

# **Challenges in Water Resources Management**

Vulnerability, Risk and Water Resources Preservation

MARIE CURIE TRAINING COURSE VENEZIA (ITALY), SEPTEMBER 7-11, 2010









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Civilta dell'Acqua INTERNATIONAL CENTRE

## Challenges in Water Resources Management

Vulnerability, Risk and Water Resources Preservation

Proceedings of the 4th training course "European Sustainable Water Goals" Venice, September 7-11, 2010

#### Edited by

Eriberto Eulisse

#### Published by

Water Civilizations International Centre 2011 http://eswg.watercivilizations.org, http://www.civiltacqua.org

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**DVD layout** Paolo Orlando

**Cover Graphics** Giorgio Algeo

#### Acknowledgements

Elena Ridolfi, Viviana Re, Elena Lynch, Barbara Francescato

**Printed by** Grafiche Antiga (Treviso, Italy)

#### Front cover

Different times, different water uses. Photo by Eriberto Eulisse/waVE Photo Library

#### This publication is supported by:

European Commission, Marie Curie Actions, 6th Framework Programme (contract n. 46161)

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# Foreword

Climate change is increasingly recognised as an important threat for mankind and ecosystems. Some impacts of climate change, in particular, are likely to have devastating consequences for human lives, social systems and natural resources, at least in some regions of the world. Among these impacts, water stress is certainly a crucial one.

Water availability is likely to be dramatically reduced in some areas, with negative repercussions on food production, biodiversity, migrations, and development. Therefore, whenever one deals with climate-related physical and economic impacts, water shortage and risks associated to water shortage must be at center of the analysis.

Symmetrically, any study of water resource management should consider global change dynamics among the crucial factors to be addressed. Water resource management needs to integrate climate related phenomena at multiple scales, in particular in most vulnerable regions.

Countries and cities of many world regions deliver inadequate water resource management. In too many cases, human beings are already misusing, overexploiting, and polluting natural resources and ecosystems. Inevitably, economic development and population growth are going to increase resource needs and to deplete the existing stocks of resources in the coming decades.

Climate change will be an additional complicating factor that will make sustainability even more difficult to achieve. In such a context, policymakers and business leaders at different scales must define their strategies for a sustainable development and for a sustainable use of world limited resources, first of all water.

Fortunately, mankind has a long tradition of efforts and culture of water management. Institutions have been established, innovative technologies have been developed, managerial skills have emerged in all societies. We just need to adapt these institutions, technologies and skills to the new challenges created by rapid economic development and climate change. Sustainable water management requires the integration of innovation, both scientific and institutional, with local cultures, institutional setting, existing political and military confrontations, etc.

This integration requires, among other things, new forms of education and continuous research efforts. This book is a clear example of results and advances produced by cooperation among scientists and scholars from different fields. Ca' Foscari University, by cooperating with the International Centre for Water Civilizations, has contributed to this book and will continue to invest resources on the analysis and policy of sustainable development in the coming years. I am very grateful to all authors and contributors for this initiative and for all forthcoming ones.

> Carlo Carraro Chancellor University of Venice Ca' Foscari

# **Preface** Water Resources Management: Towards a New Philosophy

Janos J. Bogardi

During the last decades of the 20th century water has started to emerge as a genuine global concern. Human existence, development and well-being have always been linked to water. However, the resource, its quality and availability have been taken for granted, often without considering its finite nature and intrinsic fragility. Rapidly deteriorating water quality, potential shortages, but also the recognition of disparities as to access to safe water, sanitation and water availability as a factor of development, highlighted a mounting water crisis and emphasized the limits of the world's water resources.

Even in the so called developed part of the world, with its superb technical abilities, the consequences of mistakes of an unconcerned exploitation of water resources started to be felt, acknowledged and gradually not any longer accepted by those affected.

The free-wheeling approach which allowed water resources management to be considered as a technical problem to be solved alone by experts started to fade. Instead, gloomy scenarios of "water wars in the 21st century" emerged. Water crises, at regional and global scales were predicted. Series of recurring high profile events, summits, the Millennium Development Goals, the Millennium Ecosystem Assessment, the World Water Development Reports and the triennial World Water Forum mark this process of mentality change.

The recent resolution of the General Assembly of the United Nations declaring access to water as a human right can be seen as the ultimate acknowledgment that water is not just one among the many natural resources. While water services come at a price, water is neither an economic good nor it is simply a closed, well defined service sector. Considering the multifaceted nature of water, its uniqueness without replacement, and hence the need to protect it, there is an urgent need to internalize these issues by professionals as well as by the public.

We may be on the right track, but progress is painstakingly slow. While we are still far from reaching the water related Millennium Development Goals (which,

even if reached would still leave about 800 million people without access to safe water and more than a billion without adequate sanitation), we face a harsh "water world" full of risks and uncertainties. We do not know for sure when and where how much water will occur, whether next we face drought or flood. But not only the occurrence of extremes, the spatial and temporal distribution of the resource remain elusive to our mental grasp.

Water shortage is seen predominantly as a quantitative problem, though water is a solute. Its quality must match the requirements of the use and that of the legitimate needs of ecosystems. Water quality and water quantity should be managed simultaneously. Improving monitoring and water quality analysis techniques reveal hitherto unknown threats. Some of them emerge as products and byproducts of new technologies, medicines and synthetic materials enter the water cycle. There is an urgent need to redefine what a good quality of water implies and what it excludes. We are also just starting to realize our growing vulnerabilities to the different and quite uncertain water challenges ahead.

For a water scientist the present focus on rising temperatures as the main attribute of climate change seems to be both an oversimplification and a step much too short to really move from concern to action. It is our obligation to translate temperature increases and shifting climate zones into perceivable water scenarios. Warming atmosphere means changing the global hydrological cycle. Increasing global temperatures accelerate the hydrological cycle, making it more prone to manifest itself in more frequent and stronger extremes. The specter of this trend means more trouble, especially for developing countries. Excessive floods may wash away modest successes of development and prolonged droughts may mean famine, what may trigger migration and augur potential conflicts.

Mass media is full with predictions of degrees centigrade of temperature increases whereby on the ground this translates into large amounts of metric cubes of water: either too much, or too little. Mighty as it may look, climate change is not a single, and not the most immediate driver. Increasing population, changing social aspirations, and increasing standard of living aggregate to new challenges. Food and energy security, health, but also transportation and trade have their respective substantial water dimensions.

Global change is ultimately water change. However this simple sentence does not simplify the problem. We need to reassess (and continuously upgrade) our predictions not only as far as the physical and chemical parameters of water resources are at stake, but also as far as its governance and integrated management are concerned. Involvement of multiple stakeholders in formulating objectives, policies and figuring out how to implement them, imply that water resources development planning is not any longer a task for engineers and scientists alone. While water resources management might have been placed on new foundations, new guides like the European Water Framework Directive, the resolutions of the World Summit on Sustainable Development (Johannesburg 2002), the Millennium Development Goals and the above mentioned resolution of the UN General Assembly indicate the need for legal definitions and "rules of the game" for what we may call global water governance.

Development, to make the world more equitable and just, depends to a large extent on our ability to solve the "water challenges" under different cultural, geographical and economic conditions. The global (water) change, being a biophysical process, impacts society at different scales and in different dimensions. Parallel to temporal and spatial variability of the resource, the societal variability of needs and uses, cultural exigencies and the economic dimension of rewards or losses have to be analyzed.

The multiple challenges call for inter- and trans-disciplinary approaches of analysis and processes to find sustainable solutions. There is a dual need. The present generation of professionals needs to formulate the common policies and measures, while the next generation of professionals, fully aware of the exigencies of a new type of water resources governance and management, have to be groomed. International, interdisciplinary and innovative are the main attributes of this new philosophy of the water profession and science.

This philosophy, while acknowledged as a mental and ethical basis, needs to be developed and introduced for wide scale practical use. The European Union with its Marie Curie Program and the summer schools of the European Sustainable Water Goals (2007-2010) project assist young scholars and professionals from Europe and the Mediterranean countries to prepare themselves for this, more demanding professional career.

Water resources management will in particular be challenging "at the margins". Changing phases or compartments of the hydrological cycle: from surface to ground water, from the terrestrial part to the ocean, to follow the passage of water from the upstream to the downstream country, to observe how "normal" conditions may turn into extreme events, represent the most exciting scientific and practical tasks.

The coastal belt of the Mediterranean Sea is one of the most neuralgic "water margin" of the world. Water problems like coastal aquifer deterioration due to salt intrusion, increasing irrigation water demand, flash floods and droughts, shifting climate zones, desertification, but also population pressure and seasonal tourist demands imply inherent risks and competition over the resource. These are problems which cannot and should not be "solved" alone, by one discipline or by one nation. Shared resource is shared responsibility; hence, the solution of a shared problem is the first step for sustainable partnership.

Learning and thinking together is the basis to act together. Therefore summer schools and joint events amalgamating many young professionals from different countries to a scientific/professional community subscribing to the same values and principles may achieve more than individual, even if intensive, knowledge transfer. Building a sustainable future starts with investing wisely into the next generation of professionals.

# Introduction Risk and Vulnerability: Objective or Cognitive Categories?

#### **Eriberto Eulisse**

... et fatis numquam concessa moveri apparet Camarina procul ... Vergilius, Aeneid, III (700-701)<sup>1</sup>

What risks and vulnerabilities are we exposed to because of growing global water shortages? Why are similar threats perceived and explained differently by different societies? And why are only some dangers - and not others - transformed into "risks" in specific socio-cultural contexts?

Over the past few decades, a wealth of scientific literature has produced refined, complex and sometimes opposed methodical approaches to these dilemmas. Various reasons have been suggested for the proliferation of the language of risk in experts' discourses. Most experts agree that "risk" has become today more than a key word in the news media, as it is often used instead of words such as "danger", "hazard" and "threat". It is not therefore by chance that the concept of risk has become particularly important in contemporary western societies; as a matter of fact, it would seem more than appropriate to name our present society the "risk society" (Giddens 1990; Beck 1992; Lupton 1999).

This volume is the fourth and final of a series of training publications aimed at investigating the challenges of protecting a precious natural resource, water, in times of fast technological and ecological changes. The Marie Curie training course on "European Sustainable Water Goals" started in 2007 with a focus on the Water Framework Directive implementation and aquatic ecosystem protection. In 2008 and 2009, it considered how climate change is affecting water availability and the sustainable uses of water in agriculture. The final training course, in 2010, could not find a more appropriate title for the fourth event than the present one, considering the future challenges in water resources management, and the related

<sup>&</sup>lt;sup>1</sup> "... and Camarina meets our gaze / which fate forbad to drain ..." (translated by J. Conington, New York, Widdleton, 1867).

concepts of "risk" and "vulnerability" as regards preservation of these resources. Indeed in a context of increasing fragility and scarcity of all available water resources on a global scale (UNDP, 2006), the correlated concepts of risk and vulnerability are crucial for any topical investigation about future challenges of integrated water resources management. Risks and vulnerabilities associated with water shortages because of increasing civil, industrial and agricultural demands, in fact, concern both quantitative and qualitative aspects of this fundamental resource.

In this volume, the following contributions develop some stimulating perspectives with which to tackle environmental risk, vulnerability to extreme events, and management of scarce water resources in coastal areas. Since the concepts of "risk" and "vulnerability" cross all of them transversally, it would be convenient to briefly recall the different meanings of these key concepts in their broadest, historic development, as well as in current scientific literature on risk perception.

In its evolution from medieval to post-modern (or post-traditional) societies, it has been demonstrated how the concept of risk has evolved from a meaning of total "fortuitousness" to one with deep implications for human decisions. Historians link the the emergence of the word of risk with early maritime ventures and insurance, to designate the dangers that could jeopardize a voyage. In the Middle Ages, risk was conceived as essentially related to natural events such as storms, floods, or epidemics: it excluded any idea of human fault or responsibility (Beck 1988; Giddens 1990).

Changes in the meanings of risk are associated with the emergence of modernity. During the 18th century the concept of risk started to draw upon new mathematical models relating to probability, and by the 19th century the notion of risk was extended to human beings, their conduct and liberty.

In the present age characterized by cultural fragmentation, uncertainty and ambivalence due to disintegration of traditional norms and to continuous change, the meaning of risk is inextricably associated with decisional processes and human responsibility. The modernist concept of risk, compared to the past, represents a new way of viewing the world and its chaotic manifestation and uncertainties; indeed it assumes that "unanticipated outcomes maybe the consequence of human action, rather than of ineffable intentions of the Deity, largely replacing previous concepts of fate or *fortuna*" (Giddens 1990: 30).

Such a cultural shift in the meaning of risk seems essentially linked to different perceptions of human control upon nature. Also, the historic evolution of the notion of risk highlights the dilemma of its ambivalent status as possible "cognitive" rather than "objective" category and, therefore, of how its intrinsic nature is assumed by different disciplinary approaches.

From a methodical point of view, further and certainly not insignificant questions are subjected to such assumptions. Indeed is risk an unbiased concept, or is it al-

ways culturally and historically mediated? Is danger, in other words, an "objective" reality or do we perceive it inevitably by means of particular "cultural lenses", i.e. as members of a specific society?

These are not idle argumentations but basically refer to two distinct and different methodical approaches in the social scientific literature on risk perception, which are labeled as "realistic" ("technico-scientific") perspective vs. "relativistic" (or "socio-cultural") perspective (Lupton 1999). The first, the so called realistic perspective, considers the concept of risk as an "objective category", while the second considers risk, in contrast, as a "social construct" - and, consequently, as a "cognitive category".

According to the realistic perspective - which is also the dominant approach in social sciences - risks would be "objective" and measurable in quantitative terms by statistical and mathematical models. This perspective deals with how precisely a risk can be identified and calculated quantitatively for its possible consequences. Much of the "technico-scientific" literature addresses what is seen to be the problem of conflict between the public and scientific, industrial and government organizations, as regards to health and environmental risks associated with technology and industry. The so called school of *risk analysis* is a crucial component of the realistic approach. In 1980, the Royal Society for the Risk Analyses was constituted in the United Kingdom to group experts in security and risk analysis inspired by such a methodical perspective.

Nonetheless, it has been noted that within the "realistic" perspective, risk calculations tend not to acknowledge the role played by the "way of seeing" of the experts themselves: their subjective conceptualizations of risks are too often represented as "objective facts" and "absolute truths", as if technical risk assessment could be value-free, and the nature of risk could be "taken for granted" (Douglas 1992; Lupton 1999).

In addition, as Lupton (1999) points out, another central question that tends not to be asked in this approach is: how are risks constructed as "social facts"? According to scholars of the socio-cultural perspective, the so called technicoscientific approach demonstrates all its objective limits by taking into account only un-contextualized actors and individuals, i.e. by ignoring the "social nature of rationality". The realistic approach, according to Douglas (1985) and Lupton (1999), in considering only individuals and groups motivated by "rational actions", definitely ignores how mental processes and the particular social context in which natural calamities occur, ultimately contribute to defining the same concepts of risk and vulnerability.

The alternative approach to the realistic perspective, i.e. the socio-cultural perspective, considers risk as a real "social object". By correlating the nature of disasters to the social system, this approach is aimed at understanding and explaining precisely how a dangerous event impacts on people's behavior. Indeed the same event or phenomenon that in one context is perceived as a "danger", may not be considered as such in another cultural context.

Disasters, in this perspective, are also the degree of *social disintegration* caused by the impact of a destructive agent, and not a mere physical destructive agent in itself - or just its material, quantifiable consequences. Disasters such as floods, droughts or epidemics, are not only physical events that can be measurable objectively in "absolute terms". In coincidence with such devastating extreme events, the concepts of disaster and risk have to include also the cognitive collapse of "world orders", i.e. the breakdown in the short-medium term of consolidated social relationships, everyday behaviors and networks of communication. Disasters and related risks, as such, are definitely genuine "social phenomena" (Ligi 2009).

According to this perspective, important research topics also lie in the anthropological meanings attributed by groups and individuals, i.e. how do people discuss and interpret threats and hazards or, as Geertz (1973) would have phrased it, "how risk is perceived locally by local actors". Risk, in this sense, is not a static phenomenon; rather, it is "an object constantly constructed and negotiated as part of the network of social interaction and the formation of meaning" (Lupton 1999: 20).

Understanding the particular *conditions of vulnerability* of a specific society, is another argumentation that demonstrates the intrinsic limits of the technico-scientific approach. In fact, the concept of "vulnerability" is essentially a cultural, variable factor that can not be taken for granted - as anthropology teaches us - and whose character needs to be contextualized into specific, local contexts.

In this sense, *risk perception* has to be considered always as part of a particular socio-cultural context: the same act of perceiving and evaluating a risk is inextricably part of those "embodied" and "embedded" conceptions of a specific cultural texture. At the same time, risk perception profoundly shapes the "social vulnerability" of a given community with regard to a specific threat, as far as it is perceived. As Ligi (2009) notes, the more serious risks are indeed those that are not recognized by individuals; the more severe dangers, the ones that are not perceived by local communities.

Mary Douglas (1992) and Debora Lupton (1999) stressed how the same process of "risk selection" and the different activities associated with risk management are "central to order cultural identities": those phenomena that we single out and identify as risk "have an important ontological status in our understandings of selfhood and the social and material words". The mechanism of risk selection may vary significantly from one cultural context to an other: "In some societies at some times certain phenomena are selected as the focus for anxieties. In other societies and eras, other phenomena become prominent as *risky*" (Lupton 1999: 19-20).

Not last, an interesting field of investigation is also how dangers and risks are

politicized (Douglas, 1992). An example of this is how the mass media use and spread information, or even how cover-up strategies (by governmental institutions or industrial lobbies) are organized to build certain risks rather than others. Such devices may considerably influence the risk perception of a given community; thus, it is important to include them in scientific investigations.

The fragile state in which many European aquifers lie, is a paradigmatic example that shows not only a typical kind of weak risk perception (in the common sense) in western societies but also, more generally, an increasing vulnerability we will inevitably be exposed to. Compared to surface, "visible" waters, the weakly perceived precariousness (in the common sense) of the hidden waters of aquifers, gives rise to a curious condition of protracted vulnerability to contamination from agricultural, industrial and urban sources.

It is therefore not superfluous to recall that over the past decades, water containing all sorts of fertilizers, pesticides, industrial waste, detergents, petrol, metals and even radioactive waste, has radically impaired the ecological equilibrium of many surface and underground waters. In Italy, for instance, chemical and industrial waste still continues to be dumped into rivers and aquifers, often without any purification treatment. All of these substances of course create havoc with human health. Only today, after decades of large scale pollution encouraged by far too permissive laws, do things seem to be easing slightly (Bevilacqua 1996).

Aside from punctual and widespread pollution, for many Mediterranean regions we must also add the exploitation of non-renewable aquifers for private use by illegal drilling, a practice abetted by complaisant politics, as the case of Italy, Greece and other Mediterranean countries clearly demonstrates (Ruf and Valony 2007).

Pollution, exploitation and trivialization of precious resources such as surface and underground waters are the results of a "development at all costs" model which today needs to be thoroughly reconsidered. Overexploitation is always in wait because of wrong behaviors, attitudes and even risk perceptions (Eulisse 2010).

A real perception of aquifer-related risks and vulnerabilities is perhaps one of the main challenges for future water resources management and preservation. Curiously, such an issue is considered very sparingly by experts on risk. If innovative technology is definitely an irremissible means for water resources preservation, it cannot be considered as a magic wand to solve all water scarcity problems. It is rather culture, in its broadest and narrowest sense - therefore including our own perceptions, attitudes and behaviors - that cannot be ignored by any holistic approach and policy that aims to redress the current water crisis in arid and semi-arid regions such as in the Mediterranean (Holst-Warhaft 2010).

In the last part of the 20th century, as pointed out by Beck, risks are becoming globalized and thus less identifiable but also more worrying and anxiety provoking at the same time. Indeed modern technologies, though irreplaceable and ben-

eficial, also have an unprecedented power of manipulating reality and can cause temporal and spatial side effects which are ultimately unpredictable and beyond our control. In addition, the consequences of risks are not always reckoned with adequately by governments and institutions (Beck 1988).

Recent catastrophic events in Japan (March 2011), due to earthquakes and subsequent nuclear accidents in Fukushima power plants (because of unforeseen breakdown of the security system) are not only a paradigmatic example of natural calamity combined with disasters provoked by man in the last resort, but also of how science and knowledge - as Douglas (1992) notes - seem always to be insufficient and incomplete in the present era.

The unsustainable exploitation of "common" natural resources clearly demonstrates the manifold consequences that may derive from human decisions at an institutional level (Ostrom 1990; Beck 1996).

Risks and vulnerabilities associated with global water shortages also are to be referred to the complex issue of "managing the Commons", a topic thoroughly investigated by Nobel prize winner Elinor Ostrom in her farsighted work entitled *Governing the Commons* (1990). Ostrom's approach to analyzing different examples of the management of tragically scarce natural resources (in small scale communities), and to eliciting those structural traits (degree of institutional flexibility and adaptation, cooperative individual strategies, etc) that are the base for their sustainable use in the long run, is particularly helpful towards delineating new research perspectives for risk analysis.

As many examples in arid and semi-arid regions prove, the superimposition of new, centralized water authorities has only very rarely been successful in promoting a more frugal and conscious use of water resources . The Ostrom approach - instead of proposing yet again the stereotype of the theoretically infallible, irreproachably efficient modern institutional bureaucracy - calls for a renewed, unpublished reflection on past successful management models that are surely full of hints for future research into how increasingly scarce resources, such as water, should be managed.

From the above reflections, it may be argued that risk and vulnerability as "objective" categories do not actually exist. Rather, they are "cognitive" categories, put together essentially as "social constructs". Future risk analysis, instead of persisting in sterile oppositions between these two different approaches of explanation, i.e. between the dominant, "realistic" approach and the socio-cultural one, should possibly explore new ways of integration. Only with such an integration is it possible to understand what risks a specific community is exposed to, without ignoring people's perceptions and their conditions of social vulnerability.

Neither is it, in the present era of communication, just a utopian ideal to really push for a new paradigm of water preservation, one that disseminates, on all lev-

els, a new Water Culture, built upon new attitudes and new perceptions about the real scarcity and intrinsic value of water. How to do this is definitely a question that both science and communication sciences should consider, focusing their attention on the needs of future societies whilst not ignoring history.

Upon closer examination, in the attempt to prevent the depletion of fresh water, traditional norms don't seem to have functioned any worse in the small scale communities of the past than in modern, western societies regulated by codified, formal prescriptions. Indeed those rules and mechanisms that in the past functioned because deeply embedded - as Ostrom (1990) notes - in particular social textures, as part of local symbolic meanings and traditional behavior, today may be pursued only by the most farsighted and prudent of policies. What risks will future generations be exposed to if present societies do not start really pointing their finger at those actions and the sort of behavior that has characterized the recent decades of dull neglect towards water? And this with new and farsighted communication strategies, ones that contrast mere financial speculation.

Lessons often come from the past, and some verses of Vergilius Aeneid (III, 700-701) might help us recall how the preciousness water and related risks were perceived in the ancient Mediterranean world (see note 1). To contrast the urban growth of the Greek-Siceliot town of Camarina, the taboo of Apollo's oracle was an evident warning to prevent the destruction of its marshes. According to the Olympic god, the destruction of the fresh water ecosystem of the Camarina marshes would have seriously jeopardized the whole community.

As the Aeneid tells us, it would seem that such a divine admonition prevailed for a certain time against those individuals planning to expand the town, for their personal interests, upon its fresh water reserves. Apollo's warning did not raise just an ethical issue, as we would call it in our post-modern societies. Yet, the "communication strategy" of an ethereal Olympic god still stands as a bright, rarely equaled and unanimously admired witness of civilization.

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ESWG - CHALLENGES IN WATER RESOURCES MANAGEMENT

# Socio-Economic Impacts and Consequences of Extreme Floods

# **Evan Vlachos**

Recent catastrophic floods all over the globe have raised new questions as to "traditional" approaches in dealing with such extreme events.

Many societies have accepted floods as inevitable natural phenomena to be endured. However, in modern times, a changing attitude has emerged as control over the physical environment has increased and technology and social organization have made it possible successful manipulation of natural resources.

The increasing occupation of floodplains, and competing and conflicting developmental demands have exacerbated the impacts of floods on society and the environment. Furthermore, the concerns of human vulnerability and an environment that can be further mismanaged or abused, have focused attention to the need for more integrated, anticipatory, and far-reaching water policies and strategies.

The outline of the overall argument of this paper is presented in Figure 1. It revolves around three broad categories of concern, i.e., the long history of the entwining between floods and society; the gamut of flood impacts and consequences, and the difficulty of responding to catastrophic floods in an increasingly complex and fast-changing socioeconomic context.

Underlying the outlined argumentation is the notion that floods as a "sociological" phenomenon extend beyond hydrological conditions, to encompass consequences on the well-being of human communities.

This paper, revised in December 2010, has been previously published in the proceedings of the US-Italy Research Workshop on "Hydrometeorology, Impacts, and Management of Extreme Floods", Perugia (Italy), 1995. The last underscores a number of important concerns, including:

- Changing social environments because of urbanization, sprawl, increasing densities, or industrialization which in turn may affect vulnerability to floods of larger segments of population
- Responses to flood which are becoming more complex as more interdependent systems are affected and the calls for more integrated, long-range planning are increasing, and
- Responses to flood which require also broader mobilization of institutions and people in order to accommodate adaptive policies for resource scarcities, climatic vagaries, and the uncertainty of future environments

A requisite broader ecological frame of reference implies two major elements that relate human activities to the environment, namely, interaction and adaptation.

SOCIO-ECONOMIC IMPACTS AND CONSEQUENCES OF EXTREME FLOODS An Outline Argumentation
The Challenge of Floods         • Floods and society: periodic disasters and chronic hazards         • Apocalyptic floods as history and climate change as the current concern         • Extreme hydrologic events and the changing socio-ecological context: the continuous debate between structural and nonstructural approaches         • Vulnerability to floods: acts of "nature", or acts of "man"?         • Conflicts and floods: assigning blame         • The dilemma of floodplain occupancy
The Gamut of Flood Impacts and Consequences         • Flood perception and societal repercussion         • Towards a typology of flood events and severity of effects         • The enlargement of the spatial envelope: transboundary interdependencies and changing attitudes towards nature
Responding and Adjusting to Change• The grand transformation: factors influencing short- and long-term responses• Strategies and tactics: policies for structural, non-structural and mixed approaches• The need for integrated water resources management

• The centrality of vigilance: implementing change

Figure 1. An outline argumentation of socio-economic impacts and consequences of extreme floods.

Ecology, to start with, reflects not only how human utilization of nature influences and is influenced by social organization and cultural values (the interrelationships between population, culturally styled needs and wants, technology and methods of production and the ways of dividing natural resources); but also how adaptive behaviour or coping mechanisms and ways of dealing with people and resources are developed in order to attain goals and solve problems.

Thus, in this mutually reinforcing relationship between nature and society as mediated by culture, the key problem of adaptive behaviour revolves around the question of how people respond to severe constraints and to periodic catastrophes. The literature of human ecology is rich in inference as to how populations and their culture exist in a reciprocal relationship with the surrounding environment. The key to survival that appears in the literature is the capacity for adaptation. Historians and other social scientists have pointed out that such cultural traits as flexibility, reserves, and mobility are the most important, indispensable, and inevitable values in the cultural pattern of many regions. The present abbreviated paper proceeds, then, in discussing the three parts outlined in Figure 1. Briefly, the key points to be emphasized follows.

## The challenge of floods

Underlying the discussion in this section is the notion that floods and droughts as extreme hydrological events have strong similarities in the form of both chronic and periodic hazards and disasters (Figure 2). The subsequent discussion emphasizes how flooding is the most common of all environmental hazards. The reason lies in the widespread geographical distribution of river valleys and low-lying coasts with their obvious attraction for human settlement. At the same time, flood-intensifying conditions such as urbanization and deforestation increase the magnitude, frequency, and intensity of floods. Floods, like most other disasters, have certain features in common: losses are rising, catastrophe potential is enlarging, and the burden of loss and adjustment costs falls inequitably among people and regions. Thus a series of interlocking crises (Figure 3) lead to an escalation of ecological perturbations and to what one may describe as the process of "complexification."

The Old Testament account of the Deluge represents starkly the apocalyptic natural cataclysm and is part of long historical flood legends. The profusion of legends testifies to the myriad of floods that have afflicted humanity. These are not mythical accounts but real events inspiring fear and insecurity as to the surrounding environment. The brief historical discussion attempts to relate the pivotal force that has characterized human development. More, it links old megadisaster fears with such current doomsday feelings as global climatic change, the drastic alteration of

		=	<b>MPLICATIONS OI</b>	F WATER RELATI	ED DISTURBANC	ES		
		Land			<b>Rivers and Lake</b>	S		
	Wetter = + Drier = -	Soil moisture	Groundwater	Surface water	Flow-related uses	Carrier of effluents	Use of water bodies	Use related to water depth
Social activities concerned		<ul> <li>agriculture</li> <li>forest</li> <li>buildings</li> <li>roads</li> </ul>	<ul> <li>rural water</li> <li>supply</li> <li>local</li> <li>irrigation</li> </ul>	• urban activities	<ul> <li>water supply</li> <li>hydropower</li> <li>irrigation</li> </ul>	<ul> <li>sanitation</li> <li>industrial</li> <li>waste water</li> <li>disposal</li> </ul>	• fishing • recreation	<ul> <li>navigation</li> </ul>
Problems encountered	+	• Reduced fertility	• water logging • building • damages	• urban storm run off • erosion	• failing flow • control flooding		<ul> <li>erosion/sedi- mentation</li> <li>increasing currents</li> <li>flushing of lake phosph.</li> </ul>	• flooding inundation
	I	• droughts • crop failures	<ul> <li>drying wells</li> <li>pumping</li> <li>costs</li> <li>foundations</li> <li>problems</li> <li>subsidence</li> </ul>		<ul> <li>water defi- ciencies</li> <li>reduced hydropower production</li> </ul>	<ul> <li>reduced</li> <li>dilution</li> <li>aeration</li> <li>problems</li> <li>unsafe for</li> <li>bathing</li> </ul>	<ul> <li>changing fish</li> <li>population</li> <li>reduced</li> <li>water</li> <li>removal</li> </ul>	<ul> <li>collapsing</li> <li>navigation</li> <li>systems</li> <li>reduced</li> <li>traffic</li> </ul>
Engineering measures to mitigate	+	• drainage	• drainage	• urban drain- age	• flow control		• river training	<ul> <li>increased</li> <li>level height</li> <li>reservoirs</li> </ul>
		• irrigation	• deeper wells		<ul> <li>water transfer schemes</li> </ul>	<ul> <li>flow control</li> <li>waste</li> <li>treatment</li> <li>aeration</li> </ul>	• dredging	<ul> <li>flow control</li> <li>barrages</li> <li>Sluices</li> <li>dredging</li> </ul>

Figure 2. Implications of water related disturbances for land, rivers and lakes.

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Figure 3. The series of interlocking crises leading to the process of "complexification".

the water regime, and the increased demand for flood control, storm protection, or catastrophic surges.

The expanding concerns with environmental stress tend to reinforce prevailing fears that something fundamental is changing in the relationship between individuals and nature. As a matter of fact, a number of scientists believe that the world strains today are signals of fundamental and perhaps unsolvable crises: namely, the approach of physical limits to human and material growth. This argument is accentuated by increased awareness as to what the human presence is doing into the surrounding ecosystem and to the natural laws concerning young and mature ecosystems.

The key question asked has to do with the tolerance, resiliency, or recoverability of the surrounding environment and reflects a concern with the assimilative capacity of the environment to absorb human intervention or to meet increasing demands. These last remarks are particularly important when one considers the rapid social changes, globalization and interdependence that characterize recent societal transformations. These forces increase the complexification of surrounding physical and social systems, intensifying the severity and duration of flood impacts and consequences.

Modern society, because of its size, complexity, vulnerability, diversity, environmental alterations, etc., contains a comparatively high degree of potential disorganization. They are all expressions of larger stresses and strains resulting not only from physical hazards, but also from such interdependent transformations as population changes, spatial imbalances, the rapid pace of technological changes and of significant environmental deterioration.

A central concept is that of "vulnerability" to floods. In the simplest form, the exposure to risk and the level of reaction to natural hazards vary greatly from community to community and from nation to nation.

The discussion here centers around the question as to what extent the catastrophic floods are "acts of nature" or "acts of man."

A theme that has appeared again with recurring floods in Europe (2000, 2002, 2003, 2007, 2010) and beyond, is that hydrologists and water engineers have to rethink the way they manage rivers, in front of worldwide accusations that they have only increased flood risks. The Dutch Environment Ministry has referred to the "river architects" as those responsible for ill-advised efforts to contain rivers in straightjackets. The urgent call (coupled with apprehension about climate changes) is for drastic solutions.

Turning our attention to social conflicts and floods, five crises are outlined (Figure 4). These crises provide the basis for three basic areas of conflict and disagreement (Figure 5): cognitive conflicts or disagreements about facts and "critical variables"; stakeholder conflicts reflecting coalitions of social power, or "parties-at-interest"; and, ideological conflicts or value preferences, alternative visions, or postures towards the future.

The last section of this part concentrates on the long attraction of humans to floodplains. The social and economic benefits of inhabiting and using floodplains, despite the negative effects of periodic floods, have made attractive the cohabitation with such a risk.

This affinity for floodplain occupancy serves as a backdrop for understanding the dilemma between noticeable production and settlement advantages, and the disastrous human and economic costs that follow overflow of rivers. This is the context in which many management plans must be discussed, as to larger questions of integrated land-use planning and land-use control.

#### THE FIVE CRISES

- AN ENGINEERING CRISIS: SUPPLY & DEMAND
- AN ECOLOGICAL CRISIS: QUALITY
- AN ORGANIZATIONAL CRISIS: INSTITUTIONAL MOBILIZATION & COORDINATION
- A METHODOLOGICAL CRISIS: DATA & MODELING
- A PERCEPTUAL CRISIS: PUBLIC AWARENESS, INVOLVEMENT & PARTICIPATION

Figure 4. Social conflicts and floods: the five crises.

	FUNDAMENTAL	CONFLICTS
A	Cognitive conflicts R + D	(Facts) What we know
В	Stakeholder conflicts Empower	(Parties-at-interest) Participants Who is affected
С	Ideological Conflicts	(Worldviews) Values
		Models of reality



Figure 5. The three fundamental areas of conflict and disagreement.

## The gamut of flood impacts and consequences

The centrality and importance of flood perception is reinforced by other studies of natural hazards and risk perception. Researchers have already hypothesized that heightened hazard perception could be expected where the hazard is directly related to the resource use.

Psychologists and behavioural scientists have also pointed out the socio-psychological consequences of differential perceptions. Similarly, geographers have pointed out how variations in perception of natural hazards depend on dominant use, frequency of natural events, and personal experiences.

Other recent findings from the disaster literature point out that public perception of risk is a multi-dimensional concept or a social process rather than a single variable. Perception is also related to the communication of risk.

Public risk information and communication help the public perceive both shortand long-term consequences. Risk communication (and the related concept of "warning") have been linked with the users' environment (physical and social cues); social attributes (e.g., social network, economic resources, and demographic characteristics); and psychological attributes (such as knowledge and experience with risk).

Together with perception one must also consider the long-term societal repercussions from catastrophic floods, the sapping of the human spirit, the visible scars, and the various economic costs.

The search for typologies is not only an academic exercise in conceptual clarity. It becomes the backdrop for a systematic examination of impacts, the long-term consequences, and the studying of intangible losses. When combined with a variety of damage factors (e.g., frequency, magnitude, seasonality, duration, density of occupancy, etc.), typologies of impacts can provide the consideration of important matrices leading to meaningful implementation strategies for coping with and adjusting to floods.

The discussion around the topic of expanded spatial extent points out how the spread of people over larger areas, metropolitanization, and the complexity of modern life have produced new disaster modalities. Such modalities are a combination of changes in predictability, sources of stress, and perceptions of solvability. The extension of temporal and spatial boundaries when coupled with changing attitudes towards nature (e.g., search for ecosystemic integrity) provides for new hazards dialectics and perception of flood impacts. In other words, transboundary interdependencies, global awareness, uncertainty, and socio-political cleavages strengthen attitudes of catastrophism and calls for more coordinated action.

## **Responding and adjusting to floods**

The overall emphasis on increasing complexity and the need to cope with it is based on a perceived grand transformation result of cross-cutting forces of complexity and turbulence (Figure 6). Any new agenda of responding to floods and other disasters must relate conceptual advances, methodological breakthroughs, organizational mobilization, and attention to new areas of concern resulting from more complex social and environmental interactions.

Broader policies and strategies should be considered in a manner that involves better hazard analysis, vulnerability analysis, the estimation of impacts, the identification of potential measures for minimizing losses, and selection and implementation of mitigation strategies. How people respond to hazards, how humans adjust to disasters, are parts of an increasing social sciences inventory. Yet, much needs to be learned about mobilization and implementation, comprehensive land

THE GRAND TRANSFORMATION		
GLOBALIZATION     INTERDEPENDENCE     VULNERABILITY	COMPLEXITY     UNCERTAINTY     TURBULENCE	
A. CONCEPTUAL	= shifting paradigms / complexity / chaos / heterarchization	
B. METHODOLOGICAL	= multi- GIS, ES, AI, DSS systems / computational prowess	
C. ORGANIZATIONAL	= participatory / anticipatory / contingency	
D. SUBSTANTIVE	= new focus /areas of concern	

Figure 6. The grand transformation result of cross-cutting forces of complexity and turbulence.

use planning, new paradigms of complexity and global change, and development of cross-cultural data sets.

In terms of specific strategies and tactics, current concern once again is focused on the debate as to the primacy of structural vs. non-structural approaches. The strategies that are discussed continuously in the literature seem to represent policies that have been tried mostly locally or at the national level and tend to be much more responsive to short-term impacts. Indeed, existing policies and protection programs are mainly geared toward providing short-term disaster relief.

All the above point out that there is a recognized need for anticipatory planning in order to be able to avoid later crisis-driven, reactive responses. The different adaptive mechanisms or adjustments call upon ingenious ways of preparing societies against short-term adverse impacts with little research being devoted to identifying and understanding societal adjustment to extreme events as well as long-term consequences of e.g. global climatic change. The institutional requisites for effective flood coping arise from a combination of strategies based on education, technological innovation, improved system management, the prohibition of certain activities, and comprehensive land-use planning. This is the spirit behind such efforts as those outlined in the report of "Euroflood Project" (Figure 7).

The 1993 Midwest floods in the United States have pointed out to the need for contrasting flood control against flood management highlighting different, innovative approaches of managing rivers. This transformation is also taking place because on top of everything else structural solutions have also had significant environmental costs. The contrast of two opposed ways of mitigating floods (one in which waters have space to spread out, and the other where walls constrict the river increasing the current's force, with potential major damages compared to a non-constricted river) has become quite significant of a new management paradigm.



Figure 7. Alternative flood alleviation strategies: listing the solution is simple; it is the implementation that brings the problems.

## Conclusion

The conclusion to the above remarks becomes rather obvious. Recent writings point out that as a result of increasing complexification, uncertainty, and vulnerability, four types of interdependencies call for urgent intergovernmental integration: hydrological interdependencies; political interdependencies (both horizontal and vertical); transboundary interdependencies representing both social and hydraulic transnational linkages; and exogenous interdependencies, notably the potential dramatic impacts and consequences of climatic shifts and hydrological alterations.

Whether with logarithmic graphs, rigorous scientific analysis, or with speculative journalistic accounts the conclusion must be that hysteria, panic or overreaction are not the proper responses to our shared concern with changing climate, recurring floods, or other extreme hydrologic events.

There can be remedies for more prudent responses, including interdisciplinary research, expanded knowledge, sophisticated models that can make forecasts over decades, holistic vision, and broader new paradigms in science; strong conservation measures; detailed monitoring; institutional changes and international agreements enhancing the flow of information and the sharing of knowledge; and, finally, the establishment of long-term environmental scanning, and mobilization of people and organizations for concerted action.

Perhaps one way to summarize the responses and adjustments to floods is by developing a vigilance strategy. The concrete outcome would be a contingency planning posture involving three basic premises.

The first would be expanded knowledge, allowing us to understand and forecast climatic changes, develop basic science, improve measurement, and utilize remote sensing data processing and information storage and retrieval technologies.

The second premise is continued vigilance in terms of systems of monitoring and of assessing the consequences of different types of natural or human induced changes, especially through sensitive warning systems.

The third premise of such a broad strategy is to increase our respect for nature by learning to live with a highly complex interrelationship of humans, biosphere, and climate.

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# Water Pollution and Over-Exploitation: Assessing the Vulnerability of People Exposed to Creeping Water-Related Hazards

## Fabrice G. Renaud

Having access to sufficient and clean water is critical for achieving many of the UN Millennium Development Goals, even though only one of these goals (linked to environmental sustainability) addresses directly water-related concerns.<sup>1</sup> Current estimates indicate that we are on target with respect to increasing the sustainable access of world population to safe drinking water but that we are off target when it comes to providing access to basic sanitation (WHO and UNICEF, 2010).

Despite large progress worldwide during the last two decades, some 884 million people still do not have access to improved sources of drinking water, principally in developing countries and in particular sub-Saharan Africa. Other disparities include the fact that access to safe drinking water is highest in urban areas (at 94%) as opposed to rural populations (at 76%) with a much wider gap in Oceania and sub-Saharan Africa. Access to safe drinking water shows gender disparities, and socio-economic disparities, particularly in sub-Saharan Africa (WHO and UNICEF, 2010).

Climate change will be another stressor on dwindling water resources and will affect these in many different ways throughout the world. The Millennium Ecosystem Assessment (MA, 2005) stressed specifically that 2 billion people living in arid, semi-arid and sub-humid regions are extremely vulnerable to the loss of ecosystem services including water supply and that climate change is likely to increase water scarcity in these regions that are already under water stress (dry

<sup>&</sup>lt;sup>1</sup> Target 3 of the environmental sustainability MDG states "halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation".

lands accommodate roughly a third of world population but harbour only 8% of global renewable freshwater resources). The negative impacts of climate change on water resources in already existing dry lands was also confirmed by the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007). Water is so central to the climate change discussions that the UN-Water assessed that "water is the primary medium through which climate change influences earth's ecosystem and thus the livelihood and well-being of societies" (UN-Water, 2010).

It is therefore increasingly important to determine who the vulnerable people and communities are with respect to water problems existing now (and thus not linked to climate change) and those that may arise in the future because of global environmental change, including climate change. In the next section, some methodological considerations are briefly presented and the following two sections briefly describe three case studies of vulnerability and risk assessment linked to groundwater overexploitation and to surface water pollution.

## Vulnerability of systems to water stresses

There are many definitions of vulnerability to environmental hazards or stressors (see e.g. Thywissen, 2006) depending on who is providing the definition and the school of thought considered. One definition, used at the United Nations University Institute for Environment and Human Security (UNU-EHS) is given in the box below.

"Vulnerability is the intrinsic and dynamic feature of an element at risk (community, region, state, infrastructure, environment, etc.) that determines the expected damage/harm resulting from a given hazardous event and is often even affected by the harmful event itself. It changes continuously over time and is driven by physical, social, economic and environmental factors" (in Thywissen, 2006).

The main features of this definition are that the system is not pre-defined and that vulnerability is highly dynamic in both time and space.

There are many different vulnerability assessment frameworks emanating from various schools of thoughts. These tend to be detailed and complex frameworks which capture the role of multiple agents at various spatial and temporal scales. These frameworks have been reviewed by Birkmann (2006). We can name here the SUST framework of Turner et al (2003a), the BBC framework described in Birkmann (2006) and a framework developed within a European Commission 7th Framework Programme with acronym MOVE.<sup>2</sup> These frameworks are typically

<sup>2</sup> Methods for the Improvement of Vulnerability Assessment in Europe, see http://www.move-fp7.eu/.

difficult to use outside of research settings (see e.g. Turner et al, 2003b).

Various tools can be used to characterise specific aspects of these frameworks, an approach that was taken within the UNU/UNESCO-IHP project Groundwater and Human Security (GWAHS) (see below, first case study referred in Renaud and Schuster, 2011). In this project, aspects of the SUST (which specifically addressed coupled human-environment systems also referred to in the literature as coupled social-ecological systems) and BBC models were considered as shown in Table 1. In addition to the above-mentioned frameworks, the Sustainable Livelihood Framework or SLF (DFID, 1999) was used within the GWAHS project. Briefly, the SLF is composed of (1) a vulnerability context, (2) livelihood assets, (3) transforming structures and processes, (4) livelihood strategies, and (5) livelihood outcomes. In the context of the GWAHS project, only the "livelihood assets" were considered and later on incorporated within either the BBC or SUST vulnerability assessment frameworks.

The livelihood assets are composed of the following capitals (DFID, 1999): Human (skills, knowledge, ability to labour and good health that enable people to pursue

Components of frameworks	Definition	Framework
Exposure	Allows the determination of the component at risk (such as individuals, but also industry and/or ecosys- tems) and includes the characteristics of the hazard itself in terms of frequency, magnitude and duration.	SUST
Sensitivity	This component is characterised for both subsystems (human and environment) and describes the condi- tions of both subsystems.	SUST
Resilience	In the GWAGHS project, analysis of key social and bio- physical features that are known to be critical to deter- mine if a system can or not maintain certain structures and functions despite a disturbance	SUST, but the Resilience Alliance (2007) approach was considered instead
Intervention tools	Intervention systems that can be enacted to reduce the vulnerability and risks of systems	BBC

Table 1. Selected components for vulnerability assessment used in the GWAHS project (see Renaud and Schuster, 2011).

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different livelihood strategies); Social (social resources upon which people draw in pursuit of their livelihood strategies); Natural (natural resource stocks from which resource flows and services useful for livelihoods are derived); Physical (basic infrastructure and producer goods needed to support livelihoods); and Financial (financial resources that people use to achieve their livelihood objectives). Finally, indicators related to groundwater management and vulnerability were considered to characterise some of the livelihood assets. Indicators proposed by Vrba and Lipponen (2007) and vulnerability indicators proposed by Collins and Bolin (2007) were considered (see Renaud and Schuster, 2011, for further details). Following a workshop where all project partners participated and taking into account the elements discussed above, a final list of indicators to characterise the vulnerability of communities with respect to groundwater degradation was established for the projects (Table 2).

### Groundwater case studies

The past decades have seen an increased exploitation of and reliance on groundwater resources which has allowed many communities to secure their livelihoods. Although groundwater is abundant on a global scale, like all other freshwater resources it is not homogenously distributed around the world.

In many instances, groundwater resources are being overexploited, with withdrawal rates exceeding recharge rates and are polluted by anthropogenic activities such as industrial wastes, urban wastewater, land use changes which affect recharge, and/or agricultural pesticides and fertilisers.

Unsustainable groundwater exploitation and the vulnerability of the resource itself to other anthropogenic activities either have direct consequences on populations (e.g. polluted drinking water, land subsidence in mega-cities), or represent a "creeping" threat that will materialise in the longer run. These threats combine to put increasing pressures on the resource and this in turn threatens human security in many regions of the world and as already noted above, particularly in dryland areas (Renaud et al, 2010).

The GWAHS project mentioned above was developed to address, among other things, the threats to human security and well-being currently posed by water scarcity and water quality degradation. Four case studies adapted the approach described in the section above: the village of Beni Salama, Wadi El Natroun in Egypt; the Gareh-Bygone Plain in I.R. Iran; Tra Vinh Province in the Mekong Delta, Vietnam; and Binh Thuan Province, also in Vietnam. Some selected results from the Egypt and the Mekong Delta case studies are briefly described below (for comprehensive reports on these case studies, refer to the original papers cited hereunder).

Main Category	Indicator
Hazard	Groundwater Quantity
	Groundwater Quality
Exposure	Dependence of population on groundwater
	Dependence of major economic sectors on groundwater
	Ecological vulnerabilities
	Well density
Sensitivity	Groundwater vulnerability
	Population density
	Household structure
	Education level
	Occupation
	Ethnicity
	Household income
	Access to savings / credit
	Duration since settled in the area
	Seasonal or primary house
	Health status related to water-borne diseases
	Type of provider system
Resilience	Access to alternative sources of water
	Access to knowledge of groundwater degradation processes
	Access to information about groundwater management
	Institutional set up related to groundwater management
	Existence and enforcement of legislation and policies related to ground-water management
	Groundwater related infrastructure
	Out-migration from case study sites
	Existence of and participation in social networks

Table 2. Biophysical and socio-economic indicators to describe and measure the exposure, hazard, sensitivity and resilience component in the GWAHS project (from Renaud and Schuster, 2011).

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Wadi El Natroun in Egypt is a very dry region that is seeing rapid urban, agricultural and industrial expansion despite the fact that the only source of freshwater is groundwater. In the village of Beni Salama, Salem et al (2011) attempted to quantify the indicators described above. During execution of the project, the researchers found that some of the indicators were not appropriate for their case study (e.g. duration of settlement in the area or health status related to waterborne disease) and one of their principal conclusions was that there was an unnecessary large amount of indicators which often overlapped. This was however not surprising as the list of indicators was proposed in order to be tested in practice within the case studies. With respect to vulnerability analysis, Salem et al (2011) reported that the groundwater hazard in Beni Salama was greatest for users of shallow groundwater (compounded by the fact that they are also affected by the behaviour of farmers exploiting deeper wells), and that the smallest land users were the most sensitive to the hazards. They also reported that resilience was constrained by the lack of knowledge to inform responses in the form of infrastructure and institutional development. These findings point to direct intervention strategies targeting specifically both smallholder and larger farmers (Salem et al, 2011, for a comprehensive report).

In Tra Vinh Province, Vietnam, Sanh (2011) based his analysis of the groundwater-human security relationship principally on the SLF approach, but also considered most of the indictors of the GWAHS project. In the region of concern, groundwater has been used more frequently in recent years because of increased pollution of surface water in the Mekong Delta as well as increased demand brought about by population growth and economic development. This case study particularly highlighted the social differences in terms of access to groundwater and impacts of overexploitation of the resource. Sanh (2011) reported that Khmer people living on the sandy banks of the region grow principally upland crops and raise livestock and as such require relatively large amounts of freshwater, particularly (but not only) in the dry season. Their water demand is principally satisfied through groundwater all year round. On the other hand, Kinh people living along the rivers and lowlands farm rice and shrimps, and raise livestock. Water demand during the dry season is high for them and they rely on groundwater during this period whereas they have access to more surface water than the Khmer during the rainy season. Chinese people live around the main markets and are principally involved in business. They mainly rely on groundwater for domestic uses. These groups also represent broad wealth categories (the poorer being the Khmer and the wealthier the Chinese) and Sanh (2011) reported that the poor face greater problems accessing groundwater because of their restricted capacity to invest in private wells. Residents of the area have started to adapt to the difficulties in accessing good quality freshwater year-round by storing water in small jars and tanks at the beginning of the drought period and they also share each other's drinking water captures from rainfall. With regards to agriculture, Sanh (2011) noted that many farmers have started to change to crops and animals that require less water to cope with droughts, or they have built deeper wells. With respect to drinking water, local populations have started using tap water from a common water supply station as an adaptation strategy.

The brief descriptions above are only a snapshot of more detailed reports which contain a large amount of information. All case studies reported different experiences with respect the approach in the GWAHS project but the overall methodology allowed the four research teams to draw interesting and policy-relevant conclusions with respect to the groundwater-vulnerability nexus. The two case studies have shown that different groups of people fare differently when it comes to groundwater overexploitation problems.

#### Water pollution in the Mekong Delta

The Mekong Delta in Vietnam is a key region for the country as large proportions of agricultural production comes from this region. The region is characterised by an extensive surface water system and is home to ca. 17 million inhabitants. The region is developing rapidly (Garschagen et al., 2011) and increased pressure is put on water resources. Notably, the region has seen a boom in agricultural production since the renovation or "Doi moi" period, yet there is close to no monitoring of the fate in the environment of pesticides currently being used in agro-ecosystems (Toan Van Pham et al, 2009). Within the WISDOM project (water-related information system for the sustainable development of the Mekong Delta in Vietnam),<sup>3</sup> it was decided that current use of pesticides would be monitored at edges of agricultural fields to determine residue concentrations in surface water. This was mainly to characterise the hazard and exposure components of vulnerability. Preliminary results have indicated that in two case study areas in the Delta, residue concentrations of 13 of 15 monitored compounds (buprofezin, butachlor, cypermethrin, difenoconazole, endosulfan sulphate, fenobucarb, fipronil, hexaconazole, isoprothiolane, pretilachlor, profenofos, propanil, and propiconazole) were detected in surface waters; that in 65% of all samples more than four different pesticides were detected; and that at the site were most contamination was observed, single compound pesticide concentrations were in 58% of the samples higher than 0.1  $\mu$ g/L and in 9% higher than 1.0  $\mu$ g/L, the European guideline value for residue concentration in water being 0.1 μg/L (Toan Van Pham et al., 2009).<sup>4</sup> These data are of particular relevance due to the fact that aquatic organisms are consumed in large quantities by the local populations and because many people

<sup>3</sup> See http://www.wisdom.caf.dlr.de/en.

<sup>4</sup> Updated data will be published soon.

in the Delta still rely on canal and river water for drinking and other household uses. In the latter case, water is often taken directly from canals, treated with aluminium sulphate in order to flocculate the sediments and boiled before being used for drinking or cooking. Within the WISDOM project we monitored the same compounds in "ready to drink" samples in a few households and found that in > 80% of samples, the guideline value of 0.1  $\mu$ g/L for single compounds was exceeded despite the treatments described above (Toan Van Pham et al, in preparation). This is indicative of a direct exposure of a large portion of the population to pesticides with unknown health consequences.

#### Conclusions

Water is obviously a critical resource which affects the livelihoods of everyone - yet it is under multiple threats. Groundwater in particular has allowed providing access to clean, freshwater supplies to millions of people worldwide, sometimes with detrimental effects (e.g. arsenic poisoning in Bangladesh) but in the vast majority of cases, the resource brought about improved livelihoods which has often lead to its overexploitation. As shown with the example of the Mekong Delta in Vietnam, it is also obvious that the resource is being polluted rapidly from various activities including agriculture. This applies to most countries in the world. Determining who is most vulnerable to overexploitation and/or pollution is not straightforward as shown by the case studies of the GWAHS project. But detailed analyses can in particular highlight vulnerable groups within a society. Vulnerability assessment requires, among other things:

- capturing various dimensions of vulnerability (social, economic, environmental and also looking at coping mechanisms and adaptation strategies)
- an analysis of influencing factors at various scales; and
- carrying out a refined analysis of the circumstances of all communities (no "blanket" assessments should be made).

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#### ESWG - CHALLENGES IN WATER RESOURCES MANAGEMENT

# Much Ado About Nothing? The Water Framework Directive Explained in About 2500 Words

# **Erik Mostert**

The European Water Framework Directive (2000/60/EC; WFD) is one of the most important European directives in the field of water management. Its history goes back to 1994, when the European Commission published a proposal for a directive on ecological water quality.

The Commission saw this directive as the completion of the system of water directives, but some Member States saw it as yet another directive on top of the many uncoordinated directives. Subsequently, the Environmental Council (the environmental ministers of the EU Member States) decided in December 1995 that a Water Framework Directive should be drafted.

In April 1996, a first proposal for the WFD was published, but this proposal did not meet with universal approval. Several Member States were not happy with the requirements to establish supranational river basin authorities and to recover the costs for water services.

Another controversial point was the legal status of the environmental objectives: should they be binding or not?

Since the Council and the European Parliament could not agree, a conciliation procedure had to be started, and only in October 2000 agreement could be reached. The WFD entered into force on 22 December 2000 (see on the development of the WFD for instance Kaika & Page, 2003; Lagacé, Holmes, & McDonnell, 2008; Page & Kaika, 2003; RBA Centre TU Delft & WL, Delft hydraulics, 1997).

Framework:	Water Framework Directive (2000/60/EG) and daughter directives (Groundwater directive, 2006/118/EC; Environmental quality standards directive, 2008/105/EC); Flood risk directive (2007/60/EC); Marine strategy framework directive (2008/56/EC)	
Functions of water:	Fish water (2006/44/EC)* Shellfish water (2006/113/EC)* Bathing water (2006/7/EC)	
Specific substances:	Dangerous substances (2006/11/EC)* Groundwater (80/68/EEC)*	
Sources:	Urban wastewater (91/271/EEC) Pesticides (91/414/EEC) Nitrate (91/676/EEC) IPPC (integrated pollution prevention and control; 2008/1/EC)	
Other relevant direc- tives (selection):	Drinking water (98/83/EC) Birds directive ((79/409/EEC) Habitat directive (92/43/EEC) Environmental Impact Assessment (85/337/EEC) Strategic environmental assessment (2001/42/EC) Post-Seveso directive (82/501/EEC) Environmental information (2003/4/EC)	

Table 1. Main European water Directives (\*: will be repealed in December 2013).

In this contribution, the WFD is introduced. First, its purpose and environmental objectives are presented. Next, its system of river basin management is introduced. This contribution concludes with a short reflection on the importance of the WFD for the water management practice.

#### Purpose and environmental objectives

The WFD does not replace all existing water directives, but aims to offer a framework for the management of all European groundwater and surface water (art. 1). Its environmental objectives are (art. 4):

- To prevent further deterioration of the water status
- To achieve a "good water status" by 2015 (see below)
- To reduce pollution of surface water by priority substances; and
- To reverse any significant upward trend in the concentration of pollutants in groundwater

In protected areas, such as areas protected under the Birds and Habitat directive, the specific standards and objectives from these directives apply as well.

A central issue in the WFD is the definition of "good water status". In case of surface water bodies, "good water status" refers to a situation in which both the chemical status and the ecological status are good or better (art. 2 point 18).

The chemical status is good if the water meets the water quality standards for a number of chemical substances that are set in the Environmental quality standards directive (2008/105/EC).

The ecological status is good if it deviates only slightly from the natural conditions (Annex V, table 1.2 WFD).

The water status of a groundwater body is good if both its chemical status and its quantitative status are good or better (art. 2 point 20).

The chemical status is good if (Annex V point 2.3.2, art. 17):

- a) There are no signs of saline or other intrusions
- b) The groundwater meets the quality standards for nitrate and the active substances in pesticides from the Groundwater Directive, Annex I (2006/118/EG)
- c) It meets quality standards for other substances set by the Member States (cf. art. 3 and Annex II Groundwater Directive), and
- d) Groundwater quality does not result in failure to reach the environmental objectives for associated surface water bodies

The quantitative status of a groundwater body is good if (Annex V point 2.1.2):

- a) Average annual abstractions do not exceed recharge
- b) The status of associated surface waters does not deteriorate and the environmental objectives for these surface waters can be reached
- c) No significant damage is done to terrestrial ecosystems that depend directly on the groundwater body, and
- d) The flow direction is not changed in such a way that saltwater intrusions or other intrusions occur

Some surface water bodies can be designated as "artificial or heavily modified", which results in somewhat lower environmental objectives. The WFD defines artificial water bodies as "a body of water created by human activity" (art. 2 point 8), and "heavily modified water body" as a surface water body that "as a result of physical alterations by human activity is substantially changed in character" (art. 2 point 9). Yet, such water bodies can only be designated as artificial or heavily modified if a number of additional conditions are met.

The hydromorphological changes that would be necessary to achieve a good ecological status should have significant adverse effects on "the wider environment" or a number of human uses, such as navigation or recreation, flood protection and "other equally important sustainable human development activities". Moreover, it should be impossible to achieve these objectives by other means that are technically feasible and not disproportionately expensive.

In addition, the designation as artificial or heavily modified needs to be explained in the river basin management plan (see next section). The ecological objective of artificial and heavily modified water bodies is a "good ecological potential". This is the same as a good ecological status, but considering the effects of its artificial or heavily modified character (art. 4 par. 3, Annex V point 1.2.5).

The deadline for reaching the environmental objectives may be extended by maximally twice six years or even longer when the natural conditions are such that the objectives cannot be reached in time (art. 4 par. 4, point c).

In addition, lower objectives may be set. The conditions for extension and setting lower objectives are similar to those for designating water bodies as artificial or heavily modified: technical feasibility, disproportionate costs and explanation in the river basin management plan (art. 4 par. 4 and 5).

Under very strict conditions temporary deterioration is allowed (art. 4 par. 6). Finally, Member States are not in breach of the WFD if failure to achieve a good status or potential is the result of new modifications of a surface water body that are of "overriding public interest" and/or result in benefits for "human health, (...) the maintenance of human safety or (...) sustainable development" that outweigh the benefits of achieving a good status or potential (art. 4 par. 7).

#### **River basin management**

In addition to the substantive requirements, the WFD contains many procedural requirements. It prescribes a system of participatory river basin management, consisting of seven steps, which are described below. The deadlines mentioned below refer to December 22 of each year.

#### 2003: Preparation

First, Member States have to identify their river basins and assign them to river basin districts. These consist of one or more river basins and also include transitional waters, one nautical mile of coastal waters and groundwater bodies. In case of international River basins, Member States have to identify their basins in cooperation with the other basin states.

Member States have to make "appropriate administrative arrangements" for implementing the WFD in their territory, including the identification of the appropriate "competent authority" and the necessary legislative changes (art. 3 and 24).

#### 2004: Analyses and the register of protected areas

Ultimately in 2004, three analyses have (had) to be ready: an analysis of the characteristics of each river basin district, a review of the impact of human activity, and an economic analysis of water use (art. 5). Also in 2004 a register of protected areas should be established (art. 6) (European Commission, 2007).

#### 2006: Monitoring operational

Ultimately in 2006, the Member States should operate a monitoring system, consisting of (art. 8, Annex V point 1.3, 2.2 and 2.4) (European Commission, 2009):

- a) Surveillance monitoring, to supplement and validate the review of human impact, assess long-term natural and human-induced changes, and help design future monitoring programmes
- b) More detailed operational monitoring for water bodies at risk that may not reach the environmental objectives, and
- c) Investigative monitoring in case the reason for exceeding standards is not known, if the objectives are unlikely to be achieved and no operational monitoring has been conducted, and to assess the magnitude and impact of accidental pollution

#### 2006-2009: Planning

In the period 2006-2009, Member States have to make river basin management plans. These should contain summaries of the different analyses, various maps, and the environmental objectives for the different water bodies, including the justification of designating water bodies as artificial or heavily modified, of extending deadlines and of setting lower objectives.

For each national river basin district one River Basin Management Plan needs to be written. In international river basin districts the Member States in that basin have to aim for one International River Basin Management Plan, and if failing to do so, they have to write River Basin Management Plans for the national parts of the district and coordinate these plans (art. 13).

The plans should be made in three steps:

- Publication of a timetable and work programme for producing the plan (ultimately 2006)
- Publication of an interim overview of the significant water management issues (ultimately 2007), and
- Publication of the draft plans (ultimately 2008)

In each step, the public should be given at least six months to comment in writing on these documents. The plans themselves should be adopted ultimately in 2009 (art. 14).

In addition to plans, national programmes of measures should be produced. These translate the different analyses and the environmental objectives into concrete measures (art. 11, Annex VI).

The programme of measures needs to be based on an assessment of what the most cost-effective set of measures is for reaching the objectives (Annex III, point b). In international river basin districts, the different national programmes of measures have to be coordinated (art. 3 par. 4).

#### 2010: Cost recovery and pricing policies

Ultimately in 2010, Member States have to "take account of" the principle of recovery of the costs of water services and ensure an "adequate contribution" of the different water users to the costs of water service.

In addition, by 2010 Member States have to introduce water pricing policies that provide "adequate incentives" for users to use water resources efficiently, "taking account of" the polluter pays principle. In doing so, Member States "may (...) have regard to the social, environmental and economic effects (...)" (art. 9).

#### 2012: Implementation

Ultimately in 2012, the programme of measures should be operational (art. 11).

#### 2015: Environmental objectives reached

If no use is made of the possibility to extend deadlines, the environmental objectives mentioned in the plans have to be reached by 2015.

In 2012 a second cycle starts, in 2018 a third, and so on. Throughout these cycles, Member States have to "encourage the active involvement of all interested parties" (art. 14).

The WFD does not define "active involvement", but it is clear that active involvement is not the same as consultation and implies an active instead of a reactive role of the public (Drafting Group, 2002; Ridder, Mostert & Wolters, 2005).

#### The impact on practice

The environmental objectives of the WFD are very ambitious. However, it is not yet clear what the WFD will change in practice. Does it result in more and more effective measures? Will it make Europe's waters cleaner?

For answers we will have to wait until at least 2015, and even then it will be impossible to know for certain what would have happened without the WFD.

The WFD contains many detailed provisions, but there is still a lot of uncertainty on what it requires exactly from the Member States. For instance, are the environmental objectives of the WFD binding upon the Member States? Do they always have to be achieved, unless the exemptions mentioned in the WFD apply?

There is no total agreement on this. Moreover, the exemptions may offer escapes for Member States that are not as ambitious as the WFD (Howarth, 2009; Keessen, van Kempen, van Rijswick, Robbe & Backes, 2010).

Admittedly, implementation of the WFD is controlled by the European Commission. They may bring the case before the European Court of Justice, who may impose hefty fines (art. 258 and 260).

However, it is not yet known exactly how the Court will interpret the WFD and how much discretion it will grant to Member States. Because of this, the Commission may decide to focus their control efforts on the procedural requirements of the WFD, which are clearer and therefore easier to enforce (Santbergen, Mostert, Wiering & Arend, in preparation).

This may not necessarily result in cleaner waters.

There is already quite some information on how the different Member States implement the WFD (e.g. Borowski-Maaser et al., 2010; European Commission, 2007, 2009; Keessen et al., 2010; Uitenboogaart, Kempen, Wiering & Rijswick, 2009). Some Member States, especially in the South of Europe, seem to have very serious problems in "getting their act together", while others have met most dead-lines, but without showing a high level of ambition. Examples of the latter are The Netherlands and the UK, which have designated many surface water bodies as artificial or heavily modified and make maximal use of the possibility to extend deadlines (Keessen et al., 2010).

In contrast, France has set quite ambitious objectives, but the parties that have to implement and finance the measures to reach the objectives have not been involved in the planning process. This poses a serious risk to the implementation of the plans (Borowski-Maaser et al., 2010).

To conclude, is the WFD "much ado about nothing", as the title of this contribution suggests?

It certainly is much ado (much time and effort is spent on implementing the WFD), but not necessarily about nothing. Older EU directives such as the Urban Wastewater Treatment Directive (91/271/EEC), which admittedly have a less procedural and more substantive character, did result in notable changes, such as the construction of many sewage treatment plants worth billions of Euros.

So there is no reason to be overly pessimistic. The European Commission and the European Court of Justice have proven to be quite strict in environmental matters. Few things are certain, but one thing is: the WFD cannot be ignored.

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# Multidimensional Indices to Capture Vulnerability to River Floods

# Janos J. Bogardi, Marion Damm and Alexander Fekete

The purpose of this paper is to introduce two approaches to estimate river flood related vulnerabilities.

The social vulnerability index highlights regions which may potentially experience higher losses and need more assistance. The index of social-ecological vulnerability depicts regions that may be affected by floods in terms of their ecosystem service ability. The vulnerability index maps provide an overview on national scale with district level resolution.

Two methods are presented here to illustrate the manifold directions the emerging vulnerability research may follow. Critical evaluation of the techniques applied as well as the analysis of available data can also be found in the dissertations of Damm (2010) and Fekete (2010).

The research leading to the results, presented here, has been carried out in the interdisciplinary project DISFLOOD.<sup>1</sup> This project aimed to develop a Disaster Information System for Large-Scale Flood Events Using Remote Sensing as a joint project of the United Nations University Institute for Environment and Human Security (UNU-EHS), the German Aerospace Centre (DLR), and the GeoResearchCentre (GFZ), in Potsdam.

<sup>1</sup> http://nadine.helmholtz-eos.de/events/2005/disflood\_kickoff/2005\_kickoff\_en.html

#### The concept of vulnerability

Floods are among the most devastating water-related hazard events. The consequences of floods, once they affect people, their settlements, infrastructure, industries and farmlands could turn into disasters. The hazard of the occurrence of a flood is closely associated with the risk of a flood, the expected (multidimensional) losses people and their assets may suffer as a consequence of inundations.

Statistical and trend analyses of floods are not conclusive to prove a significant and universal increase of flood frequencies and magnitudes due to climate change (Bogardi, 2009). Yet flood losses, like other disaster losses show a significant and steady increase during the last couple of decades (Munich Re, 2004). Consequently there must be additional factor(s) responsible for this discrepancy shown by the trends.

Intensive use of flood prone areas, accumulating wealth, building infrastructures along rivers, but also the lack of knowledge and experience with extreme floods and changes in the social, economic and environmental fabric contribute to the increase of vulnerability of those potentially affected. Vulnerability in the broadest sense is defined as the predisposition to be hurt (UN/ISDR, 2004). Flood risks are defined as the "product" of hazard and vulnerability, whereby vulnerability is the least known component of an equation which may express risk (R) as a function of the hazard (H) and vulnerability (V):

R = f(H,V)

Thus forecasting the hazard may not tell the whole story about flood risk, which actually matters more than the natural phenomenon itself. Hence forecasting risk must imply the prediction (or at least an estimate prior to the occurrence of flood) of vulnerability (V).

On its own turn vulnerability is also multidimensional. It is usually characterized by its social, economic, environmental, physical (infrastructure) and institutional dimensions. Vulnerability implies the question "vulnerable to what"? Hence without being exposed to this particular "what" – a hazard – people may not seem to be vulnerable.

However there is an internal core of vulnerability which does exist irrespective whether the individual is exposed to a hazard or not. This inherent pre-disposition to be hurt is suggested to be defined as a hazard-independent susceptibility. This could also be measured in different dimensions. Susceptibility may turn into hazard specific vulnerability once people were exposed to it (like living in a flood-plain). Thus vulnerability (V) is the function of susceptibility (S) and exposure (E):

V = g(S, E)

Vulnerabilities can be mitigated through certain capacities (C) people might have acquired and might deploy prior, during or after the occurrence of a hazard event. These capacities are different from those mitigating the hazard like reservoirs, dikes, flood relief channels etc. They can directly offset vulnerabilities like knowledge of the hazard, savings, insurance or applying solid building codes for houses. Hence the vulnerability which remains to contribute to risk would be:

V = h((S,E)-C)

where (*C*) represents the capacities to resist, to respond, to bounce back and to adapt. It includes also coping or even the ability to suffer or to absorb harm in any other way.

Given the multitude of their dimensions and their nature as a potential inclination to be hurt, vulnerabilities can only be approximated prior their manifestation during a disaster with the help of proxy variables. As a tool for planning or flood risk forecasting, vulnerability estimates should refer to administrative entities rather than capturing individual features. For this purpose the district scale has been identified as the most appropriate compromise between spatial precision and policy relevant information.

The susceptibility assessment covers whole Germany (well over 400 districts). Flood related vulnerabilities are estimated and shown along the Rhine and Elbe rivers.

# Indicators and indices: a word of caution towards a policy relevant assessment of vulnerabilities

Analyzing complex systems and their properties involves reducing complexity to a degree. Simplification is an accepted part of the scientific research process and is associated with choices about how much to simplify and how to do it without misrepresenting reality. Indicators and indices are useful for encapsulating a complex reality in simple terms. However there is a danger that indicators may not accurately represent the intended condition or process.

Aggregating indicators creates even more opportunities for subjectivity and thus must be even more critically appraised. By their very nature, the role of indicators is to capture an intangible process so it is not possible to "ground truth" them. The index as an aggregate measure of several indicators is contingent upon the choice of indicators. There is a real possibility that uninformed choices could filter through and can lead to an invalid index.

A critical evaluation of the limitations of indices is even more imperative given the fact that they link science and policy. By summarizing and simplifying reality they are useful to policy-makers, but the absolute certainties preferred by them are often incompatible with the uncertainties of science.

Indicators enable to simplify the very complex concept of vulnerability. They facilitate the task of mapping and comparing vulnerability across regions, but also they facilitate communication between profession, public and politics, and help to assess any progress achieved.

Adger et al. (2004) identify two different procedures for indicator selection, the deductive approach and the inductive approach. The deductive approach involves proposing relationships derived from theory or conceptual framework and selecting indicators on the basis of these relationships. When conducting a deductive approach it is important to first create an understanding of the investigated phenomenon and the processes involved, second to identify the main processes to be included in the study, and third to select the best possible indicators for these factors and processes. Inductive approaches involve statistical procedures to relate a large number of variables to vulnerability in order to identify the factors that are statistically significant. Hence, potentially relevant indicators are incorporated in a certain statistical model and indicators are selected on the basis of significant statistical relationships. Expert judgment or/and principal component analysis are common methods to select the final indicators.

The social-ecological vulnerability, using the so called "Turner Model" (Turner et al, 2003) was assessed by indicators defined by the deductive approach, while the social and infrastructure vulnerability index based on the BBC Model (Birkmann, 2006) was the result of an inductive procedure.

#### The BBC model and its use to estimate social vulnerability

The BBC framework (Figure 1) explicitly links vulnerability to the three spheres of sustainability; society, economy and environment. This framework is based on theoretical considerations, how social, economical and environmental dimensions of human security can be integrated with existing hazard and risk concepts. In the BBC framework, vulnerability is put into a chain starting from a natural phenomenon that can evolve to a hazard event and hits an exposed, susceptible population. This group may be equipped with certain capacities to encounter the hazard. Thus its vulnerability is reduced.

Vulnerability and hazard together define risk. There are two entry points for risk mitigation: during the pending risk and after the hazard event has started to affect the people. The BBC framework puts the main analytical components of vulnerability into focus for an assessment. These three components, exposure, susceptibility and capacities, provide the main entry and structuring points for the development of vulnerability indicators (see Figure 1).



Figure 1. BBC framework.

The social vulnerability assessment focuses on aspects of potential weaknesses and also capacities of the population. This means that indicators for social vulnerability have to be selected to be relevant to a hazard context. On the other hand, the BBC model shows the distinction of hazard analysis as being a different field from vulnerability analysis. The 'social vulnerability' component will be assessed by combining a Social Susceptibility Index, including a measure of capacities to reduce this susceptibility, with exposure information.

Figure 2 presents the Social Susceptibility Index for Germany. It is based on indicators capturing (personal) fragility, socioeconomic conditions and regional aspects. All data used here are available from the standard census data of the Federal Statistical Office of Germany. None of these variables seem to be related (directly) to floods, but all capture certain components of socially relevant susceptibilities which matter also in case of a flood. The results clearly indicate that forty years of separation and diverging development paths are still visible and determine to a great degree the different susceptibility and hence vulnerability of the population in the eastern and western part of the country. It is interesting to note that the Ruhr area, irrespective of its economic strength, is among the most susceptible parts of Germany.



Social Susceptibility Index

Sources: BBR 2007, BKG 2007 Destatis 2006a Colour intervals in 0.2 steps Value ranges from 1.8 to -1.8

Figure 2. Social Susceptibility Index (SSI) in Germany.

Flood exposure is estimated for the riparian districts along the rivers Rhine and Elbe. The inundation maps prepared are based on the available statistics of floods of at least 200 years of recurrence period. Within a GIS framework the affected districts were classified according to the portion of the inundated area and respective population.

Social and Infrastructure Flood Vulnerability Index (Fekete, 2010) is calculated for river floods by the simple formula:

*SIFVI=f* (social susceptibility index, exposed area of the district, infrastructure density in the district)

Figure 3 shows the social-infrastructure vulnerability index for the districts located along the two great rivers.

Flood risk and its distribution could be predicted by superposing the SIFVI map with statistical inundation scenarios (hazard forecasting). This risk assessment

yields relative, comparable results enabling a ranking of the affected districts without determining the absolute value of risk. It indicates immediately those areas where risk mitigation interventions (from social and infrastructural points of views) would be most needed and efficient.



Figure 3. Social and Infrastructure Flood Vulnerability Index (SIFVI) along the Rivers Rhine and Elbe.

# The "Turner Model" of vulnerability and its application to assess social-ecological vulnerability for river floods

This vulnerability framework identifies the social-ecological system (SES) as subject of analysis. SESs are subject to influences that operate and interact spatially, functionally and temporally across a range of nested or overlapping scales and levels. The dynamic behaviour of vulnerability in SES is indicated by integrating feedback loops and interlinkages between the system components.

The vulnerability framework which is used here is adapted from a framework published by Turner et al. (2003).



Figure 4. Vulnerability framework used in this study. Modified from Turner et al. (2003).

The conceptual framework (see Fig. 4) views vulnerability as related to a certain place constituted by several place-internal processes as well as cross-scale environmental and human influences. Vulnerability is composed of three main elements: exposure, susceptibility and capacities. Elements exposed to a hazard can be human-beings, assets, ecosystems etc. Susceptibility indicates the condition or rate of response of the SES with regard to all perturbations and stresses within the system. Capacities define the ability of a system to resist, cope and adapt to a certain hazard. It is important to distinguish conceptually between internal perturbations that determine the current condition in SESs and thus the vulnerability at a particular place and time, and external perturbations that strike a system provoking disturbance and damage.

The proposed model is still quite complex for practical use. So far few attempts have been made to implement the framework. A further constraint of the framework is the missing notion of risk. The concepts of risk and vulnerability are very often strongly interlinked in disaster research, see e.g. BBC Model. The Turner Model does not outline how risk is conceptualized.

The social-ecological vulnerability is estimated through the respective assessments of the agricultural and forestry sectors. The vulnerability component 'exposure' determines the degree to which a SES is exposed to a specific threat or perturbation. This can be forested or agricultural sites as well as people whose livelihood is dependent on the respective sectors. Exposure is seen as the starting point in a vulnerability analysis. Without having any exposed elements, no hazard specific vulnerability can be detected ( $E = 0 \Rightarrow V = 0$ ).

Susceptibility is the vulnerability component that describes the current state of the SES's elements. In other words susceptibility is a measure to determine the expected rate of deterioration. Susceptibility is a dynamic element and is changing continuously over time.

Capacities stand for the combination of all strengths and resources available in the social-ecological system. They reduce the overall level of vulnerability and thus the effects of a striking hazard. The vulnerability component 'capacities' is composed of the three sub-components 'ecosystem robustness', 'coping capacity' and 'adaptive capacity'.

Ecosystem robustness addresses the capacity of the ecological system to absorb and resist disturbance while re-organizing and undergoing change. Coping capacities stand for the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster... Adaptive capacities refer to a longer time frame and reflect the learning aspects of system behaviour in response to disturbances (Gunderson, 2000).

Table 1 summarizes the different indicators selected by the above mentioned deductive approach. The weighted sums technique was applied to create the composite vulnerability index CId which aggregates the exposure, susceptibility and capacities of the forestry and agricultural sectors as proxies for the social-ecological system. Indicators were normalized, weighted and subsequently summed up in the following equation (Damm 2010):

$$CI_d = \sum_{q=1}^{Q} w_q I_{qd}$$

where CI = Composite Indicator, d = district, q = sub-indicator, Q = number of indicators, w = weight, I = normalized indicator.

It is important to note that in this assessment based on the "Turner Model", exposure is not related directly to the spatial extent of the hazard like in the BBC Model. In the social-ecological vulnerability assessment exposure is estimated by the number of people employed in the respective sector and the percentage of the farmland or forest areas within the respective district.

Forest Sector			
Component	Sub-component	Indicator	
Exposure	Ecological system	% of forested area	
	Social system	% of people employed in forest sector	
		% of gross value added forest sector	
Susceptibility	Human condition	Unemployment rate of the district	
	Ecological condition	% of damaged forest	
		Water quality index	
Capacities	Ecosystem robustness	Forest size	
		Forest fragmentation	
		Forest type	
	Coping capacities	GDP per capita of the federal state	
		GDP per capita of district	
		Mean income of private households	
	Adaptive capacities	Reforestation rate	
		% of protected areas	
Agricultural Sector			
Component	Sub-component	Indicator	
Exposure	Ecological system	% of farmland	
	Social system	% of people employed in agricultural sector	
		% of gross value added agricultural sector	
Susceptibility	Human condition	Unemployment rate of the district	
	Ecological condition	Soil erosion potential	
		Water quality index	
		Potential contaminating sites	
Capacities	Ecosystem robustness	Water retaining capacity	
		Filter and buffer capacity	
		Dominating land use	
	Coping capacities	GDP per capita of the federal state	
		GDP per capita of district	
		% of farmers with side income	
	Adaptive capacities	% of organic farming	
		% of protected areas	

Table 1. Selected primary indicators for the forestry and agricultural sectors.

The inundated area (as consequence of an extreme flood) which was used as a measure of exposure in the BBC Model serves here as the proxy measure of the hazard itself. This approximation allows to go a step further and finally assess the flood risk, as a composite measure based on the vulnerability index CId and hazard (flood maps) estimates for the agricultural and forestry sectors. Figure 5 illustrates for the agricultural sector the vulnerability map of Germany. Similar to the SIFVI index (see Figure 3) the former border between the Federal Republic of Germany and the German Democratic Republic is still detectable.

# Elbe Rhine Danube Agricultural S. Vulnerability Vulnerability ranges between (-2, 3). Five classes are formed by using equal distances as criterio for class building. Low values indicates low vulnerability, high values indicate high ulnerability in a district

#### Vulnerability of the agricultural sector to river flooding

Figure 5. Vulnerability map for the agricultural sector on district level.



Figure 6. Presentation of vulnerability, hazard and risk maps for the rivers Elbe and Rhine for the agricultural sector.

Figures 6 and 7 summarize the flood vulnerability, hazard and risk distributions for agriculture and forestry respectively.



Figure 7. Presentation of vulnerability, hazard and risk maps for the rivers Elbe and Rhine for the forest sector.

In the lower part of Figure 6 vulnerability, hazard and risk are mapped for all districts along the Rhine River that can be affected by a HQ of at least 200 years of recurrence period.

#### Issues to be addressed: in lieu of a summary

So far, key elements, structures and underlying theoretical concepts could be verified and reconstructed for both vulnerability frameworks, the BBC and the "Turner Model". However, some analytical constraints still exist which cannot be neglected.

The analytical distinction between the components susceptibility and capacities is not absolutely clear. The vulnerability component 'capacities' encompasses the capacities to bounce back, cope with and adapt to hazardous events. These properties depend on the condition of a system which is represented by the susceptibility component. The findings showed that, for instance, healthy and vital ecosystems and societies exhibit high robustness; or economically advantaged regions have stronger capacities to cope with flood events. Thus, both components are strongly interrelated.

Another important aspect which is not clearly solved in the presented models is the exposure component. The vulnerability research community has not agreed on a common interpretation of this component yet. Visually, both conceptual models place exposure within the vulnerability frameworks. In this paper exposure was treated both as a hazard-independent component but also as the estimate of the spatial extent of the hazard phenomenon.

The vulnerability assessments cover only one important aspect of disaster risk. Thus, the hazard component has to be incorporated in the calculations to be able to assess disaster flood risk. This is no easy task since flood intensity is composed of various characteristics such as flood duration, peak flow rate, water depth, flow velocity etc.

Potential hazard extent was characterized by the HQ having at least 200 years of recurrence period. At district level, the percentage of inundated land area can be derived from flood maps. The multiplication of hazard and vulnerability scores produced maps showing flood disaster risk potential of districts along the Elbe and Rhine for the social-ecological sectors (Figures 6 and 7).

Since vulnerability is mapped for all districts in Germany, risk can be assessed for all river systems in the case enough hazard data is available. Risk mapping based on detailed vulnerability assessment is still far from becoming a routine exercise. The present paper has shown the potential and feasibility of two promising vulnerability concepts in this regard.

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#### ESWG - CHALLENGES IN WATER RESOURCES MANAGEMENT

# **Risk Management of Extreme Floods**

### **Bruno Merz**

For decades water resources engineers and hydrologists assumed a stationary world when planning flood defense. However, rapidly increasing flood losses and other global developments, such as climate warming and urbanization, have led to the widespread notion that flood risk is already changing at a significant rate and that the rate of change will intensify in the next decades.

The drivers of change are manifold (Figure 1). In many parts of the world high migration rates into flood-prone areas put people at risk. The substitution of agricultural land use in European floodplains by other land use types, such as transportation infrastructure, recreation or industry, accumulates assets in floodplains and increases the damage potential. River training and changes in land use can lead to higher and accelerated runoff rates. Climate change raises fears of considerable aggravation of flood hazard. Technological development may contribute to higher flood risk. Modern commercial premises and industrial plants are furnished with electronic and computer-related equipment which is useless after being affected by flooding, whereas their predecessors were more robust and could in many cases be repaired. The dependence of modern economy and interlinked markets on permanent flow of information, goods and services creates new vulnerabilities. It is still not possible to quantify the contributions of the various drivers to changing flood losses. Long-term reliable damage records are missing and the stochasticity of weather-related hazards complicates matters. However, the dominant driver seems to be changing vulnerability triggered by rapid economic, social, de-

mographic, technological and political changes.



Figure 1. Examples of human effects on flood risk and of drivers changing the average state of the flood risk system, including flood risk reduction options.

#### Managing risk in an uncertain and changing world

Flood risk has to be seen as a dynamic quantity. Climate change and other drivers of change will not lead to a new stable equilibrium in the foreseeable future. Predicting change is highly uncertain and partly impossible. Today, the ability to quantify possible future developments of flood risk is poor. This is not only true for scenarios on the impact of climate change on regional flood hazard, but also for future economic and social developments. In light of the often long-term planning horizons in flood risk planning (e.g. dykes are built for many decades), traditional flood risk management strategies have to be assessed for their potential to provide adequate safety in a rapidly changing environment. Flood risk management needs to be flexible enough to cope with uncertainty and surprise. The traditional view of stable systems must be substituted by strategies that enhance the capacity to adapt to changes. Such strategies may be in contrast to optimization of short-term efficiency.

#### Flood proofing of buildings and infrastructure

One way ahead are robust strategies, i.e. strategies that perform well under different possible but uncertain future developments. They may not be optimal given the most likely future development but they will not fail entirely, if certain conditions are not met. Flood proofing of buildings and infrastructure is one candidate for robust strategies. Adapting the built environment to the flood hazard can take many forms, such as sealing buildings to prevent water from entering, use of buildings and their material in such a way that inundation damages are minimised, or safeguarding oil tanks. More spectacular measures are floating buildings that can vertically move in case of inundation.

Flood resilient design and construction have clear benefits in high-risk areas. Safeguarding of oil tanks is a simple measure with possibly large gains in case of flooding. Leakage of oil and entrance of oil into building materials lead to dramatically increased losses, in many cases buildings have to be torn down and cannot be saved anymore. In high-risk areas such measures pay off, regardless of future developments. Other flood-proofing measures are expensive and one should take opportunities to increase urban resilience. The European building stock is aging and within the next three decades some one third will be renewed. In flood-prone areas flood-proofing of buildings can possibly be realized during renewal phases with little additional investments.

#### Creating dual-use or multi-functional solutions

Investments in solutions and technologies that combine more than one use or function reduce risk and, at the same time, provide additional economic, social or environmental benefits. We should think about solutions that offer benefits even if a disaster does not occur. For instance, enhancing the water retention capacity of soils contributes to flood reduction and improves soil water status for environment and agriculture. The development and operation of forecasting systems and of information systems for crisis management are expensive. During floodpoor periods flood awareness degrades and such systems may not be properly maintained, in particular in view of strained public resources. The combination of several uses within one tool may alleviate these problems. Information systems for flood crisis management could be integrated with routine management tools of urban infrastructure and educational tools for city managers. "All-purpose" warning systems could warn against several risks for a community or region, i.e. expensive parts of the warning system are not only developed and used for rare occurrences of floods but for other threats as well.

#### Enhancing risk dialogue and safety culture

Traditionally, flood mitigation consisted primarily of structural measures, such as dams, retention basins and dikes. Flood mitigation was, to the largest part, the task of administration. The current shift in flood risk management towards more holistic solutions places more emphasis on non-structural measures, such as spatial planning, private precautionary measures or public and private emergency measures. These require a much larger involvement of the public in flood risk management.

A functioning dialogue about the flood risk and about mitigation options is an essential element of an integrated flood risk management, however, it is only established to an insufficient extent in many European countries. Interesting approaches for the involvement of local stakeholders exist for quantifying risks and deriving mitigation plans. For instance, workshops moderated by risk experts may systematically collect and structure the knowledge and experience of locals, such as members of authorities and organizations involved in disaster mitigation and disaster management, or people that have been affected by floods. Such participative approaches do not only guarantee that the local particularities are considered, they also trigger a risk dialogue that improves the understanding and acceptance of the derived safety measures.

Risk dialogue is embedded in the safety culture of organizations or communities. They can be crisis-prone or crisis-prepared. One of the characteristics of crisis-prepared organizations is that they provide feedback on previous incidents. Learning from disasters and from less dramatic incidents requires an attitude of openness and a no-blame culture. A frequent response after a disaster is looking for someone to blame.

However, the identification of the culprit supports superficial event analyses: when the culpable actions are found, the analysis is often stopped without an indepth investigation why these actions have been carried out. Further, there is a tendency for anyone faced with blame to limit himself to statements which do not damage his position - an attitude that does impede understanding.

Education and training in safety issues, continuous monitoring of and reflection upon safety practices create an environment of constant awareness and improve reliability of mitigation activities.

#### Adaptive management and regular updating

This leads to the notion of continuous organizational learning and adaptive management. Investments in adaptation are not a one-time necessity. Systematic processes for improving management practices by learning from outcomes of implemented solutions are an essential part of learning.

Regular re-assessments of the risk situation and mitigation options are necessary, in order to iteratively learn, enhance and maintain the capacity to adapt to unexpected developments. The scientific basis for new flood risk management approaches are being laid by a number of European science programmes, one example being the research programme 'RIMAX - Risk management of extreme flood events', funded by the German Federal Ministry for Education and Research (BMBF). A more comprehensive discussion of these issues is given in Merz et al. (2010).

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#### ESWG - CHALLENGES IN WATER RESOURCES MANAGEMENT

# Water Challenges in Coastal Areas

## **Elena Ridolfi**

Coastal areas are complex systems, characterized by specific geo-physic aspects and by limited land availability. The presence of land, marine environment and inland water bodies, all inherently different and interlinked, adds a physical and functional greater value to coastal systems. Because of such characters, the world's coastlines became a magnet for a miscellany of human activities.

Over the time, demands and expectations have changed but coasts have continued to maintain a special attraction for humankind. Several human activities such as power generation, agriculture, industry and urbanisation have expanded and intensified along the coasts. Such activities have also given rise to a high concentration of people in urban coastal areas. Current estimates indicate that urban areas worldwide are expected to grow significantly in the next years and population living in urban areas will increase from 3.4 billion in 2009 to 6.3 billion 2050 (UN 2009).

All these factors feed a growing interest in coastlines' water issues, and in particular in their urban and peri-urban areas, where expanding population and increasing human activities have led to a relevant and rapid exploitation of the available water resources.

As stressed by Timmerman and White (1997), "coastal cities are critical areas for global environmental change". Much of the environmental change processes are driven directly by population growth as well as by multiple and competing coastal activities and high use of natural resources. Tourism is also considered one of the main drivers of global environmental change in coastal areas (Saurí et al. 2009). Recently, tourism has become worldwide a significant human activity that is
deeply transforming coastal environments. Infrastructures, resorts and recreational activities along the coasts are increasing and, as a consequence, also the demand for water resources. Indeed, water in coastal areas became a crucial resource as the demand for settlement started growing. This is quite evident in the Mediterranean basin where water, in particular, has raised serious preoccupations as to its real availability. In 2025, water demand for the urban and tourist sectors is expected to represent 15 per cent of total water demand in the Mediterranean basin (Plan Blue, 2008).

Duarte et al. (2002) stressed that the problem of water availability depends strongly on different factors which should be taken into account. First, water is a limited resource. The economic and demographic growth are increasing water demands and the three variables of time, place, and quality of demands, on the one hand, and the availability, on the other, can give rise to a serious imbalance between available resources and demands. At local level these factors may vary, but many regions of the Mediterranean coasts, as a matter of fact, are already under water stress.

Thus, water uses and management are becoming central topics for coastal areas discussion. Human activities and population depend strongly on water. In the near future they may be affected by environmental changes also due to climate change processes. Water and territorial management are strongly linked and require a management model able to respond to specific water problems of coastal areas.

This paper is based on a Urban Political Ecology perspective of water and urbanization, as investigated by Swyngedouw (2004). This approach has been adopted in order to describe environmental changes such as the socio-economic, cultural and political factors that occur in the coastal areas. As such, it focuses in particular on the processes of environmental change driven by the rapid urban and population growth, as well as by the increasing economic sectors, like tourism, that affect water resources in Mediterranean coastal areas. The following section briefly describes a case study in the Mediterranean coast of Spain in order to suggest new approaches for a more efficient use of the water resource and for its saving at the local level.

## Water resources in coastal areas

Water constitutes an essential input for economic production, therefore its consumption has become remarkable and, at the same time, more competitive and even conflicting due to intensive territorial development. In the Mediterranean coastline, urban water use is deeply linked with the rapid rates of urban population growth in the eastern and southern countries of the basin. In coastal countries such as France, Italy and Spain, for instance, urban growth has shifted patterns towards more disperse and 'sprawled' type of settlements (EEA, 2006). The transformations of the urban form, from the dense and compact cities to the 'horizontal' model of the suburbs contribute to the environmental change with important implications, of which water consumption is an example. According to Romero Renau (2006), the Mediterranean territorial model is an unbalanced model because of intensive population, traffic density, and growing activities in the first kilometres of coastal strips. Such a model is characterised by significant demands of water resources, what makes difficult its management.

In recent years, nonetheless, to ensure water to expanding human activities, new technologies and water management systems have spread in coastal areas ensuring abundant water quantities, even where the resource was scarce.

This model of water management and use has given rise to the creation of large hydraulic infrastructures such as reservoirs, distribution and drainage pipes. This model has been adopted in particular by countries with scarce water availability. To cope severe water crises, Spain and Italy for instance have developed innovative solutions for water management through desalination plants and water transfers from other cities.

Water scarcity may be a function of physical conditions, but also a function of population and consumption levels within artificially-defined territorial limits, as well as technological and institutional capabilities that change over time (Meerganz von Medeazza 2004). The concept of "scarcity", from a urban political ecology perspective, is not absolute and nature-given but is socially produced (Bakker 2000). For instance, water demands increase due to the tourism sector, especially during the summer, because of facilities such as vacation housings, swimming pools, golf courses, aquatic park gardens, spas, and the like. Although water would be sufficient to satisfy the local basic needs, water scarcity is socially produced due to the different tourist needs.

In any case, water scarcity represents one of the main constraints on the tourism and urban sector. Considering that the number of tourists in the Mediterranean in 2020 is expected to be about 350 million people (Travel Research International 2003) and that, without water, many services related to it would be unavailable, the water management has to deal with the aspects of scarcity and resource overexploitation in the future (Gössling 2006).

In many Mediterranean countries, such as Spain, over-abstraction of groundwater has caused seawater intrusion, land subsidence and damages to terrestrial and aquatic coastal ecosystems. This produces relevant impacts on water resources and makes coastal areas much more vulnerable, due to low aquifer renewal rates and few surface water sources. Moreover, urbanisation processes, as urban sprawl in peri-urban areas, and economic development have inflicted pressures and spread pollution on water, contributing to coastal environment change and deterioration of all superficial and underground water, in terms of quality and quantity. Considering the hydrologic cycle, negative impacts affecting water resources in coastal cities are expected to affect more and more the surrounding environments. Exacerbate water uses have largely contributed to make this resource even more limited. Its management, often not centred on the resource value but rather on a mere exploitation, has not taken into consideration that human well-being and economic activities and their access to coastal water resources depend on environmental integrity of coastal areas.

The next section investigates the sustainable and integrated strategies of water management applied in a Mediterranean coastal city of Spain, Benidorm (Valencia Region).

# **Case studies**

Spain is a Mediterranean country with dry or very dry summers that can be exacerbated by long droughts. Water problems in this region are in part given by natural factors but also determined by the highest increase in artificial surfaces. Urban growth and sprawl processes are responsible of an unsustainable increasing of water demand in the Spanish coastlines. Such processes are also largely induced by tourism, representing the fundamental economic strategy for many Spanish coastal cities, on the hand, and the main responsible in generating the major impact on water, on the other.

In fact, after the 2003 summer in which the tourist sector experienced a drastic loss because of the water availability crises, there have been suddenly developed new options of water supply alternatives, as the diversion and decentralization measures, reclaimed water networks, built reservoirs, new long infrastructures,



Figure 1. Benidorm (Spain), location map.





Figure 2. The "vertical model" of Benidorm (Spain).

long distance water transfers, aquifer exploitation and, more recently, desalinization plants construction.

In the last two century, Spain has been a pioneer in dealing with hydrological and hydraulic problems using a territorial policy based on drainage basins, in order to use in a rational way the scarce and irregular available water resources.<sup>1</sup>

Duarte et al. (2002) argues that in Spain "there is a growing awareness that the productive structure of the territory must be compatible with the endowment of water resources upon which it rests". Thus, in order to face the water-related problems, interesting adaptive strategies and solutions were adopted in Benidorm, located in the Costa Blanca (Figure 1). The case of Benidorm has established new regimes of water urban metabolism and promoted a new model of integrated water management.

Benidorm represents one the most important tourist destinations of Spanish coastline. Its territory is characterized by two urban models: the "vertical model", i.e. the very dense city along the coast with high aesthetic and landscape impact, and the "horizontal model", i.e. the sprawled hinterland with villas and private housing with green gardens and swimming pools. The predominant urban model in this tourist destination is at any rate the "vertical model" (Figure 2), like many other resorts on the Spanish Mediterranean coastline.

<sup>1</sup>See http://www.eea.europa.eu/soer/countries/es/soertopic\_view?topic=freshwater

In Benidorm, the urbanization process has been determined considerably by the tourist sector. It has deeply influenced the coastal skyline and the settlement pattern. Indeed this sector is strategic for the coastal city of Benidorm: it currently receives 5 million visitors annually and contributes to the regional economy more than 12,000 million euro annually (14 per cent of regional GNP).

Since tourism and the urbanization pattern consume high rates of coastal resources, as fresh water, it would be critical to attribute higher water quantities to the tourist sector. As Saurí et al. (2009) demonstrated, indeed water consumption substantially depends on the urban models and their associated different densities.

Water supply for Benidorm and its region comes from local groundwater and surface water, and especially from the so-called Tajo-Segura interbasin water transfer (Vera and Rico 1995). Because of the drought of 1978, which caused a serious crisis in the tourist sector, emergency measures were taken to supply the city with additional transportation of water by tanker. Following the 2003 further crisis, Benidorm is the first Spanish municipality to promote water transfers and a recycling wastewater system. Water is transferred from the headwaters of the Tagus river (central-Eastern Spain) to the regions of Valencia and Murcia through an aqueduct of more than 300 kilometres. As to the wastewater recycling system, about 15 cubic hectometres of wastewater are treated annually, of which 6 are used to irrigate orchards and other crops. Moreover, many hotels have installed small desalting plants to treat brackish water from aquifers, and efficient systems in toilets and washrooms are already common in the hotel sector.

In Benidorm, water consumption is intimately linked to the urban model adopted by the tourist sector and depends on the type of chosen tourist accommodation.<sup>2</sup>

Indeed water consumption may vary significantly between the hotels and apartment blocks of the "vertical model", and the single houses of the "horizontal model". For instance, considering an average of 3.5 persons/household, in apartment blocks water consumption oscillates between 140 l/person/day (lpd), for permanent residents, and 132 lpd for seasonal residents. In contrast, in single houses with gardens and swimming pools, water consumption per capita escalates to 865 l/household/ day with a sharp peak in the summer months of 2.068 l/household/day.

Therefore, the concentrated, vertical tourist model seems to be a more efficient alternative of water consumption, than the sprawled and horizontal model.

A 'bilateral agreement' between the local farmer communities and the tourist sector is another strategy of efficient water management adopted in Benidorm. The farmers let the hotels to be the first in using the fresh water; after depuration, the reclaimed water is given back for agricultural uses. This system is nowadays considered one of the most efficient water delivery networks of Spain (Saurí et al. 2009).

<sup>&</sup>lt;sup>2</sup>It may vary from 140 liters/person/day (lpd) to more than 600 lpd (Saurí et al. 2009).

In summary, the Benidorm strategy for a more efficient water management is characterized by the relatively low consumptions per capita and the high system's efficiencies that are strongly linked to the urban model adopted by the tourist sector. Some of these strategies are currently considered by other coastal cities in order to face water scarcity. For instance, Lloret de Mar (Costa Brava, Catalonia Region) has developed recently an efficient reclaimed water network both for public and private supply.

# Conclusions

In this paper, recent challenges related to coastal areas' water resources have been considered. Water is certainly one of the most affected resources of coastal areas, because of human activities and intense urban development. As such, the management of this resource has to be closely related to future urban planning. Considering urbanization and water, the Urban Political Ecology approach operates under the assumption that there is no separation between these two entities, but rather "a process by which new and more relationships of society and nature are created" (Keil 2003: 729).

The case of Benidorm demonstrates that although water scarcity may be naturally given and socially produced, an efficient water management can be developed considering the local context and its processes of urban change. By contrast, the landscape impact of the "vertical model" for coastal cities is certainly heavy and therefore opens up new research challenges on integrated water management of coastal zones.

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# The Use of Palaeowaters in Coastal Areas: Limitations and Risks

# Mike W. Edmunds

The pressure on water resources in costal regions is abnormally high due to population density, seasonal demand and the threat from saline intrusion. Yet freshwater of high quality originating from different climatic conditions to the present day when the sea level was much lower (up to 130 m) is found at depth beneath the present coast in several countries. The implications of the scientific results for management of aquifers in European Regions are considered.

This paper uses the results from an European project (PALAEAUX) which has brought together up-to-date geochemical, isotopic and hydrogeological information on costal groundwaters across Europe in a transect from the Baltic to the Canary Islands. These data have been interpreted in relation to past climatic and environmental conditions as well as extending and challenging concepts about the evolution of groundwater near the present day coastlines.

# Scientific results from European regions

Results show that information on palaeotemperature, past precipitation and recharge regimes as well as air mass circulation can be deduced from the geochemical and isotopic evidence contained in European costal aquifers. An age gap can be recognized in some aquifers which indicates that no recharge took place at the time of the last glacial maximum (LGM), for example in UK and Belgium. This indicates that these areas were free of ice cover but sealing due to permafrost

was effective. Groundwaters from Estonia have  $\delta^{18}$ O values of approximately -22‰ which demonstrates that recharge took place directly beneath the Scandinavian ice sheet during the LGM. Noble gas recharge temperatures supported by stable isotopic data provide convincing evidence in aquifers from northern Europe (UK, Denmark, Belgium, Switzerland) that recharge occurred during the cooler climates prior to the LGM and that recharge temperatures (soil, air, temperatures) were some 6°C colder then at the present day.

In southern Europe the radio carbon ages indicates continuity of recharge through the LGM. Nobel gas recharge in the Aveiro Cretaceous aquifer also indicates, as elsewhere, that atmospheric cooling of 5-6°C occurred before and during the LGM. However, in contrast to northern Europe, an enrichment in  $\delta^{18}$ O of around 0,6‰ is found in the late Pleistocene recharge waters, and is considered to reflect the enrichment in the Pleistocene Ocean waters as well as the constancy in the source of moisture from the Azores region of the Atlantic as at the present day. The overall results emphasize that the stable isotope signal in palaeowaters may either reflect the source or the temperature of the precipitation.

For most of the past 100.000 years sea levels considerably below those of the present day provide an opportunity for recharge and movement of groundwater beyond the present coastlines as well as emplacement on shore to greater depths than allowed by the present day flow regime. The greatest recorded depth of palaeo-fresh water (to about -500 m) is found in the UK East Midlands aquifer. The timescale of this groundwater movement, shown by radiocarbon data which have been calibrated and extended using chemical tracers, probably represents a continuous sequence of recharge over 100.000 a, supporting the evidence from speleothem growth for infiltration of groundwater through the Devensian glacial period. In Estonia, movement of colder palaeowaters took place to depths of -250 m and excess dissolved gases found in these waters indicate recharge beneath the ice sheet. The model proposed by Boulton et al., for deep groundwater circulation due to high heads imposed by the ice sheets has been closely examined in the present programme, but no evidence can be found from geochemical and isotopic data together with local modelling.

In several regions, waters of Holocene age have been recorded at the coast (as in the Dogger aquifer of the Caen and Atlantic coast regions of northern France) which represents recharge of marine or estuarine water during the Flandrian (Holocene) transgression. The use of borehole hydrogeophysical logging has helped to confirm the complex stratification that may exist beneath the present day coastlines. Freshwater and saline water (of modern or ancient origins) may be found side by side (as in the south coast of UK) related to structural and palaeohydrogeological controls. Direct as well as indirect evidence is found from the present study that fresh or brackish water, recharged during the late Pleistocene, is found in aquifers currently offshore (off the North Sea coast of Denmark, and the Channel coast

of UK and Portugal, for example). This is consistent with results from the drilling off the eastern seaboard of the USA were fresh/brackish waters were proven to depths of 300 m to a distance of 100 km from the modern coasts. The result of modelling show that such features may take tens of thousands of years to erase.

# **Applied aspects and Management**

The main attribute of palaeowaters in terms of water quality is their high bacterial purity, total mineralization often less than that of modern waters and being demonstrably free of man-made chemicals. As a result of long residence times, some palaeowaters may be enriched in some beneficial trace elements whilst others, especially in reducing environments, may have high iron or other species requiring treatment.

In Estonia and in the UK freshwaters found at depths up to 300 m in aquifers of Mesozoic to Palaeozoic age, are of lower salinity than the present day recharge. Very low Cl in the East Midlands aquifer is almost entirely the result of preindustrial atmospheric inputs and the lack of increasing salinity with depth is strong evidence for a lack of cross-formational flow from adjacent formations containing more mineralized waters. Modern waters usually have additional solutes resulting from human impacts. In the Mediterranean coastal areas lower recharge leads to higher salinity conditions in both palaeo- and modern waters.

The development of aquifers in Europe during the past 50-100 years by abstraction from boreholes has generally disturbed flow systems that have evolved over varying geological timescales and especially those derived from the late Pleistocene and Holocene. Hydrogeophysical logging has demonstrated time and quality stratified aquifers resulting in mixed waters which are produced on pumping. A range of specific indicators including <sup>3</sup>H, <sup>3</sup>H/<sup>3</sup>He, <sup>85</sup>Kr, CFCs, as well as pollutants have been used to recognize the extent to which waters from the modern (industrial) era have penetrated into the aquifers, often replacing the natural palaeogroundwaters.

In the costal regions where development pressure are already severe, many problems for management come together including issues relating to quantity and quality of water, seasonal demand, pollution risks and ecosystem damage.

The water balance in many coastal areas may not be fully understood and wells are drilled or deepened without the awareness that palaeowaters belonging to a former recharge regime are being intercepted.

In many areas there is induced replenishment as a modern (often polluted) waters are drawn in. However in some aquifers the rates of withdrawal exceed the natural recharge and in effect a part of the resource is being mined. In these areas there is a need for careful drilling to establish the age and quality layering as well as proper well completion.

Proper monitoring networks and strategies need to be set up to follow the position

of interfaces in both the vertical and lateral planes. Correct management is needed often for seasonal demands: this may be beneficial, allowing winter recovery of water levels.

The palaeowater, however, is a high quality resource and should be treated as a strategic reserve. It should receive priority for potable use and not be wasted for agricultural or industrial purposes which do not require waters of such high purity.

Conservation targets are needed to allow for sustainability including ecosystems preservation. Changes may be needed in the administrative and legal framework to safeguard the use of the palaeowater reserve.

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# Water Management in Coastal Areas: the Experience of Catalonia

# Felip Gobern Ortuño

Europe has a long coastline along which many human activities are concentrated. Irrigated agricultural activities and tourist resorts, with their markedly seasonal patterns, and urban and industrial uses, have largely increased freshwater demand. Coastal aquifer development is often intensive and subject to salinity problems as a result of seawater intrusion, upcoming of deep saline water, and residual salinity of aquifer. Some aquifers are carefully studied, monitored and managed, and salinity problems in many European coastal areas are today well known.

Catalonia is a region located in the south west part of Europe, in the Mediterranean Sea. It has 580 Km of coastline and Mediterranean climate. The competences in hydraulic matters in Catalonia are exercised by the Catalan Water Agency (CWA), a public law entity whose objective is the comprehensive management of the water cycle, and undertakes of hydrological planning and water resource management. The use of groundwater in Inland Basins of Catalonia is very important, being the 50% of the total use. One of the main problems of coastal aquifers in Catalonia is the seawater intrusion. With regard to this problem, two examples of coastal aquifers management are here presented.

The first example is the Llobregat case (Barcelona, Spain). The main aquifer of the lower valley and delta of the Llobregat river has been affected by seawater intrusion since 1970. The overexploitation over time of groundwater resources has led to the progressive deterioration of the groundwater quality. The aquifer is a strategic factor in the city of Barcelona's water supply, as it is used both as drinking water and for industrial uses. Already a third of the total surface area of the delta presents salinity. To mitigate the water deficit, the Catalan Water Agency, along

with government agencies operating in the same area, Agbar S.A. and the Users' Community, is carrying out various artificial recharge actions: recharge ponds are being constructed in three areas. Scarification activities are in the influent stream of the Llobregat river, and direct recharge is performed in some injection wells. The construction of a positive hydraulic barrier of reclaimed water to halt the advance of seawater intrusion is the most emblematic project here, pioneer in Europe and in operation from 2007. To complete the water management of the area, a desalination plant was constructed in 2008, but only to ensure the water supply in drought.

The second example of planning and management of a coastal aquifer in Catalonia is the Tordera case (Girona, Spain). The main aquifer of the Tordera alluvial and delta is strategic water reserve for the socio-economic development of the area. The aquifer showed before 2002 a deficit in groundwater resources. The groundwater abstraction for supply purposes (37 hm<sup>3</sup>/year) took place mainly in the summer season, due to the increased demand caused by tourism and irrigation. Until 2002 it was the only water resource of the area, and the aquifer showed serious problems of overexploitation, resulting in a substantial increase in seawater intrusion, reaching several kilometres inland. Artificial recharge of the aquifer using reclaimed water following tertiary treatment (4 hm<sup>3</sup>/year) started in 2002. The same year, pumping was also reduced by the incorporation into the drinking water distribution of the Tordera-1 desalination plant (10 hm<sup>3</sup>/year). In just a few years, these two factors led to a significant reduction of the marine intrusion of the Tordera aquifer. The management model of this area integrates now all the elements: aquifer, desalinization plant and artificial recharge. Also, numerical model of the aquifer has been used to simulate various management scenarios.

# Planning and management of the main Llobregat delta aquifer

#### The aquifers of the Llobregat lower valley and delta and seawater intrusion

The geological make-up of the Llobregat delta has been well known since the middle of the 20th century and the subject of presentation of several SWIM meetings. There is a silt and clay wedge that separates two sand and gravel aquifers: an upper one with thicknesses of 15 meters below current surface, and another aquifer with thicknesses of 10 to 20 meters approximately, which is the main and most important aquifer. It is confined and very transmissive (1000 to 5000 m<sup>3</sup>/day).





The main aquifer of the Llobregat delta is primarily used for urban and industrial supply, linked to the lower valley aquifer that is a strategic resource for supplying Barcelona and its metropolitan area. Seawater intrusion processes have affected the main delta aquifer since the 1960s. The intensive exploitation over time of groundwater resources, along with the excavation of part of the confining layer, has led to the progressive deterioration of groundwater quality. Water abstraction counts currently for approximately 54 hm<sup>3</sup>/year, but it exceeded 100 hm<sup>3</sup>/year in the 1970's. The sustainable value to avoid groundwater deterioration is around 40 hm<sup>3</sup>/year.

#### Artificial recharge actions in the Llobregat

To mitigate the water deficit, the Catalan Water Agency, along with government agencies operating in the same area, Agbar S.A. and the Users' Community, are carrying out various artificial recharge actions and an Extractions Distribution Plan. In the lower valley of the Llobregat, recharge ponds are being constructed in three areas, in order to provide a total additional recharge of 6 to 10 hm<sup>3</sup>/year, and Agbar is traditionally performing scarification activities in the Llobregat river bed to enhance recharge, as well as direct recharge through injection wells.

#### The hydraulic barrier project

The most emblematic project to improve the quality of the aquifer is the construction of the positive hydraulic barrier using reclaimed water. The objective is to halt the advance of seawater intrusion. The barrier has being implemented in two phases (Figure 2). Phase one has been in operation since March 2007 with an injection flow of 2,400 m<sup>3</sup>/day in four injection wells. The second phase has a total injection flow of 15,000 m<sup>3</sup>/day to 11 injection wells operating since April 2010. There are 17 specific monitoring piezometers with remote-control data systems for water temperature, head and water electrical conductivity. The aquifer monitoring network also includes 13 wells and 7 existing piezometers, covering more than 30 km<sup>2</sup>, in order to follow the impact of the barrier.



Figure 2. Chloride concentration in the main Llobregat delta aquifer (2007) and hydraulic barrier network configuration (injection wells and monitoring points). The barrier project has been performed in two phases.



#### Water injection of the hydraulic barrier

The injection is reclaiming water from the El Prat Waste Water Treatment Plant, near Barcelona, and undergoes several treatments. Water is subjected to secondary and tertiary treatment, the latter consisting in ballasted coagulationflocculation, lamellar decantation, filtration and disinfection. Tertiary treatment is used for environmental uses (Llobregat river flow increase and wetlands) and to feed the treatment plant of the hydraulic barrier. At the Hydraulic Barrier Plant, ultrafiltration, reverse osmosis (50% of the water) and UV disinfection are performed, prior to the distribution to the injection wells. The water quality control is carried out in compliance with the requirements of the Sanitation Authority.

#### Investment and exploitation costs of the barrier

The total investment for the construction of the Llobregat hydraulic barrier amounts to  $\notin$  23M contributed by the Catalan Water Agency, the Spanish Ministry of the Environment and Rural and Marine Affairs, and the European Commission. The total cost of exploitation is  $\notin$  0.28/m<sup>3</sup> of injected water.

#### **Evaluation and first phase results**

Injection of the phase one began on 26 March 2007, and since then around 1,400,000 m<sup>3</sup> of reclaimed water have been injected in 4 injection wells. Some parameters (electrical conductivity, pH and temperature) of the injection water are logged automatically, and bacteriological and physicochemical parameters (BOD, COD, P, N, Cl, NO<sup>3</sup> and TOC) are monitored weekly. Monthly monitoring of major elements, metals, and volatile organohalogenated compounds is performed. The average chloride content of injected water is 347 mg/l, which is similar to that found in aquifers in areas that have not been affected by seawater intrusion. The electrical conductivity of the water is around 1500 mS/cm, and turbidity is less than 0.09 NTU. To date, the presence of coliforms, escherichia coli and nematodes has not been detected in any of the samples. Injection water accomplishes the Drinking Water Quality Regulation requirements.

No change has been noted in the specific flow (flow/head increase) of the four injection wells over the last three years of operation, which would imply that no clogging incidents have been detected. This is attributed in part to the high quality of the water, as reverse osmosis and ultrafiltration prevent physical clogging, and disinfection prevents bacteriological clogging, and in part to the strict cleaning program. The wells are cleaned through the use of electropumps or compressed air once a week.

#### **Aquifer improvement**

The analysis and field monitoring of the aquifer show a progressive decrease in the amount of chlorides (Figure 3), sodium, calcium, magnesium, iron and ammonium, and a slight increase in nitrates, which are present in the injected water. The barrier clearly has an oxidizing effect on the otherwise highly reducing medium. As a result, different hydrochemical and reactive-transport studies are being carried out to determine if mobilization of metals or other processes are taking place. Until now, sodium for calcium ion exchange has been identified, and the injected water is slightly oversaturated with respect calcite. These hydrochemical studies, as well as those carried out to identify clogging processes, are important factors to understand the barrier behaviour and for its correct management.



Figure 3. Pilot phase configuration of the hydraulic barrier project and chloride evolution in monitoring control between January 2007 and September 2009. Water injection started in March 2007.

# Planning and management of the Tordera aquifer

The main aquifer of the Tordera alluvial and delta is a strategic water reserve for the socio-economic development of the area. The aquifer showed before 2002 a deficit in groundwater resources. The groundwater abstraction for supply purposes, about 37 hm<sup>3</sup>/year, took place mainly in the summer season, due to the increased demand caused by tourism and irrigation. Until 2002 it was the only water resource of the area, and the aquifer showed serious problems of overexploitation, resulting in a substantial increase in seawater intrusion, reaching several kilometers inland. The Catalan Water Agency began in 2002 the artificial recharge of the aquifer using reclaimed water from the Blanes WWTP following tertiary treatment (4 hm<sup>3</sup>/year). The same year, pumping was also reduced by the incorporation into the drinking water distribution of the Tordera-1 desalination

plant (10 hm<sup>3</sup>/year). So, the management plan of the coastal aquifer combines artificial recharge, groundwater and the desalination plant (Figure 4).



Figure 4. Conceptual model of the water management supply system in the lower Tordera, combining artificial recharge, the desalination plant and groundwater abstraction. This is the basis for the sustainability of the groundwater resources.

In just a few years, these two factors led to a significant reduction of the marine intrusion of the Tordera aquifer (Figure 5).



Figure 5. Improvements of the Tordera aquifers. The overexploitation of groundwater resources before 2002 caused the groundwater deterioration, and the seawater intruded the aquifer. The artificial recharge and the construction of a desalination plant in 2002 led to a significant reduction in salination.

#### Water Management in Coastal Areas: the Experience of Catalonia

The annual water demand in the region is highly seasonal, so that the greatest needs are given in the summer. The current system of water management is based on the desalination plant that always delivers the same quantity of water throughout the year to the water supply companies. The difference to get to the total demand is pumped from the aquifer. In winter, low quantities are abstracted, and in summer there are high drawdown (Figure 6).

As a result, some coastal areas have rather high values of chlorides in the summer. In the near future water availability will be greater because the desalination plant would be expanded to double its production capacity to 20 hm<sup>3</sup>/year, connecting to other distribution networks, and there are two new locations planned for the artificial recharge of the aquifer using reclaimed water.

This raises the possibility of new future scenarios for integrated resource management.



Figure 6. Management of water resources for drinking uses at the Tordera lower valley and delta (2009).

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#### ESWG - CHALLENGES IN WATER RESOURCES MANAGEMENT

# **SESSION I**

# Water Resources in Coastal Areas

## **Danica Jakovovic**

Some of the main issues identified during the discussion of the first session related to coastal fresh water resources, according to the experiences of participants, revolved around the lack of information on both the available water resources and the amount of their use that still exists in many European countries. Examples were given from Greece and Portugal which both still have a significant lack of monitoring networks for their groundwater resources as well as a large problem from illegal borehole drilling and abstraction for irrigation and household use. Another interesting case was that of Ireland, which due to political reasons does not charge (and therefore does not meter) for public water supply. Such a lack of information makes it more difficult to implement efficient water management practices.

A second issue was raised as to monitoring: the fact that each country has its own system and objectives when implementing monitoring measures, leads to complications when trying to compare data at an European or even international level.

Water demand, basically for irrigation, has increased rapidly in the past decades, unfortunately disproportionately to appropriate management. The overexploitation pressure, especially in coastal areas, had as a collateral effect the intrusion of seawater into fresh underground water reservoirs along with the unchanged, unsustainable use of fresh water supplies. As a result, technical solutions, legislative issues and knowledge bases have been created in the last years in order to provide positive results for managing and valuing fresh water supplies, and if possible repair water quality and salinity problems.

Unfortunately, governments and stakeholders in Greece and other southern European countries, taking in consideration the high political cost of new measures and a potential price increase had done little into the right direction. Additionally, both water and environmental management offices are very often understaffed and lack technical means and proper funding for research and development. Only under serious crisis (draughts, scarcity, salinity etc) some measures are implemented. In order to control groundwater quantity and quality, it is essential to reduce the abstraction of water from the aquifers. Policies related to water prices and penalties for those exceeding the limit imposed by the water users association, indeed may reduce the excessive abstraction of groundwater. This would lead to a more easy control and management of the groundwater quantity. To recover an almost depleted aquifer, a recharge plan involving a direct pumping or a hydraulic barrier is the best option to prevent the total depletion or an excessive saline intrusion.

Coastal water resources are under pressure due to high population density and climate change, which induces sea level rise, temperature increase and precipitation decrease. Careful management of both renewable and non-renewable (palaeowaters) water resources is necessary. However, management of this valuable resource involves always a trade-off between political, economical, environmental and social aims. Decisions on how to manage the resource should carefully consider options on the supply side, but also on the demand side (like educations on water users, water pricing, rainwater harvesting for its own consumption). However, there will be never "the optimum solution", so any strategy has to be adaptive/reversible, if boundary conditions in an uncertain future may change.

Groundwater is becoming a limiting factor and in certain areas it is facing a reduction in both its quantity and quality. Hence such water resource has to be protected. The first step towards the protection of groundwater is by to conduct experiments in order to assess the present situation. Such data should be readily available to the public to create more awareness. An educational campaign focusing on those people which use groundwater the most (like farmers) can be introduced; in such campaign, the use of models can help in explaining the future situation. Once pressures are identified, measures can be taken in order to minimise them.

In Malta or Greece, for example, the main pressures are clearly due to anthropogenic activities: groundwater sources are overexploited by too much pumping. This has resulted in an increase in conductivity and chloride concentrations in the aquifers. High nitrate concentration is also a problem. Finally, groundwater has to be protected by taking into consideration both scientific and socio-economic aspects.

Contamination of freshwater bodies by salt water poses one of the most significant environmental challenges. Within the past few decades, the water quality in many coastal aquifers around the world has rapidly degraded. Over-exploitation of groundwater basins has led to the drops of water tables and seawater intrusion into the aquifers. In many countries a common source of this salt water intrusion is the sea, although naturally occurring brines, leaching and irrigation practices can also result in contamination. The scenario we consider in this study is when sea water intrudes into a coastal aquifer, which poses significant environmental and economical challenges everywhere, because even very small proportions of seawater render freshwater undrinkable. Facing a shortage of suitable drinking water, many arid coastal countries have had either to look for alternative sources, such as imported water, or to implement costly technological solutions, such as desalination, or investigation by geophysical methods. Investigation of the aquifer using electromagnetic (TEM) and electrical resistivity (VES) measurement techniques has resulted in 1D models and 2D imaging of geoelectric structure, depicting the zones of salination of groundwater in the aquifer combined with GIS tools to analyze the impact of the intrusion and define the limitation of saline intrusion in the fresh water aquifer.

However, in order to be able to face a sustainable management of water resources, it is important to know what does the word "sustainable" exactly mean. Apparently, everybody knows and has heard about this word, but it would seem not easy to use it as a meeting point of different related factors like society, economy and environment.

To reach and follow a sustainable water use, it is important to take into account all these factors, even though they can get different weights. Also, one of the main questions is the significant uncertainty existing in each country, e.g. when someone desires to investigate about a subject, it is not always easy to get those data that are needed. In some cases, it is not possible to have access to some information (also due to administrative and political reasons). Therefore, the existence of a good knowledge and a regular communication between scientists, economists, politicians and the public is fundamental to develop a sustainable use/management of our water resources.

#### Summary

- Salinization of groundwater resources in coastal areas is a challenging problem: indeed it is the human overexploitation of groundwater that often makes possible the intrusion of the seawater affecting the fresh water quality.
- A sustainable exploitation of groundwater resources should be a primary objective: recovery actions and preservation strategies such as hydraulic barriers, artificial recharges and desalination have to be taken into account.
- An integrated water resources management is also a necessity: people should be more educated about problems of water scarcity, so they may change their behaviours and know that water has a value that needs to be preserved for future generations.
- Regulation of water resources could also be a solution to unsustainable uses: the assignment of property rights to water; water pricing to its marginal cost; taxation of externalities related specific water uses, etc.

# **SESSION II**

# **Transboundary Aquifers**

## Julia Hall and Viachaslau Filimonau

Most of the available freshwater resources are contained in river basins and aquifers. However, in many cases they do not correspond to the political or administrative boundaries, but often extend across two or more countries. Sustainable water management within a single administrative boundary already proves difficult, as economical, environmental and social matters have to be accounted for.

Water management across boundaries is even more complex than sub-national or national water management, because the water management practices often differ between countries. Water management practices within a country are, for example, influenced by its culture and history, geographical features, its socio-economic make up, its financial means, as well as by legislation and future plans. Therefore, transboundary water management requires a close coordination between all the countries sharing a water resource. Transboundary water management needs to acknowledge the different political, legal and institutional situation surrounding the shared resource.

Subsurface water resources make transboundary water management even more complex. Aquifers are hidden below the surface and because of their 3-dimensionality, it proves to be difficult to assess them as physical units. The available resource and its recharge rates (if any) have to be quantified as a good basis for management. Joint research and monitoring programs between the involved countries can foster cooperation and trust between all the stakeholders involved. To overcome some of the issues associated with transboundary water management, the EU Water Framework Directive (WFD) provides a common framework. Integrated water resource management and integrated river basin management are main features of the WFD, as defined in the Dublin Principles (1993):

[...] "Effective management links land and water uses across the whole of a catchment area or groundwater aquifer."

The WFD has to be translated into national legislation, which allows an implementation according to the institutional frameworks of different countries. As all national laws should comply with the WFD, this European water legislation stands as a departing point for cooperation and negotiation among neighbouring countries.

However, the technical guidelines presented by the WFD are not specific, so they lead to various implementations across European countries, sometimes without a common position and thus alleviating the effectiveness of the same Directive. Nevertheless, the WFD remains an important instrument within the European Union as to water resource management.

The necessity to implement a common water resource legislation, can be justified by a number of examples. The plan to construct a dam on the Nile River to provide a sufficient water supply to the agricultural areas in upstream countries, without the will-ingness to cooperate from the downstream country (Egypt), is one of those. Another example is the Aral Sea region, where water tension issues are still on agenda in Uzbekistan, Kyrgyzistan and Tadzhikistan. Examples from Europe also exist, although their scale is smaller. The limited water supply in some mountainous communities in Slovak Republic, resulting from the business and state intervention in downstream river basin, is one of those.

The successful implementation of the WFD in Europe may serve as an example that successful cooperation on water issues across borders is possible. It can also outline directions for future collaboration in other regions, thus contributing to more efficient freshwater resources management at the global scale and reducing the tension between nations.

The session on transboundary aquifers at ESWG summer school summarised the issues highlighted above and provided an insight in the difficulties of the negotiation process between stakeholders involved in different water-related development projects. Through a role-play, the participants had a chance to play the role of different stakeholders involved with a transboundary aquifer, having thus received an idea of how negotiations and discussions may take place in real life.

This role game highlighted, among other things, the issues facing the development and implementation of the EU WFD in specific countries and/or regions. Erik Mostert from the TU Delft facilitated the role game, and gave an introduction lecture on groundwater legislation in an international, national and regional context. The lecture was followed by a discussion and by participant presentations related to the topic. The presentations offered good examples of recent advances in research, addressing the problems of freshwater quantity, quality and water resources management in both transboundary and national context.

# **SESSION III**

## **Risk and Vulnerability**

## **Theodore Kyrios and Denis Lanzanova**

Environment stresses imposed by population growth, urbanization and industrialization have become a prominent theme of international concern in recent years. One of the natural resources most affected is freshwater. Demands upon the world's finite supply of water pose threats to both the quantity and quality of a commodity essential to social and economic activity of all kinds and to human life and health, thus the demand for water has increased with increased populations. This has conferred on water a new level of political attention, which needs translation into political commitment within and between states.

Current fears concerning climate change merely exacerbate the urgency of the freshwater situation. There are wide differences regarding availability of water between regions and countries, especially between those in temperate and tropical zones. Some major urban centers already face serious water shortage and water pollution crises, in which water-dependent agricultural and industrial activity play an important part. Thus, questions relating to water resources management and usage cut across many productive and social sectors, including agriculture, fisheries, industry, urban development, energy and public health. As a consequence, risk assessment is a key factor for policy making.

Risk assessment is based on the definition of risk, which also depends on the definition of vulnerability. Vulnerability is the intrinsic and dynamic feature of an element at risk that determines the expected damage resulting from the given hazardous event and is often affected by the harmful event itself. It changes with time due to physical, economic, social and environmental changes.

Risk assessment is necessary for modern water management policies but it is not often taken into consideration or may even lack. Furthermore, cost analysis of water resources is not done after impact analysis of measures. Implemented plans often do not derive directly from sound analysis. At present, few mechanisms exist at suitable levels of government to mediate clashes of interests over water husbandry and use. There are real prospects of serious disputes within and between states over water resources in the not-too-distant future. In the Mediterranean, the agricultural sector overexploits high quality water (especially in those countries where it is relatively cheap). Since farmers are now used to a certain level of water consumption, when stringent conditions are imposed on them (through policies and regulations) they do often ignore the reason of these conditions, making difficult for the authorities to control over consumption.

#### Some cases from the Mediterranean

- In Mediterranean countries there are specific problems that are not managed appropriately.
- In Greece, not actual risk assessment is taken in consideration for problems like pesticide and fertilizer overuse, apart from few specific areas with nitrate and salinity problems. Also, unmonitored or unauthorized water pumping are quite common and in many cases overexploitation of water aquifers occurs.
- In Portugal, basic problems that derive from lack of risk assessment are polluted aquifers from nitrate and human establishment into flooding areas.
- Spain faces similar problems as Greece especially in coastal areas, where there is a lot of environmental pressure, due to mixed interests in tourism and agriculture.
- Morocco also face problems from nitration and sea water intrusion salinity. Though there are several management plans, phosphorus contamination is a serious issue.
- The town of Tunis is a good example of water management and actual liaison between stakeholders. However, not serious risk assessment for new agricultural and domestic establishment in areas with water scarcity and quality problems has been done.

## **Concluding remarks**

- Scientific and technical studies must be the base of risk assessment and policy making. The lack of this liaison is more intense in Southern European countries.
- Scenario based modeling approach is useful to assess and quantify possible future outcomes, but it is always subject to deep uncertainty.
- Problems of vulnerability and risk assessment have to deal with: data, dimension and time uncertainty.
- Social issues must be taken into consideration for water management plans, together with technical, economical and environmental issues (e.g. for what is the actual cost of an abandoned agricultural-rural area, due to water over-pricing).
- Improvement of the agricultural irrigation efficiency must have a key role in water management and not only water pricing policies (e.g. the % of leak of the aqueduct system is rarely taken into consideration).
- Change in human habits may have better effects as to water preservation than a mere policy of water pricing.
- 100% cost recovery is a necessity for the future, but more research has to be done in order to find viable alternatives. Water pricing seems to pose serious problems. Policies must enforce a more holistic-oriented water management system.

#### **Book Authors**

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#### DVD Authors and Contents (audio files and power point presentations)

#### **Tuesday 7 September**

#### Josep Mas Pla - Universidad de Girona (Spain)

Water resources in costal areas

#### Teresa Melo - Lisbon Technical University (Portugal)

Ground water resources and salinization in coastal areas. Main concepts on seawater intrusion, monitoring and exploitation effects on ground water quality

#### Felip Ortuño - Agència Catalana de l'Aigua (Spain)

An overview of the coastal aquifers of Europe. Planning and management of coastal areas: the experience in Catalonia:

1. Llobregat case: the overexploitation of groundwater resources and the solutions: the hydraulic barrier, the artificial recharge and the desalination plant

2. Tordera case: integrated management of the groundwater, artificial recharge and desalination

Mike Edmunds - Oxford Center for the Environment (United Kingdom)

The use of paleowaters in coastal areas: limitations and risks

#### **Students' Presentations**

Danica Jakovovic, Levent Keskin, Filippo Resente, Miryam Martinez

#### Wednesday 8 September

#### Erik Mostert, Delft University of Technology (Netherlands)

Role play on transboundary groundwater

- 1. What is the importance of regulation for groundwater management (in general, in your country, in a transboundary context)?
- 2. Should consultants and scientists be bothered with regulations (or with stakeholders, politics, or anything that is not technical or scientific)?
- 3. What do you do with regulation and what would you like to do with regulation?

#### **Students' Presentations**

Alessandro Boldo, Julia Hall, Tektas Keskin, Viachaslau Filimonau

#### **Thursday 9 September**

#### Janos Bogardi, United Nations University, Bonn (Germany)

Facing hydrological risk and environmental deterioration

Fabrice Renaud, United Nations University, Bonn (Germany)

Water pollution and over-exploitation: assessing the vulnerability of people exposed to creeping water-related hazards

Bruno Merz, Geoforschungszentrum - Geo Research Centre, Potsdam (Germany)

Flood risk management and global change: risk assessment and flood mitigation

#### **Students' Presentations**

Denis Lanzanova, Theodoros Kyrios, Hssaisoune Mohammed, Goncalo Caleila Rodrigues, Itsasne Cerro Cia, Mounir Belloumi

#### Friday 10 September

Field trip to the Alpine region

Ca' Foscari University of Venice has a national and international outstanding reputation for academic excellence in both teaching and research. Founded on 6th August 1868 as the first Italian business school, and second in Europe, it has grown and developed new relevant subject areas: arts and humanities, foreign languages, sciences. Ca' Foscari is now a modern and well-renowned university which offers a wide range of teaching and research activities across four main subject areas: economics, languages, science and humanities.

Ca' Foscari offers 30 first level and 43 second level degrees, 20 first level masters courses, 7 second level masters courses and 16 doctoral research programmes; it also carries out research, consulting and training activities for public and private organizations; it is involved in partnerships with several Venetian cultural institutions and associations in the framework of scientific information, training and research. Every year almost 800 cultural and scientific events are organized within the University.

Ca' Foscari has important cooperation programs with national and international institutions and research centres in the framework of both training experiences for students and teachers (ERASMUS and LEONARDO DA VINCI programmes) and individual scientific agreements across specific departments.

The Water Civilization International Centre (waVE) is a Non Profit Organisation aimed to promote trans-disciplinary and holistic research approaches in order to change unsustainable behaviours and practices in water perception, use and management.

Water is a key issue of civilization. Today, however, water has lost the spiritual and ethical dimensions that have characterized many past civilizations, and has been reduced to a mere 'commodity'. waVE's objective is to restore a positive relationship between Man and Water.

The Centre manages projects and disseminates research findings aimed to seek for sustainable solutions to global water crisis. waVE promotes the recovery of both the material and non-material heritage of past water civilizations, and the use of local/traditional knowledge of those societies that have elaborated original practices to face water scarcity and draughts.

The Centre was established in 1996 in Venice and is supported by different institutional partners, among which the Provinces of Venice, Treviso, Belluno and Trento; the Benetton Research Foundation; the Acque Risorgive Land Reclamation Syndicate; the water agencies of Veritas, Alto Trevigiano Servizi, ETRA and AATO of Venice Lagoon; the Municipality of Venice, and Fontanafredda (PN); Legambiente 'Piavenire'; Spresiano Primary and Secondary School (TV); B&M Engineering (TV); Terra Studio (VE).