EC Water Framework Directive (WFD). Even though the case chosen for this study is the implementation of the WFD in Sweden, the argument and analysis should be of more general interest. The reason for this is that the case study reflects and discusses more general challenges facing European nations trying to manage a vital natural resource under continued degradation and stress.

Limitations of the Study

An important note should be made here. This policy paper focuses on *certain* selected *organizational* and *institutional* aspects of emergent interdisciplinary theories on resilience and the WFD. The reason for this is that a complete and encompassing study that investigates all aspects of resilience theory – including the full array of both ecological and social aspects of the concept - and the WFD would not only require the work of a whole working team, but also at least a couple of years work. This paper should hence be viewed as a *first attempt* to make theories of adaptive management operational on the WFD, rather than as a final evaluation. As will be shown however, even a limited analysis of resilience and freshwater issues raises important and previously ignored issues.

Outline of the Paper

The paper is organized as follows. In the second chapter I shortly present emerging theories of resilience. Here I present some key concepts to be used in the paper such as *resilience* and *adaptive management,* and tease out the implications for water policy in general. In the third chapter section I present the implications following from the realization of the EC Water Framework Directive in Sweden. The fourth chapter consists of an in-depth analysis of the Swedish case according to three key questions – to be specified and motivated in detail later - all related to resilience theory and adaptive freshwater management. The forth and last section summarizes and discusses the findings, and draws out some policy implications.

II. What is Resilience?

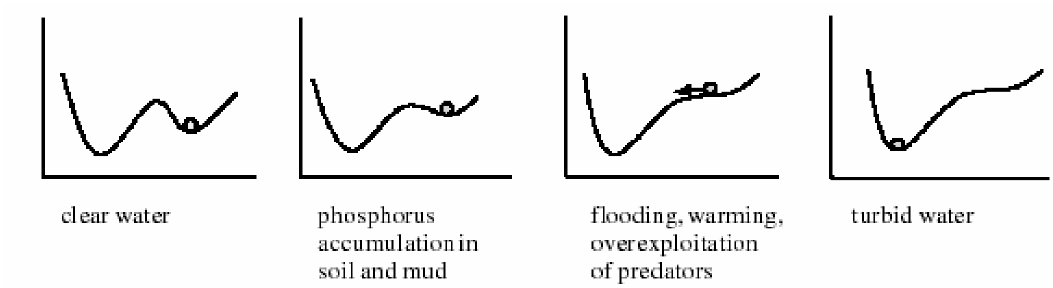
Freshwater resources may seem to be in good shape. But when freshwater systems faced with diminished *resilience* are subject to a sudden event (like a flood or heavy rainfall), a critical threshold may be reached and they may slide into another less desirable state with a reduced capacity to supply life-supporting functions for societal development (Scheffer *et al.* 2001). This is one important conclusion from ecological research that has important implications for how we understand the interaction between social and ecological systems (Gunderson and Holling 2002, Berkes, Colding and Folke 2003), and as will be discussed in this paper, for freshwater management in general (e.g. Folke 2003).

An important assumption is that freshwater systems – just like any other ecosystem - are complex, adaptive systems that are characterized by historical dependency, nonlinear dynamics, threshold effects, multiple basins of attraction, and limited predictability (Levin 1999). Increasing evidence suggests that ecosystems often do not respond to gradual change in a smooth way (Gunderson & Pritchard 2002).

Floods, droughts, nutrient leakage, metal pollution are only a few examples of many natural disturbances affecting water resources and hence human development. In recent years however, their effect has been greatly exacerbated by human induced changes of water flows and ecosystems as well as migration to vulnerable areas. Moreover, the UN climate advisory body (IPCC) has warned that global environmental change will entail increasing environmental variability and increased occurrence of extreme weather events. Wet areas are likely to become wetter, with more frequent episodes of flooding, whilst dry areas may become drier, with longer periods of drought. Modelling attempts also indicate that global environmental might radically affect water quality due to increased nutrient leakage as a result of higher temperatures (Andréasson et. al. 2004, EC-JRC 2005).

The implications of environmental change combined with increased human induced changes of water flows and ecosystems should not be underestimated. In a vulnerable social-ecological system even a small event (such as extreme weather events) may be devastating for the persistence of the system. This is illustrated in figure 1.

Figure 1. Resilience and Water Clarity (from Folke 2003)



Phase I **Phase II** **Phase III** **Phase IV**

As the figure illustrates, water clarity in lakes during Phases I, II and III does not seem affected by inflow of nutrients from the surrounding catchment until a critical threshold (Phase IV) when the lake shifts abruptly from clear to turbid, eutrophied waters. Phosphorous accumulation in this case thus undermines the resilience of the system making freshwater resources more vulnerable. Regime shifts in freshwater resources are far from uncommon and have been analyzed for both lake systems (Carpenter et. al. 2004, Carpenter and Cottingham 2002) and oceans such as the Baltic Sea (Jansson and Jansson 2002). The implications are important. In numerous cases, the regime shifts are also resilient, a fact that can counter restoration efforts (Carpenter and Cottingham 2002:57f, Troell et. al. 2005).

Box 1:

What is Resilience?

Ecosystem resilience is the capacity of an ecosystem to cope with change and perturbation, such as storms, fire and pollution. Loss of resilience leads to more vulnerable systems, and possible ecosystem shifts to undesired states that provide fewer ecosystem goods (like fish and crops) and services (like flood control and water purification). Such loss of resilience can be caused by, for example, pollution, climate change, loss of biodiversity or altered freshwater flows. With decreased resilience, clear lakes can suddenly turn into murky, oxygen-depleted pools, grasslands into shrub-deserts, and coral reefs into algae-covered rubble. Resilience is the capacity of a system both to withstand pressures and to rebuild and renew itself if degraded.

Resilience as the "Immune System" of Ecosystems

Stressed, sleep-deprived and/or poorly nourished people are more susceptible to illness and recover more slowly afterwards. Likewise, studies of rangeland, forest and ocean ecosystems show that human-induced stress and overexploitation of species reduce their resilience to storms, fires or other events which they coped with before. Just as a person might seem unaffected by his or her destructive lifestyle, an ecosystem with low resilience often seems unaffected until a disturbance causes it to exceed a critical threshold. When resilience is lowered, even minor disturbances can cause a shift to a state that is difficult, expensive or even impossible to reverse.

Social Resilience

Social resilience is a measure of a community's ability to cope with change (for example in its environment) without losing its core functions as a community, including its economic and management possibilities. Human societies depend on ecosystems for survival but also continuously impact them from local to global scales. For such intertwined social-ecological systems (SES), resilience is the capacity to absorb, or even benefit from, perturbations and changes that affect them, and so to persist without a qualitative change in the system's structure and function. Notably, social resilience differs fundamentally from ecosystem resilience by having the added capacity of humans to anticipate and plan for the future.

Resilience for social-ecological systems is often referred to as related to three different characteristics: (a) the magnitude of shock that the system can absorb and remain in within a given state; (b) the degree to which the system is capable of self-organization and (c) the degree to which the system can build capacity for learning and adaptation (Folke et. al. 2002, see Box 1).

Regime shifts in ecosystems as the one illustrated in figure 1, are increasingly common as a consequence of human activities that erode resilience, for example, through resource exploitation, pollution, land-use change, possible climatic impact and altered disturbance regimes (e.g. Gordon et. al. 2005). Management – and freshwater management is no exception - can hence destroy or build resilience. There are many examples where human behaviour unconsciously contributes to a modification of the important variables that structure and sustain desirable states, through, for example, land-use change, redirection of freshwater flows and change in freshwater quality (Carpenter et al. 2001, Gunderson and Pritchard 2002), and may thereby cause loss of resilience (van der Leeuw 2000). Put bluntly, decision-making agents and actors involved in management create vulnerability without knowing it.

The argument is that focus in freshwater management should not be solely on variables of the moment (water levels, population numbers) and their correlative rates, but rather on more enduring system properties such as resilience, adaptive capacity, and renewal capability. This framework involves both the human components of the system (operations, rules, policies, and laws) and the biophysical components of the landscape and its ecosystems.

Contrasting Adaptive Water Management with IWRM

The consequences of this perspective for water management and water policy should not be underestimated. Taking uncertainty and resilience seriously has important implications water management and policy, and adds and specifies some important perspectives on what is usually denoted Integrated Water Resource Management (IWRM, c.f. GWP 2000). The main differences are three (c.f. Johnson 1999):

First of all, adaptive management takes vulnerability and risk seriously. Managing to maximize benefits may actually increase some types of risk. An alternative is to promote resilience of the natural system and of the management system, such that we maintain acceptable, but perhaps not maximal, levels of resource use while avoiding unacceptable negative effects and catastrophes.

Second, adaptive management takes uncertainty and complexity seriously. Seeing the natural world as a moving target implies not only an important shift in thinking about freshwater resources, but also on the institutions and organizations created to manage this uncertainty. Put more precisely, it is critical that institutional and organisational structures allow for experimentation with different strategies for natural resources management. Adaptive management sees ecosystem management as a continuous learning-by-doing process that recognises public participation and joint learning. To help develop new institutional arrangements, we might apply adaptive management experiments not just to the resource, but also to institutions themselves. These experiments would explore the relationships within and among agencies and stakeholders to find new ways to promote flexibility, cooperative management, and a long-term outlook.

Third, it takes the importance of interactions across organizational levels seriously. This more participatory approach often denoted adaptive *co-management*, involves a system of flexible decision-making shared by many different democratic subunits, from national governments to local villages, seeking a balance between local and central governance. Subunits are allowed to experiment with different kinds of rules and can learn from the experiences of parallel units. This makes governance less rigid and less vulnerable, since the failure of one or more units can be compensated by the successful reaction of other units in the area.

Figure 2. Contrasting conventional and adaptive freshwater management.

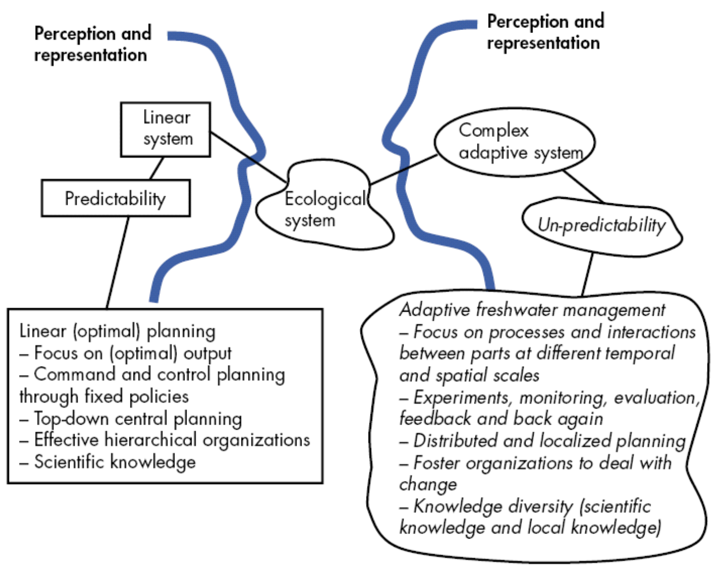


Illustration: Henrik Ernstsson.

The shift proposed is to a learning basis that requires flexible linkages with a broader set of actors or networks. Another way of saying this bluntly is that, until management institutions are capable and willing to embrace uncertainty and to systematically learn from their actions, integrated water resource management is doomed to fail to deal with complexity and uncertainty in freshwater management.

This being said however, does not imply that all top-down water management initiatives will fail at all times. Freshwater systems and their governance structure including policy, knowledge base and organizational skills differ significantly not only between countries, but also across regions. The table below shows six different and stylized freshwater management "outcomes" depending on both if freshwater systems are perceived as predictable or complex and uncertain, and the degree of involvement of local stakeholders.

Figure 3. Freshwater Management Options

		Freshwater Governance		
		Top-down	*Participatory*	*Co-management*
Ecological system	*Linear*	Centralized Conventional	Multistakeholder Bodies	Devolution of power
	Dynamic	Adaptive management	Collaborative learning	Adaptive co-management

Comment: The figure shows four stylized freshwater management options.

The upper outcomes illustrate three different approaches to freshwater management that differ on the level of stakeholder involvement. The left upper outcome (i.e. Centralized Conventional) imbeds only limited stakeholder involvement, while the second category (i.e. Multistakeholder Bodies) includes multi-stakeholder initiatives where government create forums to sound out ideas or as a mechanism to defuse an imminent conflict (Berkes 2002:304, e.g. Kellogg 1998). The upper right box (i.e. devolution of power) denotes water governance that implies real shared management power to local parties. While the three alternatives differ on whether local users are actively involved, or if management power is shared, it is important to note that all entail a view of freshwater systems as linear and predictable.

Once freshwater systems are viewed as dynamic (i.e. systems in which functionally different states or multiple stability domains exist and the system can move from one stability domain to another, e.g. "flip") three other management options are available, and argued to serve as a better basis for sustainable freshwater management (e.g. Folke 2003, Falkenmark and Folke 2003, Schusler et. al. 2003, Walker et. al. 2002).

Adaptive management is an approach that seeks to use management intervention as a tool to strategically probe the functioning of an ecosystem. Interventions are designed to test key hypotheses about the functioning of the ecosystem. This approach is very different from a typical management approach of 'informed trial-and-error'. Adaptive management identifies uncertainties, and then establishes methodologies to test hypotheses concerning those uncertainties. It uses management as a tool not only to change the system, but as a tool to learn about the system (Resilience Alliance 2005, Habron 2003).

Box 2. The Foundations of Adaptive Management

The foundations of adaptive management rests in many fields, but its initial presentation was in the 1970's, when it was offered as a way to help managers to take action in the face of uncertainties, to reduce uncertainties, and to craft management strategies capable of responding to unanticipated events. Adaptive management is not a "one size fits all" process. There are multiple views and definitions regarding adaptive management, but elements that have been identified in theory and in practice are: management objectives that are regularly revisited and accordingly revised, models of the system being managed, a range of management options, mechanism for incorporating learning into future decisions, and a collaborative structure for stakeholder participation and learning.

Adaptive management's core principles emphasize concepts such as uncertainty, surprise, and resilience. These concepts run counter to traditional engineering planning concepts of deterministic systems, precision, and model predictions.

Source: National Research Council (2004:2ff).

Although adaptive management has been linked primarily with natural resource management, it has been used to manage other types of systems. For example, sectors such as trade and transportation employ similar principles: a range of future outcomes are considered and probabilities are weighed, small-scale pilot projects are tested, actions are designed to be useful across a range of potential futures, reversible actions are favoured over irreversible, results are monitored, and policies are modified accordingly (National Research Council 2004:5, see also Weick and Sutcliffe 2001).

This approach does however, not necessarily imply wide stakeholder involvement. There are two other alternatives here, in which one (denoted "**Collaborative Learning**") consists of central agencies inviting stakeholder to provide local knowledge and their views, before managers strategically explore the functioning of an ecosystem. Actors in The Northern Highlands Lake District of Wisconsin provide such an example (Peterson et. al. 2003). In this case, the use of scenario planning combined with the determination of social and ecological driving forces was used as a base for stakeholder dialogue.

Stakeholder involvement can however, be much more extensive. This approach often denoted **adaptive co-management** implies not only a non-linear view of freshwater systems, but in addition shared management power (Berkes and Carlsson 2005). The important difference is that adaptive co-management implies "a partnership in which governmental agencies and local communities (including resource users, local governments, non-governmental organizations, and other stakeholders) negotiate and share, as appropriate, the responsibility for management of a specific area or a set of resources" (Schusler et. al. 2003:311, see also Berkes 2002).

When Is Adaptive Freshwater Management Appropriate?

Which of the options discussed earlier are seen as suitable depends heavily on whether freshwater systems are considered as linear and predictable, or dynamic and non-linear. While centralized management strategies certainly might be applicable and efficient in cases where freshwater problems are viewed as simply resolved, uncertainties are minimal and social and ecological driving forces are static, this is likely to be the exception rather than the rule, especially in a long term perspective.

Consider the case of regional groundwater resources (e.g. Moench 2005), coastal ecosystems (Troell et. al. 2005), or lake systems (e.g. Carpenter and Cottingham 2002, Imperial and Kauneckis 2003). Both these freshwater systems crucial for human development face the threats posed by human intervention such as land use change, and global environmental change. In the next decades, strong driving forces in terms of continuing population growth, globalisation, industrialisation and efforts to alleviate poverty and hunger can be foreseen to produce even larger landscape modifications (Falkenmark 2003, Foley et. al. 2005). Both these drivers are likely to force future water managers and policy-makers to reassess water management institutions.

The need to create a more adaptive approach to freshwater management can also derive from other sources. First, *scientific advances* can provide better understanding of complex linkages between social and ecological systems. As an example, the U.S. Army Corps of Engineers experienced a radical shift in thinking and policy after discovering that their flood control strategy radically failed in the 1930's (National Research Council 2004:16f).

Second, *shifts in social objectives and preferences* may challenge conventional water management and force water managers to assume additional or different tasks than their organization is used to.

The factors above are not only likely to create an increasing *complexity* - i.e. by increasing both the number of actors involved at various scales in water management, and the number of factors that are likely to affect water quality and quantity such as global environmental change, demographical change, land use change, European agricultural policy etc. In addition, these factors are likely to increase the *uncertainty* in freshwater management as the interactions and feedbacks between these factors, in combination with environmental variability are difficult – if not impossible – to predict fully (see appendix 3).

In short, as complexity and uncertainty increases, so does the challenge for freshwater management initiatives that put their faith on centralized command-and-control strategies. Whether this is the case for the EC Water Framework directive is the issue of the following analysis.

The Analysis

The question now is what characterizes management strategies and institutions that are able to tackle the complexity and uncertainty in freshwater systems. The questions to be asked during the case study are the following:

1. Analytic Deliberation

a) Does the WFD and its realization promote *collective action and network building* among relevant stakeholders and at relevant scales?
b) Does the WFD and its realization promote *learning* among relevant stakeholders and at relevant scales?

2. Be prepared for Change

Are institutions designed to allow for *adaptation to environmental change* and crises?

3. Institutional Nesting and Variety

a) Is policy treated as *hypotheses and management as experiments* from which central managers can learn?
b) Does the WFD integrate *aspects of multi-level governance* in such a way that the ecological knowledge of local stakeholders is incorporated into institutional structures in a multi-level governance system?

The questions presented above are based on state-of-the-art and published transdisciplinary research that analyzes how natural resource users can enhance the resilience of social-ecological systems to tackle complexity, uncertainty and global environmental change (e.g. Walker et. al. 2002, Anderies et. al. 2004, Dietz et. al. 2003, Folke 2003).

III. European Water Policy is Changing

That European water managers should take complexity and uncertainty in freshwater management seriously might seem like an obvious statement. The European Environmental Agency, as an example, has been keen on identifying the driving forces, impacts and responses concerning extreme hydrological events such as floods and droughts in Europe, and several European countries have developed both preventive and responsive strategies to deal with these events (e.g. EEA 2001). What is the difference between the perspectives presented in this paper, compared to the work presently done within the European Union?

The following chapter is gives a short introduction of the ambitions and scope of the European Water Framework Directive, and its realization in Sweden. Here I also present the methodology and material used in this study. This chapter hence provides a basis for the analysis of the following chapter that deals exclusively with whether the WFD enhances, or reduces the resilience of freshwater systems.

European Water Policy is Changing – A Short Presentation of the EC Water Framework Directive

While discussions of how to reform the fragmented legislation that characterized European water policy had been held on several occasions within various EU-arenas earlier, the two day Water Conference in May 1996 is often named as the event that came to set the agenda for the future work of the EC Water Framework Directive (WFD). This Conference was attended by some 250 delegates including representatives of Member States, regional and local authorities, enforcement agencies, water providers, industry, agriculture and, consumers and environmentalists. In response to this, the Commission presented a Proposal for a Water Framework Directive with the following key aims[1]:

1. expanding the scope of water protection to all waters, surface waters and groundwater
2. achieving "good status" for all waters by a set deadline
3. water management based on river basins
4. "combined approach" of emission limit values and quality standards
5. getting the prices right
6. getting the citizen involved more closely
7. streamlining legislation

The primary purpose of the WFD is hence to improve and manage the quality of water within the community by identifying and controlling all pollutants and wider activities that affect the status of water. Additional aims are to control the quantity of surface and ground waters and to protect aquatic ecosystems and wetlands. It is expected that eventually each body of water should benefit the community by achieving EU 'good water' status, including both a chemical and ecological perspective, for quality, quantity and pollution levels by 2015, unless there are grounds for derogation. There is also a general "no deterioration" provision to prevent deterioration in status. These will require the management of the quality, quantity and structure of aquatic environments. The Directive also requires the reduction and ultimate elimination of priority hazardous substances and the reduction of priority substances to below set quality standards. The Directive maintains existing European water policy commitments and introduces a number of new areas into legislation, but perhaps most importantly creates a new administrative instrument for accomplishing its aims (Howe and White 2002).

The importance of the WFD should not be underestimated. The framework will not only have a long lasting impact for all EU-members, which implies that the water use of 380 million inhabitants is to be secured through this common legislative framework. Important deadlines for the joint implementation of the directive are the following:

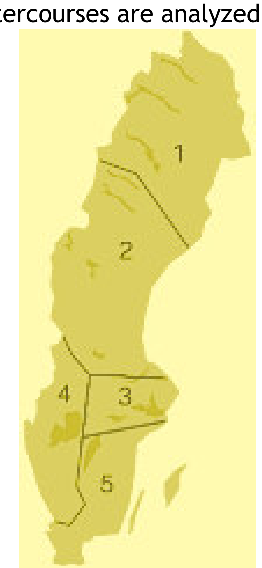
December 2003	National and regional water laws to be adapted to the WFD. River Basin cooperation to be made operational.
December 2004	An analysis of pressures and impacts on European waters has to be completed, including an economic analysis.

[1] From http://europa.eu.int/comm/environment/water/water-framework/index_en.html [accessed 2005-01-19].

December 2006	Monitoring programmes have to be operational as a basis for water management.
December 2008	River Basin Management plans presented to the public.
December 2009	Publishing first River Basin Management Plans.
December 2015	Waters to meet "good status".

The WFD in Sweden

How the implementation the European framework was to be realized in Sweden was investigated In Sweden by a "one- man committee", i.e. the director-general Joakim Ollén. The results from this investigation were presented in 2002 in the report "*Klart som vatten*" (SOU 2002:105). The committee suggests that Sweden is divided in five water districts based around the connection of geographical areas with the sea basins of the Bay of Bothnia, North Baltic Sea, South Baltic Sea and North Sea. In each of the five districts, a water authority is suggested to be established with the purpose of ensuring fulfilment of the environmental objectives for water. The official responsibility will initially be assigned to a delegation at one of the district's county administrative boards. These authorities are to be responsible for environmental objectives, programmes of actions and administrative plans for their respective water districts and will ensure that watercourses are analyzed and monitored.

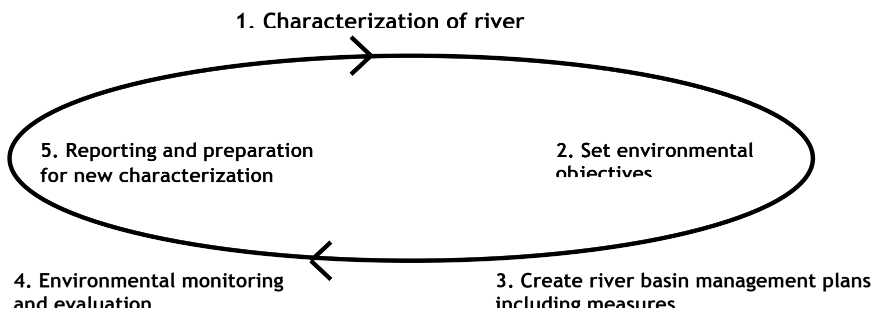


At the local level, local bodies for cooperation are suggested to be established through the agency of the municipalities, and based on Sweden's main river basin areas. These bodies may also comprise organizations, water conservation associations etc. Their task will be the management of local water conservation activities. Water pricing policies are to be implemented, and a basic model is proposed. The general principle is that water users that affect water physically, chemically or ecologically should assume financial responsibility for their actions. These financial resources should be used for water improvement projects, and not to cover the administrative costs of the reform. (SOU 2002:105). These suggested reforms have all been implemented, or are in the process of being so.

Comment: The new five water districts.

So far, key legislation is in place (chapter 5 in the Environmental Code, and SFS 2004:660), and chief directors of the five water authorities have been assigned by the Swedish government.

Figure 4. The Water Planning Cycle



Comment: Extracted from SOU 2002:105, pp.60-67 and NVV (2003:15f).

Research Design and Material

The analysis in this paper and presented in detail in the next chapter builds on several sources of information to get a rich picture of the present implementation of the WFD, and of the strategies key water policy makers are likely to apply in the nearest future.

One of the most important sources of information is previous research that is used to provide important background information to the analysis. In addition, a number of official documents have been included in the analysis such as status reports and working papers from the Swedish Environmental Protection Agency (*Naturvårdsverket*, NVV) the Swedish Environmental Ministry, and the European Union (i.e. reports formulating a Common Implementation Strategy).

As several of the issues to be analyzed in this paper concern work that is in process, and questions concerning policy-makers *view* on socio-ecological complexity, the material described above has been complemented with interviews with key water policy-makers in the country. These include: key actors in charge of implementing the WFD in Sweden at the Swedish EPA, and the newly assigned Water Authorities Chiefs (5). These interviews have all been semi-structured according to the themes presented above (Kvale 1996), and a description can be found in Appendix 1. One of the interviews has been made in the respondent's office, while the rest (5) have been phone-interviews. All interviews have been recorded on tape.

IV. Does the WFD Build Resilience?

I. Analytic Deliberation

Does the WFD promote collective action, network-building and learning among relevant stakeholders?

As discussed earlier, achieving collective action among key actors is essential from a resilience perspective. Getting actors such as farmers, municipalities, regional authorities and various NGO's to work together is a widely recognized prerequisite to achieve sustainable water management, and to enhance the adaptive capacity of social actors to tackle environmental change (e.g. Ostrom 1990, Berkes and Carlsson 2005, Adger and Tompkins 2004).

The importance of getting a wide span of social actors together is widely recognized both in the WFD and important Common Implementation Strategy documents (e.g. EC 2003). In this latter document, aspects of collective learning, trust and network building are all recognized as keys to sustainable freshwater management (EC 2003:50-60). Several tools to promote trust among stakeholders and the public are also presented, such as demonstration projects and to provide emerging networks of stakeholders with improved access to information (pp. 54f). Interesting enough, the document also includes an extensive discussion on how to evaluate public participation projects, hence treating attempts to achieve efficient stakeholder participation as experiments from which managers can learn and adapt.

Concerning the implementation of stakeholder participation in Sweden, some fundamental aspects seem to be integrated. The importance of stakeholder participation is extensively acknowledged in the Swedish governmental report *Klart som vatten* (SOU 2002:105). This formalized cooperation among stakeholders is expected to evolve at both catchment, local and - as the investigator chooses to denote it – the "super local" level (SOU 2002:105:169ff). The most complex and important of these new organizations are the catchment based water users associations (or '*samverkansorgan*' in Swedish, henceforth CBWUA), projected to be designed by municipalities, existing water user associations, water consuming industries, farmer organizations and other stakeholders *themselves*.

The authority provided to these new organizations in comparison to the new, and extensively more powerful water authorities and Swedish municipalities is, however, far from clear at this time (Lundqvist and Galaz 2003). This seems to have created a hard-resolved conflict between the Environmental Ministry and organized Swedish municipalities that fear that the current realization of the WFD will undermine their autonomy.

The explicit ambition presented by the Swedish government is nevertheless that these new river catchment based organizations are to develop voluntarily and without involvement from central government (SOU 2002:105:161). These new CBWUA:s are to supply water authorities with ecological data, take part in the formulation of precise ecological standards for the resource and if needed, detailed river management plans (*förvaltningsplan* in Swedish) to improve the quality of the resource (SOU 2002:105:159f). This procedure is expected to facilitate the new Regional Watershed Authorities to design efficient solutions sensitive to the needs of local and regional stakeholders (Svenskt Vatten 2002:27).

Incentives for Collective Action

Collective action among water stakeholders in Sweden is and continues to be important for the sustainable management of water resources. The reason for this is the well-recognized lack of congruence between ecological (i.e. the catchment area) and administrative boundaries. The fact that water resources more often than not are shared by a number of these actors across administrative boundaries forces stakeholders to cooperate to build networks and create water management institutions (c.f. Ostrom 1990). Hence despite detailed state regulation and formal central control at national, regional and local level, Swedish water politics is profoundly dependent on the voluntary contribution and cooperation of water users such as municipalities, County Administrations, industry and other stakeholders to monitor and to deal with concrete quantity and quality problems. This remains a fact despite the present implementation of the European Water Framework Directive (Galaz 2005).

Collective action among water stakeholders in Sweden has to this date however, not been impressive. The reason is that this collective action tends to involve rather limited tasks such as environmental monitoring (Gustafsson 1995, Lundqvist 2004) which should be considered as highly problematic keeping in mind the water related environmental problems that the country is facing.

This lack of ambitious collective action has one major drawback; it seriously inhibits the adaptive capacity – i.e. the ability to respond to environmental change and surprises - of these organizations. The reason for this is that the existence of social networks built up by trust and social capital often resulting from long-term collective action (Ostrom 1998) has proven crucial for natural resource users' ability to deal with environmental change and crises such as sudden flooding, unexpected high levels of water pollutants, or lake systems "flipping" into a new undesirable state (e.g. Folke 2003, Tompkins and Adger 2004, Moberg and Galaz 2005). Put bluntly, this implies that actors in Swedish water politics have a poor ability to adapt to environmental change or crises (Galaz 2005).

The implementation of the EC Water Framework Directive does obviously create a "window-of-opportunity" for policy-makers by providing an opportunity to reorganize the incentives in water governance to promote collective action. What is troublesome however is that Swedish authorities seem to lack both the capacity and incentives to promote such cooperation. The reasons are two.

Firstly, key implementation documents such as SOU (2002:105), NVV (2003) and NVV (2005) all lack an analysis of what factors that actually drive and promote collective action. Although various sorts of stakeholder cooperation alternatives are discussed, and various "tools" to promote participatory processes are extensively discussed (NVV 2005, SOU 2002:105, pp.169-196), it is both surprising and worrying that all reports fail to integrate insights from at least two decades of extensive research dealing with what factors drive collective action in natural resource management (e.g. Ostrom et. al. 2002) and in particularly the notable number of international case studies concerning collective action and network building in freshwater management (e.g. Sproule-Jones 2003, Olsson and Berkes 2003, Peterson et. al. 2003, Kellogg 1998).

Second, this lack of analysis is far from unproblematic. Interviews with key actors in the ongoing implementation of the WFD in Sweden (i.e. water directors) expose the necessity in guidance concerning how to promote ambitious collective action (i.e. catchment cooperation) among key stakeholders. More precisely, all water directors interviewed acknowledge the key role voluntary cooperation plays for the realization of the intentions of the WFD, but none of them have an explicit plan for how to promote such processes (I1, I2, I3, I4, I5[2]).

[2] I1, I2 etc. denotes the codes assigned to each of the interviewees. See appendix for more detailed information.

Incentives for Learning

If the first challenge is to get people together, the second is to make them do the right thing. An issue related to collective action is the ability of actors to achieve *social learning*. Learning here is the development of a common framework of understanding, the creation of a joint basis for action, and the joint analysis of system dynamics - i.e. identifying feedbacks, driving forces, thresholds, possible regime shifts and major uncertainties (Walker et. al. 2003, Gallopín 2002, Schlusler et. al. 2003). This learning is the result of a "process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of trial and error" (Folke et. al. 2002:20). Learning processes of this sort are crucial in adaptive management initiatives (Westley 2002) and imply the inclusion of different competences, and distributed decision-making. In these arrangements central actors might have a minor or major role, but are rarely the only players on the scene (Gunderson 1999, Carlsson and Berkes 2005).

The ability of actors to actively learn from their actions has hence been proven to be fundamental in dealing with complex and uncertain ecological systems. How well does the current implementation of the WFD address this issue? The short answer is: not at all. The arguments are two.

First, though citizen and stakeholders are expected to take part of various parts of the water planning cycle (see figure 4), they are not likely to be invited in the authorities' attempts to understand system dynamics. As the interviews show, the emphasis of stakeholder involvement will be on supplying data and providing feed-back to the plans presented by water authorities. None of the five water authorities has concrete plans to invite stakeholder groups to joint learning processes that deal with the joint analysis of freshwater system dynamics - i.e. identifying feedbacks, driving forces, thresholds, possible regime shifts and major uncertainties.

The reason for this is not that the water directors assume to have full knowledge over freshwater dynamics, on the contrary. Interviews show that water managers are fully aware of the difficulties in assessing the environmental status of freshwater resources, the uncertainties associated with realizing water improvement projects, and a number of organizational and political issues that remain to be solved and that lead to intense social uncertainty (I1, I2, I3, I4, I5, I6).

Second, none of the water authorities have yet formulated a strategy for in what way, or what actors are to participate in the water planning cycle evaluation. While two directors argue that the main work has to be done by central agencies in collaboration with the water authorities (I1, I4), one does not know (I3), the other two welcome as broad participation as possible (I2, I5).

Relying on Models

As the interviews show, water authorities seem to put their faith in existing models such as those developed by the Swedish Meteorological and Hydrological Institute (e.g. the HBV-model), or the IVL Swedish Environmental Research Institute (e.g. EQMS-Watshman) as a way to deal with complexity and uncertainty. At this point however, there are no materialized plans on how to use these models in collaboration with stakeholders, nor to promote joint discussions and learning processes using these models (I1, I2, I3, I4, I5, I6).

This state of affairs is troublesome considering the fact that stakeholders tend to disregard sophisticated, and what they regard as too generalizing models. This is one important result from the use of advanced modelling tools in collaboration with local actors such as farmers and municipalities in Sweden (Alkan-Olsson 2005, see also Smith Korfmacher 2001). Put bluntly, trying to use the models in a "top-down" manner without seriously opening up for two-way communication results in the absence of the analytical deliberation required hence blocking any attempt to understand system dynamics, and in the end tackle serious water related environmental problems.

The lack of ambition concerning stakeholder involvement and learning seems moreover, to be a more general problem in the realization of the WFD. A discussion of how actors are supposed to learn together is clearly absent in several Swedish key implementation documents at both the national level (e.g. SOU 2002:105, NVV 2003), and at EU level (e.g. EC 2003). Although "learning" is extensively discussed in the latter publication (e.g. EC 2003:50ff), what is meant here is that central managers and stakeholders are to learn to respect each other views and the diversity of stakes, and *not* to mutually understand system dynamics.

In short, although networks and learning are critical components in adaptive freshwater management, the WFD does not seem to create such an arena for discourse or learning.

Harnessing Uncertainty and Complexity in Stakeholder Participation

Though citizen and stakeholder participation is extensively discussed in the guideline document discussed earlier (EC 2003), some key aspects seem nonetheless to be missing. Before moving on to the next issue, one such important drawback remains. The fact that freshwater systems often are complex and embed vast uncertainties is not discussed at all, nor integrated into the stakeholder processes proposed by European authorities. How managers and stakeholders are supposed to tackle uncertainty in freshwater management jointly hence seems to be a missing puzzle in present guidelines to member countries (see EC 2003:66ff). More precisely, *there seems to be no preparation for how managers are supposed to tackle the fact that ecological systems are far from being fully predictable and under pressure from environmental change, or that unpredictable changes in social and political circumstances might seriously change the conditions for stakeholder participation and the creation of social networks* (see Box 3 below for an example).

The implications from this drawback should not be underestimated for two important reasons. First of all, uncertainty concerning freshwater systems might lead to either locked in and unsuccessful collective action (Galaz 2005), or to decisions that are extremely cautious, which in itself is a form of rigidity that forestalls innovation (Walker et. al 2003). Hence water managers are in need to suggestions on how to progress with stakeholder participation despite vast uncertainties. A second, promoting and harnessing social process such as stakeholder cooperation is far from a simple task under social and ecological uncertainty. Getting actors together and designing complex negotiation processes to reach a common strategy or measure plan, but ignoring uncertainty might destroy, instead of build trust and social capital. The reason for this is that a sudden external disturbance (e.g. environmental variability or unexpected changes in key policies) or environmental change (e.g. Carpenter and Cottingham 2002:57), might seriously undermine existing social capital among the actors. Box 3 describes one such scenario.

Box 3. Destroying Social Capital? Three Scenarios

Consider a case where managers and local stakeholders (such as farmers interests, local decision-makers, environmental NGO and business community representatives) in a highly eutrophic river basin intend to create and implement a common strategy plan to combat nutrient leakage. An ambitious goal to decrease nutrient leakage by 30% in a five year period is set by authorities for their joint collaboration. There are several possible scenarios emancipating from this setting. The first one is that collective action is achieved and the goal achieved (**Scenario I**). From a resilience perspective however, at least two other important scenarios are possible. One is that collective action is not achieved at all because key stakeholders refuse to contribute to the process. The argument is the several uncertainties concerning the sources of pollution and the possible improvements of the realization of the plan (**Scenario II**). The goal is hence not achieved. The third scenario (**Scenario III**) is that collective action is achieved, measures are implemented, and the reduction is realized. A couple of years later however, nutrient leakage increases again and eutrophication processes are visible again for uncertain reasons. This time managers are facing a situation where not only freshwater resources are degrading, but also highly skeptical stakeholders disappointed by the fact that their efforts did not result to real improvements. Water managers trying to rebuild trust with local stakeholders are facing an immensely difficult task.

II. Be prepared for Change

Are institutions designed to allow for *adaptation to environmental change* and crises?

Freshwater resource management is facing a number of adaptive challenges. One of the most important are those resulting from an expected climate change. Even though the impacts of climate change on both the quantity and quality of freshwater resources is difficult to grasp and predict, some initial modelling attempts and case studies highlight both possible and troubling scenarios. Andréasson et. al.

(2004) elaborate the impacts of climate change on nutrient leakage and water quality in Swedish freshwater systems. As they demonstrate in their scenarios, we may expect increased annual load from land to sea, and “radical changes in lake biochemistry” (ibid, pp. 3).

The European Commission’s Joint Research Centre makes an up-to-date scientific synthesis of the possible impact of climate change on water resources and quality in the European inland and coastal waters in its publication “Climate Change and the European Water Dimension” (2005, for summary see Appendix 4). Some of the possible implications of climate change on freshwater systems should be of central concern for water policy makers, such as:

- The incidence of extreme precipitation events is predicted to increase, which suggests implications not only increased contamination resulting from run-off but also decreased groundwater recharge and increased incidence of flooding (EC-JRC 2005:34).
- Changes in precipitation patterns might influence availability of surface water resources, leading to increased exploitation of groundwater, which might at worst impact wetlands and coastal ecosystems (ibid).
- Because of complex interactions, biological changes induced by climate change are inherently unpredictable. Small variations in climate can have dramatic effects on biota (EC-JRC 2005:52)
- Future climate change will influence the distribution patterns and mobility of organic pollutants and toxic metals (e.g. lead, cadmium, mercury) in freshwater systems and lead to changes in the uptake and accumulation of these substances in freshwater food chains (EC-JRC 2005:144).
- Water bodies may change in type, like changes in lake mixing type. These changes “will have a major impact on the ecosystems of these water bodies” (EC-JRC 2005:138).

So the question is: are we prepared? Interesting enough, climate change and its possible impacts on water bodies has been left out of the scope of the WFD. It is remarkable that the term “climate” does not appear in the text of the Directive (EC-JRC 2005:137). This absence is also present in the documents that are supposed to support the realization of the WFD in Sweden. More precisely, key documents targeting water managers and guiding the future work assumed by water directors in the country such as NVV (2002), NVV (2003), NVV (2004a,b,c), (SOU 2002:105) *do not mention the possible impacts of climate change on freshwater resources*. Nor does the newly made analysis of Swedish freshwater resources acknowledge the possible threats of climate change (e.g. NVV 2005). As a consequence, none of the present water directors in the country have materialized plans on how to approach environmental change. On the contrary, only one out of five water directors acknowledge the need to integrate global environmental change into the work of the water authorities. Put bluntly, Swedish water directors seem to apply a “wait-and-see” strategy to the possible impacts of climate change (I1, I2, I3, I4, I5).

Interesting to note is that even if the primary causes of climate change are beyond the scope of river basin planning, the river basin management plans as discussed in the WFD can be used to mitigate adverse effects of climate impact. As climate change and freshwater experts argue, “there will be adverse effects of human-induced climate change that cannot be avoided, even with co-ordinated action at a European level. As a consequence, classification scales and therefore river basin management plans need to be adapted taking into account the effects of climate change” (EC-JRC 2005: 138). This is presently not the case in the realization of the WFD in Sweden.

A Note on Modelling and Climate Change

The use of various sorts of models in river basin planning might seem like the way to go for managers to deal with increased complexity and uncertainty. At best, models are able to place environmental changes in a tangible spatial and temporal perspective, as they are able to aggregate large amounts of data. Models are also able to integrate knowledge about ecological quality with costs for attaining such a quality in the future, which creates a solid basis for communication between experts and the public (Alkan-Olsson and Berg 2005).

One largely ignored fact is however, that these models often must rely on simplified assumptions that seriously limit their capacity to predict the impacts of climate change. As elaborated by Bleckner (see Appendix 3) the predictions for hydrological changes in a specific catchment or region as a result of global environmental change are rather uncertain. There are several reasons for that. Concerning the model design, first, precipitation varies largely in different climate models due to uncertain and nonlinear processes in the atmosphere. Second, the coupling between climate and hydrological models is still a challenge. A recent study coupled a Swedish regional climate model with a hydrological model (HBV). This coupling, or better, interfacing has been performed with a so called delta change approach. This fairly common approach refers to the relative change between the future and recent climate. The large limitation of this simplification approach is that it excludes future climate variability and extremes. The only way to overcome this problem is to fully integrate the hydrological model into the climate model, which would require a precision of climate models which has not yet been reached (see Bleckner in appendix 3).

III. Institutional Nesting and Variety

a) Is policy treated as *hypotheses and management as experiments* from which central managers can learn?

The argument that social-ecological systems are characterized by complexity and uncertainty implies that managers are far from having full knowledge or control over freshwater resources. Command-and-control approaches might hence seriously undermine the services provided by freshwater resources (Folke 2003, Holling and Meffe 1996). As discussed earlier, it is critical that institutional and organizational structures allow for experimentation with different strategies for natural resources management. To help develop new institutional arrangements, we might apply adaptive management experiments not just to freshwater resources, but also to institutions themselves.

The WFD does indeed include an evaluation phase in the water planning cycle. More precisely, European water authorities are supposed to evaluate whether the environmental targets have been met every six years. This evaluation cycle might - at best - be viewed as an attempt to allow for adaptive responses to environmental change. Evaluation of this kind, and treating policy as hypothesis and management as experiments, should however not be conflated. The reasons are the following.

First, even though environmental targets will be evaluated on a regional level, there seems to be no plan to actively experiment and *systematically* evaluate local water improvement projects to understand system dynamics, nor to assess the thresholds of freshwater systems to avoid sudden and unwanted state shifts (I2, I3, I4, I5, I6). As discussed earlier, crossing the threshold brings about a sudden, large, and dramatic change: for example, the shift from clear to turbid water in lake systems (Walker and Meyers 2004, Scheffer et. al. 2001, Carpenter 2003).

Second, there are no plans neither in key guideline documents such as NVV (2002), NVV (2003), NVV (2004a,b,c), (SOU 2002:105) nor among water directors (I2, I3, I4, I5, I6) to actively experiment and evaluate institutional or organizational alternatives. On the contrary, water directors seem to try to *suppress* both institutional and organizational diversity to secure homogeneity in the five water districts (I1) thereby risking to stall potentially future efficient social innovation hence actually *creating* institutional vulnerability (c.f. Streeter 1992, Anderies et. al. 2004, Dietz et. al. 2003).

It is crucial to keep in mind that several of the social processes – such as collective action and social learning – needed to reach the environmental objectives set by water authorities are also complex, which implies a need to experiment and evaluate both successes and failures in a systematic fashion. The WFD and existing guideline documents from Swedish central authorities provide no guidance here.

How Does Water Directors Tackle Uncertainty?

If policies are not treated as hypotheses, and management is not approached as experiments, how do Swedish water managers intend to tackle social and ecological uncertainty? As the interviews with the water directors show, the strategies assumed are both unsystematic and passive manner. Environmental uncertainty is either tackled by using existing expertise within the organization (I2, I3, I4, I5) or by relying on previous experience and research (I1). Models seem to, again, play an important role in identifying and elaborating scenarios for river basin management. The fact that the models normally applied by Swedish authorities imbed various uncertainties, especially when it comes to non-linear processes (see appendix 3 for details), is not acknowledged.

When dealing with social uncertainties, water managers tend to use strategies that involves discussions with other central agencies (I2, I4, I5), or to concentrate their work on areas "where uncertainty is low, instead of analyzing uncertainties" (quote from interview I3). None of these strategies can be seen as systematic attempts to tackle an increased complexity in freshwater management.

b) Does the WFD integrate *aspects of multi-level governance* in such a way that the ecological knowledge of local stakeholders is incorporated into institutional structures in a multi-level governance system?

There is no doubt that the intentions of the WFD create possibilities to include the ecological knowledge of local stakeholders in the resulting multi-level governance structure. The importance and potential of so called "public participation" is extensively discussed in e.g. (CIS 2003, CIS 2003b). Swedish authorities also seem to take the issue seriously (e.g. SOU 2002:105, NVV 2005b). There are nonetheless three circumstances that seem to be missing if the outcome of public participation is to build social-ecological resilience.

First and as discussed earlier, Swedish authorities have no concrete plans on how to engage local stakeholders in social learning, but instead rely heavily on existing and scientifically based (i.e. from the natural sciences) models. Arenas where local stakeholders, government bodies and modellers can interact and complement each others knowledge is at present absent in the realization of the WFD in Sweden.

Second and as discussed above, Swedish authorities seem to plan to engage the public assuming linear freshwater systems, hence ignoring the possibilities of surprises, regime shifts and possible impacts of climate change. As argued above (i.e. Box 3), this might seriously undermine the existing trust between water authorities and local stakeholders.

Third, there are reasons to question whether the present competence in Swedish water administration is fit to tackle complex social processes such as collective action and social learning. The issue here is not ignorance; on the contrary, Swedish water directors and managers such as Environmental Chief Inspectors and municipal environmental representatives often have extensive experience in interacting with local stakeholders. The problem is instead that the financial resources at present seem to be very limited, which results in water directors very limited recruitment possibilities (I2, I3, I4).

V. How? Resilience Analysis in IWRM

The analysis so far has been characterized by an evaluation of the WFD and its implementation in Sweden. Before summing up the analysis however, I would like to contrast the difference a resilience approach makes to integrated freshwater resource management, and point out some constructive solutions to some – though certainly not all – of the questions and problems raised earlier.

The focus of this chapter is on how to design participatory processes that 1) include local stakeholders' ecological knowledge into multilevel water governance, 2) takes uncertainty and complexity seriously, and 3) helps to build, rather than undermine social-ecological resilience. As will be shown, enough substantial progress has been made by natural resource researchers the last decades to be able to give some initial suggestions to water policy makers and managers.

Walker et. al. (2003) develop a framework for analyzing and managing resilience that should be applicable for freshwater management, and that specifies how IWRM can be redefined to tackle uncertainty and complexity. It involves a stakeholder-driven description of the system and the issues, leading to a limited set of scenarios that capture the major uncertainties. Important steps in this process are the following (see Walker et. al. 2002 for details):

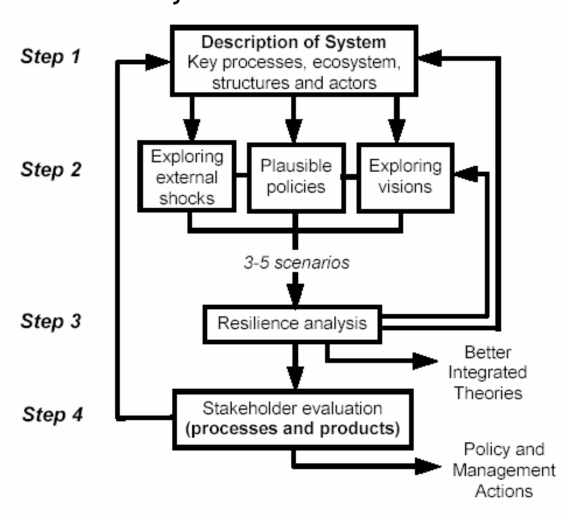
Step 1. Description of the System

This process is strongly based on stakeholder input, and is intended to define the problem and to obtain information on the important issues and the major drivers. In this first step, uncertainties are exposed and discussed jointly to specify which factors are controllable (e.g. land use), and which are not (e.g. climate). The product of this first step is a conceptual model embodying what is known about the system in terms of issues seen as important by stakeholders, at the same time as it defines major uncertainties.

Step 2. Visions and Scenarios

In this second step, a limited set of possible scenarios - that include the outcome of uncontrollable and ambiguous external drivers - are defined. These scenarios are developed by considering different kinds of drivers of the systems future and developed considering both external shocks and disturbances; the visions, hopes and fears that people have for the future; and a set of policies that might conceivably be imposed.

Figure 5. Resilience Analysis in IWRM



Comment: From Walker et. al. (2002).

Though this might sound like an overwhelming task, there a number of relevant cases where such an approach has been assumed. As an example, Peterson et. al. (2003) describes such a process conducted in The Northern Highlands Lake District of Wisconsin (USA). In this particular case, actors have been able to identify key social and ecological driving forces, and three alternative scenarios to the year 2025 in which the projected use of ecological services is substantially different, are presented. The SLIM project - Social Learning for the Integrated Management and sustainable use of water at catchment scale – provides another highly relevant example for how social learning can be promoted.[3] (For other related examples, see Bennet et. al. 2003, Peterson et. al. 2003b).

Step 3. Resilience Analysis

This third step consists of combining modelling and non-modelling methods to further specify both key drivers, with a specific focus on threshold effects and other non-linearities. The process is iterative and begins with a discussion among stakeholders, policy makers, local

[3] URL: http://slim.open.ac.uk/page.cfm

experts and scientists aimed at examining how the system will respond and change under various scenarios. The use of a number of simple models of the system's dynamics, highlighting the significance of variables at different time scales, and focusing on the underlying driving variables, could in this phase advance the understanding among policy-makers and stakeholders.

It is difficult to describe step 3 more precisely, because it is context dependent and each freshwater system will require a different combination and balance of models and non-modelling analysis. There are nonetheless a number of prototypes that could provide fruitful alternatives to freshwater management (e.g. Carpenter et. al. 1999, Janssen et. al. 2000, Carpenter et. al. 2001). For a discussion of how "thresholds" can be identified, see Walker and Meyers (2004). See also National Research Council (2003), Castella et. al. (2005) and Garaway and Arthur (2002) for concrete examples of how learning is promoted trough integrated monitoring, modelling and research.

Step 4. Resilience Management - Evaluation and Implications

The final step involves a stakeholder evaluation of the whole process and the implications of the emerging understanding for policy and management actions. A successful resilience analysis identifies the processes – both social and ecological - that enhances or reduces resilience and that therefore form the basis for resilience management and policy.

Resilience and the Water Planning Cycle – What is the Difference?

The process described above might seem to be a slightly modified version of the water planning cycle proposed in the WFD. And there are some important similarities. First, they are both iterative processes. Second, they both aim at including a number of non-government actors such as academia and local stakeholders. Third, they both try to promote collective action and social learning among actors. There are however, at least four crucial differences are worth highlighting.

First, while the WFD intends to promote stakeholder participation and social learning, a resilience analysis does this *with the explicit intention to identify the major uncertainties in the system's future dynamics*.

Second, though various models are likely to be used by future water authorities, resilience analysis attempts to use models to describe the dynamics of the system to *work through scenarios to* *identify the components of the system's resilience*, and how resilience may be lost or enhanced through management initiatives.

Third, resilience analysis has an explicit ambition to try to identify the processes that drive the *dynamic behaviour of freshwater systems, and to identify critical threshold*s. These aspects are not an integrated part of the present Water Planning cycle,

Fourth, the aim of resilience management is to prevent freshwater systems to move into undesired states in the face of external stresses and disturbances. In contrast to the WFD, the *focus is not on monitoring activities and achieving a fixed water quality target*, but rather on nurturing and preserving the elements that enables freshwater systems to renew and reorganize itself following a disturbance.

VI. Conclusions and Policy Implications

We all make decisions that rely on assumptions about an uncertain future. Freshwater management also relies on the process of decision-making based on our understanding of the world and our predictions about the future. Traditional planning however, is frequently based upon the belief that the application of professional expertise to achieve well-defined goals will ensure efficient and effective management. Unfortunately, such plans might fail to consider the tendency for changing situations to create extraordinary surprises. This sightlessness to surprise and external disturbances can lead to costly failures (Holling and Meffe 1996).

The analysis in the preceding chapters has highlighted a number of drawbacks of the current realization of the EC Water Framework Directive in Sweden. The reason is that the incentives that result from the current realization of the WFD, simply do not promote water management approaches that is able to take ecosystem dynamics, complexity and uncertainty seriously.

The table below illustrates a number of aspects that differ significantly between the resilience approach presented in this paper, and the current realization of the WFD.

Table 1. Contrasting the EC Water Framework Directive and Adaptive Freshwater Management

Dominant WFD Perspective	Adaptive Freshwater Management
Stakeholder participation is promoted to secure the legitimacy and efficiency of water management activities.	Collective action and network building is promoted to strengthen actors' joint capacity to tackle social and ecological uncertainty, and unexpected events.
Social learning is limited or realized to create consensus around water management initiatives.	Social learning is institutionalized to understand freshwater system dynamics and identify major uncertainties.
Institutions are designed to achieve fixed quality and quantity targets.	Institutions designed to allow for adaptation to environmental change and crises.
Evaluation is unsystematic, and experimentation is applied *ad hoc*.	Policy is treated as hypotheses and management as experiments from which central managers can learn.
Strategies to deal with uncertainty and complexity are absent.	Developing strategies and stakeholder driven processes to tackle uncertainty and complexity are a fundamental aim.
Emphasis on solutions to achieve fixed water quality and quantity targets.	Emphasis on solutions that change structures in freshwater systems with the objective to reduce vulnerability and to strengthen users' capacity to respond and adapt.
High reliance on models to describe status of water resources, and as a base in river management plans.	Models are important in collaborative processes aiming to define the dynamic behaviour of freshwater systems, and to identify critical thresholds.
Institutional homogeneity is promoted to secure administrative equality along the country.	Institutional diversity is encouraged to promote innovation and reduce vulnerability.
Multi-level water governance is encouraged to secure legitimacy and efficiency of fixed targets.	Multi-level governance is promoted to secure local ecological knowledge, reduce vulnerability and to strengthen users' capacity to respond and adapt.

More precisely, the analysis of the Swedish case indicates a number of issues summarized below in the following three key points:

Key Point 1

Collective Action and Analytical Deliberation is Highly Limited

- Collective action among Swedish water users is seldom ambitious, which implies that the adaptive capacity of key local stakeholders is highly limited. None of the interviewed water directors have an explicit strategy for how to improve the current situation.
- Learning processes which include the joint analysis of system dynamics is currently a non-issue. Water directors hence do not have an explicit strategy on how to stimulate learning processes between local stakeholders, academia and managers.

Key Point 2

Water Management Institutions Disregard Complexity and Uncertainty

- There is no preparation for how water managers are to promote stakeholder participation in the face of high social and ecological uncertainty. In addition, the fact that unpredicted changes in social, political and ecological circumstances might seriously change the conditions for stakeholder involvement is not recognized.
- There are currently no plans to actively experiment, *systematically* evaluate local water improvement projects, or to assess the thresholds of freshwater systems to avoid sudden and unwanted state shifts.
- Water authorities seem to try to suppress both institutional and organizational diversity hence risking stalling potentially future efficient social innovation. This might at worst create institutional vulnerability.

Key Point 3

Water Policy is Poorly Prepared to Tackle Global Environmental Change

- Climate change is likely to pose fundamental challenges to Swedish freshwater resources.
- These impacts have received limited attention in both the Common Implementation Strategy documents produced at the EU level, and by key Swedish authorities such as the Swedish EPA.
- Four out of five water directors apply a “wait-and-see” strategy to climate change, and there are no concrete plans to adapt classification scales and river basin plans taking into account the effects of climate change.
- The model expected to provide an important basis for the activities assumed by water authorities is not able to handle nonlinear interactions and feedbacks across scales. This implies that future river basin plans are likely to misinterpret potential impacts of climate change.

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Interviews

Code	Name	Water Authority/Central Agency
I1	Lennart Sorby	Norra Östersjöns vattendistrikt
I2	Björn Sjöberg	Västerhavets vattendistrikt
I3	Bo Sundström	Bottenvikens vattendistrikt
I4	Dea Carlsson	Södra Östersjöns vattenmyndighet
I5	Åke Bengtsson	Bottenhavets vattenmyndighet
I6	Ulla-Britta Fallenius	Swedish Environmental Protection Agency

Appendix 1.

Questionnaire used in interviews

1. Could you please start by telling me something about what you worked with before you became a water director?

Uncertainty and Complexity

2. Two important parts of your work is to make both an assessment and monitor freshwater resources, but also to initiate concrete water improvement programs. Which are the major ecological and biological uncertainties that might create a problem for these tasks according to you?
3. Which are the major social and political uncertainties?
4. How do you plan to tackle these uncertainties concretely?

Dealing with Environmental Change

5. Your district has just realized an assessment of the status of freshwater resources, to fulfill the report requirements posed by the Water Framework Directive. Would you like to tell me something about this assessment?
6. Does this assessment include future challenges such as those posed by climate change?

Collective Action and Social Learning

7. How well is voluntary water user collaboration developed in your district? Will these associations play an important role in your future work?
8. How do you plan to involve these groups? How important role will existing freshwater models play for your future work?
9. Will these be used in collaboration with local stakeholders? How?

Evaluating and Experimenting

10. Your district is supposed to assume an evaluation according to the water planning cycle every six years. What exactly is to be evaluated according to you?
11. Which actors will participate in this evaluation?

Competence

12. What kind of expertise are you likely to recruit in the nearest future?

A Scenario

13. Before I end, allow me to present a scenario, and then I would like you to give a rough estimate of the likelihood of such an outcome. Assume that your authority realizes a highly ambitious water improvement plan to tackle eutrophication in an important lake system. Despite these measures, there is no notable improvement. What would you do in such a scenario?
14. Is this a likely scenario?

Appendix 2. Interview Summary

Question/theme	I1	I2	I3	I4	I5	I6
Uncertainty and complexity						
Major ecological uncertainties?	Lack of ecological and biological data. Status classification of freshwater resources. Effects of water improvement projects.	Biological parameters. Effects of water improvement projects. Status classification of freshwater resources. Quality target for freshwater resources.	Status classification of freshwater resources. Lack of ecological and biological data.	Lack of biological and chemical data. Effects of water improvement projects.	Lack of biological and chemical data. Difficult to assess quality target for freshwater resources. Processes concerning the possibility of improvement of freshwater resources.	Hazard substances Lack of biological and chemical data. Dynamics of diffuse pollution (e.g. nutrients). Flows from land to coastal areas and sea.
Major social uncertainties?	Legal status of river management plans. Distribution of	Financing. Conflicting legislation (Miljöbalken and	Legal status of a measurement plan.	Economic data Distribution of power between central	Lack of financial support. Lack of efficient coordination at	Lack of financial support. Legal status of

	power between central government and municipalities.	PBL) Distribution of power between central government and municipalities.	Financing. Swedish government's political will and level of ambition. Swedish municipalities involvement.	government and municipalities.	the central level (i.e. ministry).	river management plans. European agricultural policy. European marine strategy.
How will you deal with these uncertainties?	Use of previous experience Use of the water planning cycle to evaluate earlier projects.	Discussions with other authorities and university. Waiting for material from Swedish EPA. Meetings with central agencies and organizations to build support, and get the issue on the agenda.	Rely on existing data, ask available expertise. Concentrate on taking action where uncertainty is low instead of analyzing uncertainties.	Discussions with central agencies responsible for providing standards etc. Discussions with central policy investigators and others that might be able to provide required expertise.	Work with existing resources and motivate other government authorities to contribute. Continuous contact with different central policy investigators.	n.a.
How do you deal with the threats from climate change?	Not certain that we will be affected. Wait and see.	Not certain that we will be affected on the long term. Wait	Does not affect us our work at this stage. Maybe an issue at	Has been discussed though, but no specific strategy	Is not part of present work, but will be assumed in the realization of the	n.a.

		and see.	later stage of our work.	or concrete plan.	river management plans in the future.	
Collective action and social learning						
How well is local stakeholder involvement developed in your district?	Well developed.	Well developed, about 31 associations.	Not well developed.	A number water associations exist, not sure of how well they work.	A few.	n.a.
How will these groups be involved in your work?	They are important, they are knowledgeable. Main responsibility to stimulate involvement lies on regional authorities. No specific plan to involve stakeholder groups.	Important as they provide important information. No specific plan to involve stakeholder groups.	No strategy or plan yet.	Will be important in the work, especially concerning the measurement plan.	Will be important due to the lack of data. Difficult to achieve voluntary participation from these actors, there is a risk that important actors will not participate..	Important, help with monitoring activities and provide data. No specific plan to involve stakeholder groups.
How important to your work will existing models	They will play an important role. Scenarios will be	Very important. Will be used to describe the	Yes, they are in principle important and	Yes, they are important.	Yes, very important due to the lack of data.	Important, will be used to design river

be?	developed by experts, these will be used in status classification and in measurement plans.	status of freshwater resources, as a base in improvement plans to simulate effects. Also as a pedagogical tool.	are likely to become even more important in the future. Simpler models will be used. No explicit strategy or plan.		Will provide the base for water planning activities.	management plans.
Will these be used in collaboration with local actors?	Yes, we will initiate such initiatives. No specific plans.	Yes, that is very important. Maybe in 30-40 water associations and in collaboration with local stakeholders. Otherwise, no specific plans.	No specific plans.	The main work will be made by authorities and experts. Stakeholders to be invited to discuss what measures are needed.	Yes, will be used together with stakeholder groups. River management plans must emancipate from "the bottom".	Probably, to secure local knowledge. No concrete strategy or budget for how to realize ambition.
Evaluation and experiments						
What will be evaluated?	Monitor whether implemented measures have had the intended effect. A new	Monitor whether the status of freshwater resources has changed. Revised	No specific strategy.	Will be done by the Swedish EPA to monitor the status of freshwater	To assess whether the quality targets have been reached. Besides	River management plans and freshwater

	characterization.	characterization and measures.		resources, whether the quality targets have been reached, what new measures might be needed etc.	from that, no specific plans.	status.
Which actors will take part?	Those who are interested. Main work will however be assumed by water authority.	As broad as possible. No specific plans.	No plans.	Do not know, no plan.	No specific plan, but it should be actors such as academia, water users such as industry, and representatives for the general public.	Will be assumed by water authorities in collaboration with stakeholders. No concrete strategy.
Scenario	Reanalysis of why no improvement has been experienced. New measures.	Reanalysis using models and simulations. New measures.	Use the six-year water planning cycle to evaluate measures, or lower level of ambition.	In general, we will not change the way we work. New data on the sources of pollution might be needed, new monitoring programs assess the impact of measures.	If funding is provided, research activities. Further but more efficient measures.	n.a.

Is it likely?	Yes, in some areas this is likely to happen. Other measures will be needed besides nutrient load mitigation.	Very likely for eutrophication and acidification.	Likely.	Likely for some of our lakes, and in coastal areas.	Likely.	n.a.
Competence						
What kind of experts do you expect to recruit in the nearest future?	Modellers, economists, monitoring, groundwater expertise, data analysis, webmasters.	Groundwater expertise, limnologists, oceanographers, data analysis, legal expertise.	A mix of natural and social scientists. Depends on future financing.	Social and economical experts. Depends on future financing.	-	Environmental economists, lawyers, natural scientists. Depends on future financing due to present lack of resources.

n.a. = not applicable. This interview has been used to provide information about the present status of the WFD in Sweden, and as background information to the rest of the interviews.

Appendix 3.

Nonlinear processes and model uncertainty

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Nonlinear interactions and feedbacks across scales and their associated thresholds are common features of systems in general and ecosystems in particular. These spatial nonlinearities challenge scientists and engineers to understand and model system behaviour, as cross-scale often results in a "point of no return" (thresholds) or surprise with considerable consequences for the environment and human welfare. Good examples are floods, initiated by heavy rainfall, which spread nonlinearly over large landscapes, in that case a result of positive feedback between weather, river basin management and urbanization and only all three components together determine the area affected by the flood. Therefore, nonlinear processes can have large impacts on ecosystem function, local and regional economy and human health (Schimel and Baker 2002).

At the moment, many scientists focus their work on data analysis and develop models to predict nonlinear processes and feedbacks to reduce the uncertainty of for example flood predictions under a future climate. However, at the same time, some groups (e.g. policy makers and managers) want or need to know the answers, e.g. the risk of floods in the near future, well before scientists have resolved the large uncertainties in the understanding of the processes.

These interest groups are therefore forced to base their decisions of high political importance on rather unreliable, uncertain system information. At this point, two different approaches are possible:

a) to improve the knowledge and reduce the uncertainty from the scientific part of view.

b) to build a high stressor tolerance in the system, i.e. increase the resilience of the system, (see also Janssen and Carpenter 1999; Folke et al. 2004) which reduces the impact of possible stressors in the future.

Before models/knowledge reach a better certainty or, in other words, a lower risk of failure is feasible, a management towards a high stress tolerance remains necessary (b). The challenge for science meanwhile is to understand the nonlinear interplay of high impacting factors beyond a point of no return which result, for example, in large floods.

The only way how thresholds behaviour can be understood is through the incorporation of processes across spatial scales that cross traditional disciplinary boundaries (Peters et al. 2004). In a mathematical model, thresholds are critical values of the independent variable around which the ecosystem flips from one stable state to another. These thresholds are mostly associated with nonlinear processes, i.e. already a minor change can lead to dramatic consequences. To study such processes, mathematical models are necessary.

Hydrological models calculating the water balance of a catchment are such a tool. The most common approach in this field are conceptual models, using more simple assumptions of the complex processes, which can be applied to many problems (see for a review Xu and Singh 2004), e.g. the hydrological change of the future climate in a particular region. One of the most significant potential consequences of changes in climate may be the shift in hydrological cycles, which will affect agricultural productivity, energy use, flood control, water supply and ecosystem management.

The assessment of a number of different climate models simulating the future climate change indicates a non-uniformly large change in temperature and precipitation with large regional variation in the near future (IPCC 2001). By using the results of a climate model as an input for hydrological models, the predictions for hydrological changes in a specific catchment or region are rather uncertain. There are several reasons for that. Concerning the model design, first, precipitation varies largely in different climate models due to uncertain and nonlinear processes in the atmosphere. Secondly, the coupling between climate and hydrological models is still a challenge. A recent study coupled a Swedish regional climate model with a hydrological model (HBV). This coupling, or better, interfacing has been performed with a so called delta change approach (Andréasson et al. 2004). This fairly common approach refers to the relative change between the future and recent climate. The large limitation of this simplification approach is that it excludes future climate variability and extremes (Bergström et al 2001, Andréasson et al. 2004). The only way to overcome this problem is to fully integrate the hydrological model into the climate model, which would require a precision of climate models which has not yet been reached (Bergström et a. 2001).

The main challenges within in the conceptual hydrological model are mainly two a) calibration and b) not fully physically-based processes. The calibration of the model is based on the fact that conditions during the calibration period are similar to the application. This is of course never the case when the model is used in a climate change assessment. Thus, non-linear processes, which may occur in the future, cannot fully be captured by the model, as the past range was partly based on linear assumptions.

This problem is hard to overcome but important to recognize. Additionally, it is again important to realize that these are "simple" conceptual models, which means that not all processes are physically-based on processes in reality. Therefore, important processes such as snow melting and soil moisture are very simplified, due to complexity and the lack of adequate data, and will therefore be modelled with uncertainty. The advantage of physically-based models or subroutines in conceptual models is that they have a direct physical meaning and are thus measurable, which improves the validation (i.e. the test of the model) significantly and will include more nonlinear and stochastic processes.

Overall, the modelled hydrological change will be rather uncertain and will, therefore, under-represent stochastic and extreme events, making it for example very difficult to evaluate the risk of extreme events such as floods.

However, from the scientific point of view, this is a first start to evaluate potential future changes, which today are still significantly uncertain. It is therefore of highest importance to quantify this uncertainty by improving the understanding of nonlinear and stochastic processes in order to include such processes in the model. That would also allow for a mindful use of the future projections, for instance in water resources management (such as the European Water Framework Directive). The current uncertainty, i.e. the fact that you are not dealing with a final result, needs to be (more) clearly transported to the end-users (e.g. water authorities), as model predictions are of limited practical use without clear information about their reliability and accuracy (Seibert 1999). Therefore, model predictions should be given as uncertainty ranges, rather than single values.

Even if scientists do not yet fully understand the systems and the underlying processes, it could be possible that its recognition might help to set critical risk guidelines for relevant processes and scales in order to significantly reduce the possibility of surprises.

More intensive cross-disciplinary studies that identify the role of cross-scale interactions, stochastic and deterministic elements are essential to understand and forecast changes in the various components of the Earth System. Therefore, focus should be put on the identification of thresholds and the local/regional ecological and human tolerance to those, rather than on environmental changes in annual median conditions as such.

In the meantime, while scientists work on the reduction of uncertainties, ecosystems should be managed in a holistic and precautious way in order to maintain natural resilience and thus be prepared for future changes.

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Appendix 4.

European Commission, Directorate General Joint Research Centre, report:

Climate change and the European Water Dimension, A report for the European Water Directors, 2005

Summary by Thorsten Blenckner
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The compilation of this report follows a request from the European Water Directors (representatives from EU Member States and the European Commission). The study has been co-authored by more than 40 leading scientists from around Europe and the Directorate General, Joint Research Centre's Institute for Environment and Sustainability (IES). The report, (as a synthesis of scientific information especially updated since the 2001 findings of the International Panel on Climate Change) will be used to assess existing water policy and whether it can accommodate real or anticipated impacts of climate change.

The report offers additional convincing evidence of the warming of the atmosphere and European lakes and seas, alterations of biological, chemical and physical characteristics of European water bodies, and the dramatic impact on ecological processes in response to sea level rises, extreme events and warming. Some of the major findings are:

- The incidence of extreme precipitation events is predicted to increase.
- Responses of lakes to climate forcing are most coherent for physical parameters with a high probability for earlier ice-out, increase of lake temperatures, and stronger thermal stratification in a warmer future.
- Biological changes induced by climate change are inherently unpredictable. Small variations in climate can have dramatic effects on biota.
- Changes in extreme climate are likely to have a greater impact on society than changes in mean climate. Flood magnitude and

frequency are likely (a 66-90% probability) to increase in most regions of Europe.

- Europe's vulnerability to drought is increasing due to increased demand for water in some sectors and regions and the impact of climate change.
- Reference conditions, the basis for the ecological classification in the Water Framework Directive, are likely to change with climate and therefore cannot be considered as static.
- Agriculture is the most vulnerable human activity under unfavourable climatic conditions. In Europe, this applies for the northern (temperature-limited) and southern (moisture-limited) regions. Agriculture uses ~ 38% of the abstracted water with large regional differences - 50 to 80 % in southern Europe, < 5% in northern Europe

With the following suggestions for adaptation and action:

- Develop and apply regional climate change models at the river basin scale to assess potential response of land and water systems
- Quantify at the European and river basin scale the impacts of climate change on water quality and quality of surface water and ground water, including extreme events such as floods and droughts
- Evaluate the effectiveness of different protection measures in trans-national river basins with hydrological models as a response to possible increase in extreme events
- Establish long term monitoring at the pan-European scale of marine/coastal systems using earth observing satellites and other tools of those parameters sensitive or indicative of climate change

In terms of the Water Framework Directive, it is extremely important to view the reference conditions as non-static as it has been shown that the interannual climate variability and climate change of the last decades can lead to nonlinear changes (only climate-induced) in the ecological status of water bodies. Many water quality problems that were once thought to be due to local factors are now known to be affected by variations in climate. Therefore, dynamic reference conditions in combination with long term monitoring and water resource models capturing climate-related nonlinear processes are very important in order to account for climate impacts on the ecological status of water bodies.

The Report is available at URL: http://ies.jrc.cec.eu.int/