HYDROLOGICAL SCIENCES & WATER SECURITY:
PAST, PRESENT & FUTURE

EDITORS: Siegfried Demuth, Anil Mishra, Christophe Cudennec, Gordon Young

11th KOVACS COLLOQUIUM
UNESCO, PARIS, 16-17 JUNE 2014
Hydrological Sciences and Water Security: Past, Present and Future

This colloquium is the continuation of a series of biennial international scientific meetings organized jointly by the International Hydrological Programme (IHP) of UNESCO and the International Association of Hydrological Sciences (IAHS) in the most challenging fields of water resources research. These scientific meetings commemorate the late George Kovacs, an established authority on hydrology, who served as Chairman of the Intergovernmental Council of IHP and as Secretary General and President of IAHS. George Kovacs was a renowned groundwater scientist who graduated from the Budapest University of Technology in 1947. In 1969-70 he worked for UNESCO in Nairobi (Kenya), coordinating scientific and training activities in hydrology and hydrogeology in 34 African countries. From 1970 to 1975 he was Secretary–General of IAHS, then Vice President and from 1983 to 1987 was President of the Association.

This 11th Kovacs Colloquium takes place on 16 and 17 June 2014 at UNESCO Headquarters, Paris, prior to the 21st Session of the Intergovernmental Council of the IHP. The Colloquium is comprised of a series of invited lectures, an interactive panel session plus a poster session.

Water Security is first defined by the IHP as “the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards – floods, landslides, land subsidence and droughts”, (UNESCO-IHP, 2012) which was further reiterated by UN-Water in its policy brief on Water Security and the Global Water Agenda. Thus, Water Security not only addresses the threats posed by floods, droughts and pollution spills to human societies, but also includes the impacts of inadequate supplies of water, both in quantity and quality, for their critically important support to food and energy production, for domestic and industrial purposes and for sustaining ecosystem productivity.

The Colloquium addresses the emergence and development of water security concepts over the past decades, the state of present day ideas and opinions and looks to likely developments in the future. A special emphasis is on the new phase of IHP which aims to improve water security in response to local, regional, and global challenges through multidisciplinary and environmentally sound approaches to water resources management. Of particular importance is inclusion of the new IAHS decade of research “Panta Rhei – Change in Hydrology and Society” and its relevance to Water Security.

Some 13 invited keynote papers will be presented during the Colloquium, abstracts of which are included in this brochure. The scene is set with a number of overview papers. Blanca Jiménez Cisneros of UNESCO introduces how the subject is central to the IHP in her presentation entitled “Water Security: Needs to address the theme under IHP VIII”; Hubert Savenije of IAHS shows how the research agenda of the Association is relevant to the subject with his presentation on “Panta Rhei, the new science decade of IAHS”; Howard Wheater of the Global Institute for Water in Canada addresses “Water Security – science and management challenges” and Frans Berkhout introduces water within “The Anthropocene”.

The overview presentations are followed by a series of presentations on more specific topics: Zbignew Kundzewicz and Piotr Matczak of Poland on “Hydrological extremes and security” followed by Grigory M. Barenboim and his colleagues from Russia who present on “New problems and opportunities of oil spill monitoring systems”; José Galizia Tundisi and his colleagues from Brazil present on “New problems and opportunities of oil spill monitoring systems”; José Galizia Tundisi and his colleagues from Brazil on “Water availability, water quality and water governance: the future ahead”; Pradeep Mujumdar from India considers “Uncertainty in regional

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2 UN-Water, 2013 (1), Water Security & the Global Water Agenda, United Nations University, UN-Water Analytical Brief, 01/2013
impacts of climate change: A growing challenge for water management in the developing world”; Yan Huang from China speaks on the importance of infrastructure development in “Flood management and drought relief using engineering measures”; Bruce Stewart of the World Meteorological Organization speaks on “Measuring what we manage – the importance of hydrological data to water resources management”; Vazken Andreassian and his colleagues address “What part of natural flow can be considered a water resource?”; Michela Miletto of the United Nations World Water Assessment Programme speaks on the “Water and Energy nexus: findings of the World Water Development Report 2014” and Heribert Nacken of Germany addresses “Capacity building for hydrological change – using a Blended Learning approach”.

The keynote papers will be supplemented by a number of poster papers, extended abstracts of which will be included in the final Colloquium proceedings to be published in late 2014 (IAHS Publ. 366, 2014).

The Colloquium concludes with a Panel Discussion drawing together the themes introduced by the keynote papers and poster papers. The Panellists include: António Chambel, Vice President, International Association of Hydrogeologists; Blanca Jiménez-Cisneros, UNESCO; Roger Falconer, President, International Association for Hydro-Environment Engineering and Research; Ania Grobicki, Executive Secretary, Global Water Partnership; and Alberto Montanari, Chair, Panta Rhei initiative, IAHS.

Thus, this Kovacs Colloquium provides a very comprehensive overview of water security issues including a wide variety of perspectives from around the world.

Editors

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11th KOVACS COLLOQUIUM

Hydrological Sciences and Water Security: Past, Present and Future

16 and 17 June 2014

UNESCO Headquarters, Paris

Room IV (Fontenoy)

AGENDA
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|               | **Ms Blanca Jiménez-Cisneros**  
|               | Director, Division of Water Sciences, UNESCO;  
|               | Secretary of the UNESCO International Hydrological Programme (UNESCO IHP);  
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| 9.30 – 11.00  | **Chair: Mr Siegfried Demuth, UNESCO IHP**  
|               | Rapporteur: IAHS  
|               | *Responding to the challenges of Water Security: the Eighth Phase of the International Hydrological Programme 2014–2021*  
|               | **Ms Blanca Jiménez-Cisneros**, UNESCO IHP  
|               | *Panta Rhei, the new science decade of IAHS*  
|               | **Mr Hubert Savenije**, IAHS  
|               | *Water Security – science and management challenges*  
|               | **Mr Howard Wheater**, Global Institute for Water Security, Canada. |
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| 11.30 – 13.00 | **Chair: Mr Christophe Cudennec, Secretary–General, IAHS**  
|               | Rapporteur: IHP  
|               | *Anthropocene Futures and Water Security*  
|               | **Mr Frans Borkhout**, Future Earth, France  
|               | *Hydrological extremes and security*  
|               | **Mr Zbignew Kundzewicz and Mr Piotr Matczak**, Institute for Agricultural and Forest Environment, Polish Academy of Sciences, Poznan, Poland, and Potsdam Institute for Climate Impact Research, Potsdam, Germany  
|               | *New problems and opportunities of oil spill monitoring systems*  
<p>|               | <strong>Mr Grigory M. Barenboim et al.</strong>, Institute of Water Problems of Russian Academy of Sciences, Russia |
| 13.00 – 15.00 | Lunch break |</p>
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|              |                                | Mr José Galizia Tundisi et al., Instituto Internacional de Ecologia, Brazil  |
|              |                                | *Uncertainty in regional impacts of climate change: a growing challenge for water management in the developing world*  
|              |                                | Mr Pradeep Mujumdar, Indian Institute of Science, Bangalore, India  |
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<td><em>Measuring what we manage – the importance of hydrological data to water resources management</em></td>
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<td>Mr Bruce Stewart, Climate and Water, WMO, Switzerland.</td>
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<td>Mr Vazken Andreassian <em>et al.</em>, IRSTEA - National Research Institute of Science and Technology for Environment and Agriculture, France.</td>
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End of the session
Responding to the challenges of Water Security: the Eighth Phase of the International Hydrological Programme 2014–2021

B. JIMENEZ-CISNEROS
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UNESCO’s International Hydrological Programme (IHP), founded in 1975, is entering its eighth phase (IHP-VIII) to be implemented during the period 2014–2021. Today an encompassing, holistic programme, IHP facilitates education and capacity development and enhances water resources management and governance. It fosters an interdisciplin ary and integrated approach to watershed and aquifer management, which incorporates the social dimension of the water cycle and promotes and develops international research in hydrological and fresh water sciences.

As the only intergovernmental water science programme of the United Nations, the priorities and needs expressed by the Member States are shaping IHP. Thus, IHP-VIII commenced while the international post-2015 agenda for sustainable development is being conceived and was designed to be an adaptive part of the agenda’s implementation process in pursuit of the forthcoming Sustainable Development Goals. Accelerating global change, expressed in population growth, degradation of water quality, growing impact of floods and droughts and other hydrological effects, is an increasing concern. The challenges associated are among the greatest dangers for humanity and call for water security.

Currently, 85% of the world’s human population lives in the drier half of the Earth. All regions – in particular Africa – are confronted with serious freshwater challenges, albeit in different contexts. Under increasingly severe pressures from climate change, urbanization, intensified agricultural and industrial production, growing numbers of users and in combination with the current economic and financial crisis, this situation endangers the significant progress achieved over the last decades in providing safe drinking water and adequate sanitation.

Close to 800 million people still have no access to safe drinking water, near 2.5 billion lack access to basic sanitation, and 6 to 8 million human beings are killed each year from water-related disasters and diseases. Climate change is aggravating this situation, as the projections show that water scarce regions will receive a lower pluvial precipitation, water demand will increase worldwide for municipal, agricultural and industrial purposes (mostly for cooling), and droughts and floods will be more frequent and intense. Women, children and those living under conditions of poverty suffer most of the burdens caused by the water crisis. They often walk for hours to fetch unsafe water, often under life threatening conditions, jeopardizing their chances for education.

This situation contrasts dramatically with the goal of Water Security, defined by UNESCO as “the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards — floods, landslides, land subsidence and droughts.” (IHP/2012/IHP-VIII/1) As per its title, IHP-VIII aims to deliver on Water security: Responses to local, regional, and global challenges.

This paper will present how IHP is dealing with the complex challenges through seeking holistic, multidisciplinary and environmentally sound approaches to water systems (including societal components), to water resources management and to protection policies. This requires a deeper understanding of the water – energy – food nexus and applying it to enhance integrated water resources management (IWRM). IHP-VIII also fosters an improved understanding of the role of human behavior, cultural beliefs, and attitudes toward water and a better integration of social and human as well as economic sciences, so as to develop tools that will help societies to adapt to impacts of changing water availability and water-related risks of various origins.

IHP-VIII focuses on six knowledge areas translated into themes. These themes address issues pertaining to managing water security, water quality and pollution control; adaptation to the impacts of climate change and natural disasters on water resources; management and protection of groundwater resources for sustainable living and poverty alleviation in developing countries and in arid and semi-arid regions and small islands; integration of catchment scale ecohydrological concepts and processes in advanced water management models; management
of water resources for human settlements of the future; and water education as a key element to attain water security.

In order to apply a systems approach to the challenges of water security, IHP-VIII has been designed to connect thematic contents and address issues that cut across the defined areas of knowledge domains or themes, such as: conjunctive and sustainable surface water and groundwater management; integrated management consistent with transboundary water resources to prevent and/or overcome potential international conflicts over water; evaluation of the impact of key global change drivers on water availability and quality and population vulnerability; formulation of the framework for water governance policy; increased efforts in water education (also in view of providing equal opportunities for children), training, capacity building and hydrological research. Furthermore, IHP-VIII contributes to the UNESCO priority of fostering gender equality, both as a means for and in water-related management and cooperation.

IHP-VIII also ensures the continuity of crosscutting programs and projects conceived in previous phases, while bringing innovative methods, tools, models, technologies and approaches into play to optimize resources. IHP makes use of the advances of water sciences, social and/or economic opportunities. As UNESCO’s water flagship programme, the IHP further consolidates, expands and strengthens its implementation mechanisms, to which belongs the network of 30 regional category 2 centers, 30 chairs close collaboration with the UNESCO-IHE Institute for Water Education and contributions to the UN World Water Assessment Programme (WWAP), hosted and led by UNESCO. This paper will also present examples of the strong cooperation between these entities and Member States in support of global and regional water management.

The consultative process leading to the conception of IHP-VIII identified key challenges of water security, comprising technical, institutional, political, financial and information-related categories. Global and regional change pressures and associated risks and uncertainties further compound these challenges.

For instance, a great technical challenge for the hydrological community is to identify appropriate and timely adaptation measures in a continuously changing environment. Institutional challenges comprise overcoming the operation of water institutions as separate entities in a “silo perspective”, the lack of appropriate institutions at all levels or the chronic dysfunction of existing institutional arrangements, especially in developing countries. A major political challenge is to mobilize the political will to improve the sustainability and resilience of water systems in a long-term perspective. Financial challenges include dealing with the huge investments necessary for expanding and maintaining access to water, a particular challenge for the water utilities in developing countries. Poverty continues to be a major impediment to increasing access to water services. The information challenges concern the deteriorating quantity and quality of hydrological data due to lack of maintenance and development of hydrological networks, particularly in developing countries. On an opposite note, the proliferation of information calls for the structuring of a solid clearing house mechanism. A range of dynamic global and regional change pressures mentioned earlier will further impede on the sustainability of managed water systems, such as population growth, urbanization, deterioration of infrastructure systems, socio-economic changes, water quality and new emerging contaminants and climate.

While the challenges are daunting, they also provide opportunities to transform unsustainable water systems into sustainable ones. Strategic planning processes, integrated water management, sustainable, flexible and resilient technologies, emerging economic development, emerging urban centers in developing countries and the green economy and a culture of water-related cooperation are among them. Their outlines in the context of IHP-VIII will conclude the paper.
Panta Rhei, the new science decade of IAHS

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A NEW SCIENCE AGENDA

Panta Rhei is the new research agenda of the International Association of Hydrological Sciences (IAHS) for the coming decade (2013–2022). It aims to enhance our understanding of how people and the hydrological system interact and how they co-evolve under the influence of changing circumstances. This knowledge will help us to better predict probable futures and to make better decisions on interventions for the sustainable management of our natural resources.

Panta Rhei focuses on three themes, or foci: Understanding, Estimation and Prediction, and Science in Practice. The first focus aims at furthering our understanding of how people and the natural system co-evolved and what the feedback mechanisms are driving co-evolution. The second focus aims at applying this understanding in models that can be used to predict development and to explore feasible future scenarios with their related uncertainties. The third focus aims at making this information useful for society and to develop applications that can be used in practice. For details about Panta Rhei please consult the open access paper on "Panta Rhei" by Montanari et al. (2013).

At the start of the Anthropocene, one of the first things human societies undertook was to tap water from the natural system: designing wells, diverting river water, harvesting rainwater, tapping groundwater by underground tunnels (qanats), and building canals and aqueducts to convey the water to where it was needed. Although sometimes highly complex engineering works, this was only a first step towards manipulating the natural system. In guaranteeing access to water, people soon realized that it was necessary to create sufficient storage to offset the high variability of hydrological fluxes in the natural system. The building of reservoirs dates back as early as 3000 BC, when the first reservoir was built in the Middle East, not surprisingly in an area with high hydrological variability. Since then people have continuously responded to environmental pressures and adjusted their management of natural resources to climatic drivers. Learning from their mistakes, societies adjusted their interventions in a continuous feedback with the natural environment. In recent years these developments have accelerated in a way that it is no longer possible to study the natural system and the human system in isolation or in parallel as loosely coupled systems. The only way to explore feasible developments is by a close coupling between society and the natural environment.

GOING BEYOND THE TRADITIONAL LIMITS OF HYDROLOGY

How to do this may be an almost impossible question to answer. But 'impossible questions' are perfect to guide innovation and creativity of a scientific community, even if it will not result into clear-cut answers. Also we realize that addressing these questions can only be done if we approach it from a multi-disciplinary angle, involving natural sciences, social sciences and their sub-disciplines, e.g. ecology, history, archaeology, physical geography, economics, just to name a few. If we want to understand our future, we'll have to start understanding our history, particularly the way in which people interacted with and responded to the dynamics of the natural environment, and how this in turn changed the dynamics of the natural system.

At present the community has generated 10 overarching research questions and set-up 22 multi-disciplinary and international working groups addressing these questions.

REFERENCES

Water Security – science and management challenges

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The multiple dimensions of water security are discussed and a set of thematic challenges defined for science, policy and governance. Current pressures on freshwater resources include unsustainable use of water, increasing competition for water at local, regional and international scales, degradation of water quality, and increasing flood and drought risk. These are set against a background of changing societal needs, due to population growth and economic development, changing climate, and land use and land management change. This raises a set of significant challenges for science and society.

A new science agenda must recognise the role of human influences in shaping the land and water environment. For example, most of the world’s major rivers are impacted by the effects of water management, and in many areas groundwater levels are rapidly declining due to over-abstraction. Water allocation and water management ultimately reflect social preferences and political choice, perhaps seen most obviously in decisions related to environmental flows. Key science questions for water security therefore not only include the challenging issues of understanding and predicting the effects of environmental change on water quantity and quality and aquatic ecosystems, but also understanding the effects of social values and societal controls on land and water management. Translation of scientific understanding into useful information for policy and management is a further challenging area. New approaches are needed to develop appropriate policy and governance in the face of highly uncertain water futures. More generally, engagement with stakeholders including water managers, local non-governmental organisations and the public in general is necessary to bridge the divide between scientists and decision-makers.

To move the science agenda forward requires inter-disciplinary focus on common problems and common places. This can be facilitated by global programmes. For example, the World Climate Research Programme’s Global Energy and Water Exchanges (GEWEX) project includes a global network of Regional Hydroclimate Projects (RHPs). These are designed to address GEWEX priorities related to large-scale science, but draw on local and regional funding sources and commonly address linkage to stakeholder needs and concerns.

These issues are illustrated by drawing on a case study of the 336,000 km\textsuperscript{2} Saskatchewan River Basin (SaskRB) in Western Canada. With one of the world’s more extreme climates, it embodies many of the challenges of water security faced world-wide and includes environments of global significance, including the Rocky Mountains (source of the major rivers in Western Canada), the Boreal Forest (representing 30\% of Canada’s land area) and the Prairies (home to 80\% of Canada’s agriculture). Management concerns include: provision of water resources to more than three million inhabitants, including rural and indigenous communities; balancing competing needs for water between different uses, such as urban centres, industry, agriculture, hydropower and environmental flows; issues of water allocation between upstream and downstream users in the three prairie provinces; managing the risks of flood and droughts; and assessing water quality impacts of discharges from major cities and intensive agricultural production. Superimposed on these issues is the need to understand and manage uncertain water futures, including effects of economic growth and rapid environmental change, in a highly fragmented water governance environment.

The SaskRB project is currently the only active RHP in North America. It focusses research at intensively monitored sites and small watersheds to improve understanding of hydro-ecological processes and the impacts of climate and land use change, in conjunction with development of improved fine-scale models. To understand large-scale effects on river flows and quality, land–atmosphere feedbacks, and regional climate, integrated monitoring, modelling and analysis is being developed at large basin scale. And to support water management, new tools are being developed for operational management and scenario and risk-based planning.
that can be implemented across multiple scales and multiple jurisdictions. Socio-hydrology research includes research into attitudes and values related to water security, engagement of local communities in field-based research, study of the impacts of water management on livelihoods of First Nations communities, development of modelling and decision support tools to support interactive modelling of water futures for engagement with water managers and other stakeholders, and outreach activities including an interactive theatre production.

We argue that this exemplifies the new integration of the natural sciences, engineering and the social sciences that is needed to meet the challenges of Water Security, and that the emerging field of socio-hydrology provides a vehicle for addressing human impacts on the hydrological cycle, the need for translation of science into useful information for policy and governance, the challenges of managing emergent systems that are transitioning to new states of behaviour, critical thresholds, and tipping points, and the need to facilitate communication and engagement with a wide range of stakeholders. This is a challenging agenda, but, encouragingly, one which is increasingly being recognised and pursued by the international community.
Anthropocene Futures and Water Security

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THE ANTHROPOCENE AND WATER SECURITY

A central claim about the Anthropocene is that this new epoch, in which people have become the primary geological force, raises profound questions about the sustainability of human development (Crutzen, 2002). Human populations have grown dramatically especially over the past two centuries, these people have grown on average wealthier, drawing on massively greater natural resources and environmental services, including water (Steffen et al., 2011).

A number of ‘planetary boundaries’ have been defined (Röckstrom et al., 2009), which point to the most urgent dimensions of the global sustainability problems that flow from the scale and scope of human appropriations and interventions in biophysical Earth Systems. These include by now familiar changes and impacts associated with climate change, ozone depletion, biodiversity loss and land-use change, as well as global freshwater use. Röckstrom et al. (2009) suggest using consumptive water run-off (or blue water use) as a proxy for global freshwater use. Assuming an upper limit of ~12 500–15 000 km³ yr⁻¹ of accessible blue water resources, they suggest that consumptive uses above a threshold of 4000–6000 km³ yr⁻¹ would represent a significant risk to ecosystems, moisture feedbacks and freshwater/ocean mixing. Given that consumptive use is now at about 2600 km³ yr⁻¹ the authors conclude that there appears to be some room for manoeuvre, although there continues to be a trend of rapidly growing consumptive water use at the global scale.

In addition, a number of other problems associated with access to resources have been pointed to: peak oil; peak phosphorous; and the resilience of ecosystems services (Steffen, 2011). Beyond this, there is the growing awareness of ‘systemic risks’ to global economic, financial and political systems linked to the degradation, failure or transformation of key biophysical and ecological systems. Perhaps one of the most striking claims is that an epoch of relative stability in these systems (the Holocene) has been replaced by a new period of rapid change, instability and continuing transience, with growing risks of thresholds and tipping points (Lenton et al., 2008).

GLOBAL CHALLENGES, GLOBAL RESPONSES?

An Anthropocene framing of global sustainable development problems seems to invite planetary-scale responses, such as geo-engineering and appeals for the global governance of planetary boundaries. But there are questions about whether the planetary (or global) scale is really the appropriate scale at which to govern many of the critical global resources and environmental services, including water. Water is typically governed at the level of the river basin and ecosystem. Moreover, while for some global environmental problems, like stratospheric ozone depletion, global governance appears to have been, in large part, successful, there are questions about whether such global coordination can be achieved in other cases. While global governance regimes now exist in many environmental domains, including climate change, achieving an alignment of interests leading to a common understanding of the problem and effective action at the global scale has often proven elusive. Water security emerges at many different and connected scales, from the local to the global. And there are important legal, regulatory and voluntary dimensions of global water governance that contribute to water security across these scales. These include norms about rights to water, technical and other standards for water use and quality, as well as international transfers of knowledge, technology and finance to support water security goals. Nevertheless, a global water governance regime oriented towards delivering a specific planetary boundary seems a far-off prospect.
ACHIEVING WATER SECURITY IN THE ANTHROPOCENE

For the time being, the right question to ask is: how will the Anthropocene perspective influence the perceptions, norms, plans and actions of people, organisations and governments? Clearly social science can play a major role here. For the most part, social scientists are cautious in making predictions and forecasts for the future. This is partly because futures, including Anthropocene Futures, will not be universal – just as there are multiple realities in the present, there will be multiple realities in the future – and partly because there remain deep uncertainties about what the future will look and feel like. The future is not a stable object of study – awareness of it leads immediately to changed expectations and behaviour, changing the stream of events that shapes the future. Bearing these profound limitations to all future scenarios in mind, here are some predictions about Anthropocene Futures.

Costs and opportunities

There are both costs and opportunities presented by the global sustainability problems presented by the Anthropocene analysis. Costs and opportunities are the drivers of innovation. For instance, water scarcity and insecurity are both a problem and a trigger for technological and behavioural innovations. Growing systemic risks to food security as a result of climate change, growing pressure on global land resources and the desire to protect biodiversity will likewise generate the search for new, more diversified, but intensified global food production systems. Changing relative prices and preferences will change the role of meat in the diets in unpredictable directions. Even a looming limit to phosphorous production is likely to lead to innovations in low-P agriculture.

Access to resources is not a static zero-sum game. Relative prices, geopolitics and ingenuity reshape technologies and supply and demand continually. Scarcity and crisis lead to new strategies among producers and preferences among consumers, and this in turn leads to the emergence of new scarcities, crisis and innovation in patterns that can only be guessed at. It is true that fossil carbon-based energy has been at the heart of economic development for the past 200 years or more, but if the problems of energy density and storage can be solved in coming decades, there is no reason to believe that absolute decoupling of carbon from growth will not occur. There is therefore a major research task in seeking to understand not only the connectedness of global change and sustainability problems, but also the interactions shaping social and economic responses.

Useful knowledge

While there is consensus that in the long run and at the global level, the consequences of scarcity of key resources and transient global environmental systems will be severe, the way in which these costs and opportunities will unfold over the coming decades and in particular places is still not well-established. The Anthropocene perspective, with its emphasis on the global and the long-run, may be an obstacle here. This is not to say that social and economic actors do not act on the long-run – we all save for our pensions, companies invest in infrastructures with lifetimes of many decades – but there is still much to learn about precisely when, where and how serious risks will turn out to be for cities, infrastructures, water services, food security and so on. Bringing the Anthropocene into focus over the coming decades and at spatial and social scales that matter to people remains a formidable analytical task.

Global inequalities

The costs and opportunities of new planetary risks will be highly unevenly distributed – there will be winners and losers – and this affects the capacity to ‘act globally’. Global responses to global risks are most likely when powerful economic and political interests are at stake. Risks tend to be shifted to the weakest and this will continue to be the case, even as more global and connected challenges to sustainable development emerge. Just as global environmental change is an outcome of past inequities of access to natural, economic and human resources, so global environmental change has often acted to exacerbate those inequities in access to resources and environmental services. It may even be argued that the greater the intensity of global competition for resources and services, the less likely is international cooperation to achieve their stewardship. The experience of the United Nations Framework Convention on Climate Change may bear this out. A study of the
geopolitics of the Anthropocene would seek to understand these dynamics of power and to inform the development of new institutions that can foster cooperation for planetary stewardship.

These inequalities will mean that the capacity of people and organisations to deal with constraints on access to resources and to cope with transient environmental services will continue to vary in the future. Much of this resilience and adaptive capacity will be expressed across social scales, at regional, national and local levels, often down to the level of individuals and households. Economic growth will provide greater capacities, while distributive policies, nationally and internationally, will aim to build capabilities to achieve sustainable development. But there are also likely, perhaps sooner rather than later, to be limits in these capacities to adapt (Dow et al., 2013).

Winners and losers

Finally, we can predict that there will be multiple Anthropocene futures – it depends on who you are and where you stand. And perhaps this is the most confusing aspect of the idea of the Anthropocene. Tickell (2011) suggests that, ‘…humans can be regarded, like certain species of ants, as a super-organism’. This is an arresting metaphor because it suggests an emergent property in the global collective action of individuals and societies. But there is unlikely to be a single perspective or consciousness through which to view the predicaments that are presented by the Anthropocene. Short of a real cataclysm, it is likely that ‘good’ and ‘bad’ Anthropocenes will continue to exist side-by-side for a long time to come.

SCIENCE FOR THE ANTHROPOCENE

We are living through a time of great transformations towards sustainability in energy, food, transport and urban systems. The Anthropocene provides one of the underlying narratives propelling these transformations. Such impacts in shaping expectations and rationales – for investment, for regulation, for lifestyles, for a planetary ethics – are hard to measure and disentangle from the many other influences on social action. The role of programmes like Future Earth (www.futureearth.info) will be to continue to support research on the long-run and the global. But we also have a charge to do science that connects to the knowledge and actions of social actors as we find them; in the boards of corporations, in government ministries, in households and in civil society. Connecting to these lived futures challenges us to think again about how we pose questions and how we seek to answer them.

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Hydrological extremes and security

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Economic losses caused by hydrological extremes – floods and droughts – have been on the rise. They are higher, in absolute terms, in developed countries, while relative fatality rates and economic losses expressed as a proportion of GDP are higher in developing countries. This has grave security implications.

In terms of exposure to flooding, about 800 million people worldwide are currently living in flood-prone areas and about 70 million of those people are, on average, exposed to floods each year. The number of people exposed to droughts, globally, is even higher. The highest relative share of population and percentage of economy exposed to floods can be found in Cambodia, Bangladesh and Vietnam, while Bangladesh is the country with the highest number of people exposed to floods, both in absolute and in relative terms. A train of regional droughts in the Sahel commencing in 1960s has had devastating effects.

Hydrological extremes jeopardize human security and have impact on societal livelihood and welfare. They can pose serious challenges for the state, which needs to cope with them.

Security can be generally understood as freedom from threat and the ability of states and societies to maintain their independent identity and their functional integrity against forces of change, which they see as hostile. Different dimensions of security can be reviewed in the context of hydrological extremes. The traditional interpretation of security, focused on the state military capabilities, can be replaced by a wider understanding, including economic, societal and environmental aspects that have been getting increasing attention. There is no doubt that hydrological extremes can undermine security. Floods and droughts can pose a burden to the state, responsible to sustain economic development or at least stability and overcome economic crises and disturbances. Floods and droughts can also undermine societal security, related to social identities and social tensions, rooted in culture, traditions, and religion. Environmental security can be regarded as the maintenance of supportive services of the environment, on which a society depends. An important part of it is water security which can be defined as the availability of an adequate quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies.

Characteristics of water-related extremes – droughts, intense precipitation, and floods – have been changing with time. Frequency and intensity of heavy precipitation have grown in many, but not all, areas of the globe. However, no gauge-based evidence has been identified so far for a clear, and widespread, observed change in the magnitude/frequency of river floods and low flows.

Droughts may have become more widespread, more intense and longer in many regions around the globe, due to reduced land precipitation and/or warming that enhances evapotranspiration and drying. Meteorological and agricultural droughts have become more frequent in some regions (e.g. southern Europe and western Africa) but not everywhere. However, results of trend detection in hydrologic drought do not support the general hypothesis of increasing severity or frequency of drought conditions. Studies do not even agree on the sign of the global trend in droughts.

There are several factors that may explain a perceived increase in hydrological extremes: higher frequency and/or intensity of the hazard, increased exposure of population and assets, increase of property value and degraded awareness about natural risks (due to less natural lifestyle), increased vulnerability, and – not least – improved and expanded reporting of disasters. River discharge is an integrated result of processes in the drainage basin—from precipitation to runoff. There are multiple factors influencing hydrological extremes and climate change is one of the most important. Climate change amplifies mechanisms that can lead to insecurity. Disaster risk that depends on the hazard of weather and climate events, exposure, and vulnerability of human
society and natural ecosystems, is shaped by climate (subject to natural variability and the ongoing anthropogenic climate change), and development.

Changes in population size and development, and level of protection, strongly influence changes in exposure to hydrological hazards. Exposed population and assets have increased more rapidly than overall population or economic growth because of increasing concentration in flood-prone areas. Adaptation strategies need to jointly consider landscape changes, the location and protection of people and property at risk, as well as changes in climate.

The frequency of heavy precipitation or the proportion of total rainfall from intense events will likely increase over many areas of the globe. A large increase in flood hazard is projected in some areas (e.g. south, southeast, and northeast Asia, as well as parts of Africa and South America), while in other areas decrease is likely. Population growth will continue to increase exposure to floods.

Some studies indicate that drought projections show a net overall global drying trend. The drought-affected land surface and the proportion of the land surface in extreme drought at any one time are projected to increase. Climate change is likely to increase the frequency of droughts in presently dry regions. It is likely that many millions of people living in water-stressed areas will be adversely affected by climate change and severity of impacts would partly depend on adaptation to change.

Even if we have only low confidence in projections of changes in magnitude or frequency of hydrological extremes resulting from climate change, yet these projections provide an indication of future risk trends and thereby can support the assessment of future risks.

Security concerns arise, because over large areas, hydrologic extremes, floods and droughts, may become more extreme (more frequent and more severe) in the changing climate, adversely affecting water quantity and quality. In terms of dealing with water related risks, climate change can increase uncertainties, which makes the state’s task to deliver security more difficult and more expensive.

The beneficial impacts of projected increases in annual runoff in some areas, e.g. (south) eastern Asia, are likely to be tempered by adverse impacts of increased variability and seasonal runoff shifts on water supply and flood risk, in particular in heavily populated low-lying river deltas. Additional precipitation during the wet season in those regions may not alleviate dry-season problems of growing severity if there is no capacity in place to store the extra water. Clearly, areas in which runoff is projected to decline are likely to face a reduction in the value of the environmental services provided by freshwater resources, e.g. as habitat for freshwater fauna and flora, or as energy sources.
New problems and opportunities of oil spill monitoring systems

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One of the daunting problems of modern environmental science is the pollution of aquatic ecosystems by oil and oil products, which suppresses the vital functions of flora and fauna and makes the water body hazardous for use as a drinking water supply, if the oil spill occurs on water bodies, which are sources of drinking water. Large oil spills also have a negative impact on social infrastructure (recreation, fishing, etc.) The urgency of this problem is determined by the current operational and developmental scales of the oil industry and of continuous oilfield development in new regions, which is accompanied by the increase of oil spills. According to the National Report on the State and Environmental Protection of the Russian Federation, in 2010 in Russia there were about 27,000 pipelines crashes (including field and main pipelines).

When oil gets into water it ceases to exist as a mixture of components as the result of various chemical, physicochemical and metabolic transformations, produced by hydro biota. As a result the oil spilled in water is represented by different combinations of individual hydrocarbons (HC): by original (primary) and by their transformation products (secondary) at different vertical levels of the water body and bottom sediments. In this regard, toxicity (intensity and types of toxicity) distributes over the water body depth irregularly as components of the oil spill are distributed in water depending on its physical and chemical properties.

In this paper the calculation method is proposed, which allows to predict the biological activity of individual HC, including toxicity (mutagenicity, carcinogenicity, embryotoxicity, etc.), based on knowledge of the chemical structure of the HC. Data on the actual distribution of toxicity in depth allow optimizing the management of environmental risks in the process of mitigation of oil spills.

The essential feature of the oil pollution consists in the presence of heavy metals and natural radionuclides (known as naturally occurred radioactive materials, or NORM), which increases the environmental risks associated with the spill. Uranium (238U) and thorium (232Th) isotopes and the daughter isotopes of their radioactive families (e.g., 226Ra, 228Ra, 222Rn) are contained in heavy oil fractions (primarily in asphaltenes) and produced water at concentrations that significantly exceed background levels in the environment, especially in the oil production zone.

This can be considered as radioactive pollution and additional long term toxicological hazard for aquatic organisms due to its low solubility of heavy oil fractions in water, slow decay time of U, Th, Ra and the ability to accumulate in bottom sediments for years. In the North of the European part of Russia near Usinsk oil produced water was poured directly on the area. This led to the fact that for many years this area is not suitable for agriculture due to high radioactive contamination. In turn such areas are a source of radioactivity contamination of ground and surface waters. Our own and published data indicate that this aspect should be taken into consideration by emergency and post-emergency oil spill monitoring.

According to our studies there is no universal device or method making possible to solve completely the problem of the early detection, emergency and post-emergency oil spill monitoring. In respect to the oil spill detection fluorescent lidars (FL) have many advantages.

Monitoring with use of FL is based on the measurement and interpretation of fluorescence spectra, remotely induced in the test object by the monochromatic laser radiation. FL sensors investigate the surface of water with light pulses from an ultraviolet (UV) laser, for example in UV spectral region, and analyse the spectrum of the received signal of fluorescent radiation of the probed surface in a longer-wave spectral region. The measured spectrum includes a combination of the fluorescent responses of the individual components presented in the sample. Since the spectral composition of the fluorescent response is related to the molecular
structure of experimental objects, the analysis of the fluorescence spectra makes it possible to identify the substance and to evaluate its concentration in the object in some cases.

Unlike other methods FL can detect the oil presence on any surface, but also under the surface up to a certain layer thickness (e.g. water, ice, snow). Because of several limitations for the FL application in specific conditions (e.g. large ice thickness) a combined system of remote and contact type detectors can be used.

In last case FL can be installed inside an automated monitoring station (AMS). The AMS includes a waterproof container (buoy), which allows the placement both on the water surface and in underwater position and a set of contact type sensors that measure simultaneously 14 different physicochemical, hydrological and oil pollution parameters (including hydrocarbon content, gamma-radioactivity measurement) in real-time mode and can transmit the measured data by wire, wireless and satellite communication. The top of the AMS has an optical window (transparent for back-scattered and probe radiation), which keeps to a minimum ambient light by FL sensing.

The AMS combined with FL and radioactivity detector allows detection and identification of HC at each water depth and measurement of radioactivity of oil pollution up to near the bottom layer.

More precise localization of bottom sediments radioactive contamination can be traced by remote a radiometer system mounted on a flying platform. Such measurement is possible in each particular case when choosing a certain flight height and a certain water body depth.

Such combined system was first introduced in our work. Combined monitoring system, which includes remote monitoring technology and technology for contact underwater observation was developed by us for the stationary sea ice platform for oil production "Prirazlomnaja" in the Barents Sea. Offshore oil production platforms will be provided with such systems on a global scale.

Complex computer models are to be used for environmental risk management during the oil spill on land surface water bodies. This complex includes the transport model of oil on the surface of the water and in the water column, taking into account the dynamics of the distribution of oil in water on the density and the hydrophobicity, model of transition of sediments, as well as a model of transition of heavy metals, including radionuclides. Computer models of radionuclide transport in water bodies have not been applied in the situations involving oil spills. However, research in the field of modelling of radionuclide transport developed in connection with emergencies only with radioactive contamination. It is proposed to create the database of such models to pick out those models which are adequate to the conditions of the transfer of radionuclides from oil spills.
Water availability, water quality, water governance: The future ahead

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The global future water demand is expected to increase due to population growth, expansion of the per capita water use and the multiple and diversified uses of water. Current water uses for food production are also increasing depleting and degrading surface and groundwater resources and producing stress in several regions of the world.

Availability of water resources, surface water and groundwater in different continents shows areas of abundance and scarcity and significant spatial variations within continental scales. Information on supply/demand of water for continents, regions and watersheds are still needed to be improved. Since water also supports the functioning of ecosystems this indirect support is often not taken into account in the data for availability of water. The role of water in the biogeochemical cycles, water as a source for sinks of gases, ions and its dilution capacity has to be considered in the statistics for water availability, in order to balance human and ecosystem needs.

Water quality is another concern for the future. Water scarcity and pollution impair water availability in many regions, producing risk and increasing the vulnerability of the human population. This is especially evident in the periurban areas of the great metropolises of the world.

The human-caused threats to water quality such as acidification, eutrophication, sedimentation of surface water, degradation of underground sources and the POPs (Persistent Organic Pollutants) have cumulative effects, increase the costs of treatment for producing potable water and can lead to several problems of human health. The history of degradation of water quality shows a continuous deterioration with increasing complexity mainly in the 20th century with cumulative impacts on human health. The economic connections of water quality deterioration, human health degradation and loss of ecosystem services have to be quantified. Changes due to climate variability and in the chemical composition of the atmosphere can affect the aquatic biota and the water quality of rivers, lakes and reservoirs. Measurements of atmospheric deposition (dry and wet deposition) are needed especially in rural areas and in the metropolitan regions. Mining operations are another threat to water quality. Protection of natural water sources is a fundamental action for decreasing costs of treatment and conserving water quality and potability. A complete evaluation of economic impacts of water quality impairment is necessary for several regions.

An integrated watershed management is a key initiative to overcome the problems caused by water availability, water demand and water quality. The economy of the watersheds and the sustainable development is and will depend on a basin society with accurate analysis of water availability/water demands/water quality. A governance system based on technical and scientific information, participation of stakeholders, the community and new approaches such as ecohydrology, combining ecological principles, engineering and a systemic and integrative process can probably overcome the challenges ahead. A predictive, ecosystem (watershed) approach integrating multiple uses is required for water governance. The governance can be improved by introducing modeling approaches and prediction using biogeophysical, economic and social data.

The concept of the hydrosocial cycle needs to be strongly considered and connected with the water governance at watershed level. Water and sanitation for the poor populations in periurban areas of large metropolises pose a great challenge for future water governance. The implementation of networks of competence around the world is a possible working solution to overcome the problems of water availability/water
demand/water quality and vulnerability. Risk analysis and vulnerability of human populations to both scarcity and water quality deterioration is a field for research and management that needs to be improved. Education and capacity building with a systemic approach at all levels is fundamental for water governance.

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Uncertainty in regional impacts of climate change: A growing challenge for water management in the developing world

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Climate change results in regional hydrologic change. The three prominent signals of climate change, viz., increase in global average temperatures, rise in sea levels and change in precipitation patterns transform into signals of regional hydrologic change in terms of modifications in water availability, evaporative water demand, hydrologic extremes of floods and droughts, water quality, salinity intrusion in coastal aquifers, groundwater recharge and other related phenomena.

A commonly adopted methodology for assessing the regional hydrologic impacts of climate change is to use the climate projections provided by the Global Climate Models (GCMs) for specified emission scenarios in conjunction with the process-based hydrologic models to generate the corresponding hydrologic projections. The scaling problem arising because of the large spatial scales at which the GCMs operate compared to those required in hydrologic models, is addressed by downscaling the GCM simulations to hydrologic scales. Hydrologic projections obtained with this procedure are burdened with a large amount of uncertainty introduced by the choice of GCMs and emission scenarios, small samples of historical data against which the models are calibrated, downscaling methods and other sources. These uncertainties pose a mammoth challenge to water managers in the developing countries.

Even without the likely adverse impacts of climate change, many developing countries are already living on the edge as the water crisis becomes more pronounced every year, with the following common symptoms: several stretches of rivers polluted beyond acceptable levels; groundwater contaminated in many regions because of both natural and anthropogenic causes; inaccessibility of safe drinking water to sizable sections of the population; indiscriminate and unsustainable exploitation of groundwater; transport of water to cities over large distances with huge pumping involving enormous energy; unplanned urban growth encroaching upon natural water bodies and drainage pathways, resulting in frequent and intense flooding of cities; severe water shortages in some seasons almost every year and intense floods during others causing huge loss of property and life.

Climate change is likely to only exacerbate this situation. Water managers in the already water-stressed developing countries are faced with the challenge of evolving adaptive responses in the face of not only a large uncertainty associated with the projected impacts but also a sense of perplexity that the issue of climate change seems to have created because of conflicting views, opinions and even scientific projections on the impending regional water scenarios. It is thus incumbent upon the scientific community to quantify and reduce uncertainties in the hydrologic projections and to communicate the research results in a manner useful for water managers and policy makers.

This presentation begins with an overview of the current water scenario and the national water problem in India, as a typical example of a rapidly developing country and then provides a summary of recent work carried out on addressing scale issues and uncertainties with a specific goal to understand the evolving regional water situation under climate change. Discussion on possible impacts on regional water availability, water quality, irrigation water demands and urban floods with an emphasis on water management issues is provided.
Integrated water resources management using engineering measures

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Integrated Water Resources Management (IWRM) has been defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" by the Global Water Partnership (GWP). The management process of IWRM consists of aspects of policies / strategies, measures (engineering measures and non-engineering measures) and organizational management structures, etc., among which, engineering measures such as reservoirs, dikes, canals etc., play the backbone which enable IWRM through the functionality of redistribution and reallocation of water in time and space. In general, engineering measures are adopted for different objectives such as water utilization and water disaster preventions (such as flood control and drought relief).

Implementation of engineering measures for IWRM normally follows two major processes: planning and operation. During the planning stage, engineering measures shall be developed according to the needs from water issues, such as water deficit which requires storage and canals to store and distribute water, and flooding issue which requires either extra storage (such as reservoir or retention basin) to store flood water temporarily, or dikes to protect people from flooding, or canals to divert flooding waters. After the planned engineering measures have been constructed, how to make the best use of those measures becomes another essential work in IWRM. In this paper, to demonstrate how IWRM be realized using engineering measures, examples are given on planning and operation of engineering measures at different rivers, focusing on how those works are carried out, how the engineering measures are operated at real time to realize designed and desired objectives, and the benefits or problems that might occur sequentially.

The first example is the water resources planning in basins where water distribution does not match the distribution of population, i.e. most people are living in the western area whereas water is much richer in the eastern area where not many people are living. In this planning, the water deficit situation has been analysed through water balance computation considering future water demands (predicted) and available water at different planning horizons. In the water allocation computation, four major water users of domestic use, agriculture use, industrial use and environmental flow, are taken into account. Various engineering measures such as pond, reservoirs, water diversion canals and pumping stations etc., are proposed with scales to satisfy water demands considering integrated water utilization; in addition, multiple objectives are also considered, for instance, a reservoir is planned to provide storage for irrigation or drinking water as demanded, at the same time, it can also be used for flood control if necessary during the wet season, and hydropower generation. As a result, layouts of numbers of engineering measures are developed for the planning horizons of short-term and long-term. Cost-benefit analysis shows that the planning will not only solve the water shortage problem, but also optimize the water resources situation by using the inter-basin water-diversion projects, to satisfy water demands at the west area of the study where the major social-economic activities occur but where however there is lack of water resources.

The second example is the operation of Three Gorges Reservoir (TGR) in Chang Jiang River, China. As the most representative engineering measure of IWRM, reservoirs play an important role in power generation, flood management, navigation and water supply. TGR has been put into operation since 2007, originally planned and developed with three major objectives: flood control, power generation and navigation, in order of priority. After the project has been put into operation, water supply for downstream areas has drawn more stakeholder attention due to the increasing development of water supply / demand (i.e. increased demand which will result in a higher supply needs). The newly raised water demands at downstream areas of Chang Jiang River are water intake, ecological use to stimulate fish breeding, or to possibly reduce the risk and pressure from saltwater intrusion at the estuary area (which is a new topic under study). The key of reservoir operation of TGR is risk
management, under which rules are developed to deal with limited flood level during the flooding season so that
the reservoir can generate more power while the flood storage can remain sufficient for future coming floods,
rules for water impoundment to ensure that the reservoir can be filled up in time so that it can provide sufficient
water resources for the demands at downstream during dry season. Examples of real time operation are given
particularly on flood management and ecological demands downstream.

The examples of water resources planning and the operation of Three Gorges Reservoir from China
show that well-planned and regulated engineering measures can benefit IWRM significantly. However, attention
shall be given to issues of (a) how to make better use of the engineering measures considering support of non-
engineering measures; and (b) how to deal with or reduce the impact of the use of engineering measures to the
natural river regime.
Measuring what we manage – the importance of hydrological data to water resources management

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INTRODUCTION
One of the essential elements of life on this planet is freshwater. Sustainable development therefore demands sustainable management of the world's limited resources of freshwater. The Integrated Water Resources Management (IWRM) approach is a more holistic approach to water management aimed at the efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands.

In implementing IWRM, water resources management institutions and professionals deal with a highly variable environment, in terms of, inter alia, weather, climate, land use and natural vegetation. They must be aware of and manage the response of a particular water regime to climatic and human interventions on hydrological regimes and water courses including land use changes, changes in water use patterns as well as the construction and management of dams and embankments and changes in the freshwater–ocean interfaces. Water managers have developed a range of standard methods to assess and manage water-related risks. Functioning water observation networks and sharing of observations are therefore key for informed decision-making for water management, minimizing uncertainties (WMO, 2009).

NEED FOR WATER RESOURCES INFORMATION
Water resources cannot be managed, however, unless we know where they are, in what quantity and quality, and how variable they are likely to be in the foreseeable future. Data from hydrological networks are used by public and private sectors for a variety of applications, including, inter alia, planning, designing, operating, and maintaining multipurpose water management systems; the preparation and distribution of flood forecasts and warnings aimed at protecting lives and property; the design of spillways, highways, bridges, culverts; floodplain mapping; determining and monitoring environmental or ecological flows; managing water rights and transboundary water issues; education and research; protecting water quality and regulating pollutant discharges (USGS, 2006).

The data quality required for a specific purpose will depend to a significant degree on the requirements of the above application areas and it needs to be recognized that not all data are fit for use in all application areas. For example, where there is a safety of life issue, greater confidence is required in the quality and accuracy of the data.

REQUIREMENTS FOR SOME PURPOSES
Storage Yield
Although there are no formal guidelines for the minimum period of record, reasonable stability with respect to yield analyses is generally reached with a record length of 10 to 20 times the critical period. Where little variability in streamflow occurs and where the need is mainly for seasonal storage (less than one year), a minimum record period of 10 to 20 years may be acceptable. However, in semi-arid to arid areas, over-year storage is generally required, as critical periods of 5 to 10 years and longer are common. A record length of 50 to 100 years should preferably be used in such cases. Even where reasonably long streamflow records exist, worse floods and worse droughts than those historically observed are bound to occur in future. It is also virtually certain that the exact configuration of a streamflow sequence, as recorded in the past, will never be exactly repeated in future. It is evident, however, that the longer the period of record on which the inflow sequence is based the more reliable the estimation of the yield is likely to be (WMO, 2009).
Design Rainfalls

Sevruk and Geiger (1981) argue that for extreme precipitation frequency analysis a 25-year period of record may be sufficient in humid regions such as the northern Russian Federation, but even a 50-year period is not adequate in other regions where a distinct periodic fluctuation of precipitation exists. According to these authors, a record of 40 to 50 years is, in general, satisfactory for extreme precipitation frequency analysis. Yue et al. (2002) and Yue and Pilon (2004) show, as well, how statistical characteristics of the sample and record length can impact upon the power of common statistical tests (WMO, 2009).

Benefit–Cost Ratios

There have been many studies in the past that have shown the high benefit–cost ratios associated with the use of hydrological data and this paper will not go further into that topic. Suffice to say that the value of hydrological time series records increase over time. For example, stream gauges with a long period of record are particularly valuable as they form a baseline for information about future changes. It is also important that in the future, both the number of users and the ways in which the data are being used will increase, and the information’s value will increase accordingly (USGS, 2006).

CURRENT STATUS OF NETWORKS

Despite the above, there is growing evidence that hydrological networks are in decline. It is recognized that the cost of maintaining hydrological observation systems is growing and that the promise of next technologies that would provide quality data at reduced costs has not been realized at this time. There is a need for the hydrological community, together with the hydrological instrumentation industry to look for improvements in monitoring systems that will enable the collection of quality data through systems that are more easily managed and maintained. National governments must also recognize that the collection of data of the required quality and accuracy does cost, but the costs are far outweighed by the ensuing benefits, especially in a changing and highly variable world.

THE VALUE PROPOSITION

The above said, it is essential that data be collected for the information (services and products) that can be derived from them and not just for the sake of data collection. Data must be raised up the data value information chain such that the true benefits of the data can be realized. This is accompanied by wide spread recognition that data in themselves only become of value when they are used to produce services and products that can be used for decisions in support of socio-economic and environmental benefits. Indeed free and unrestricted access to data can and does facilitate innovation and the discovery of new ways to use, and purposes for, the data.

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What part of natural flow can be considered a ‘water resource’?

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Man is used to look at water flows in a very utilitarian manner, and the press (either generalist or scientific) often uses the expression "water resources" as a synonym to "river / groundwater flow". In this presentation, our aim is to discuss this unfortunate semantic shortcut, which causes much confusion in all discussions concerning water security issues. More specifically, we want to discuss the flow-to-resource conversion efficiency, while focusing on six issues of importance for a realistic assessment of water resources, which we will illustrate by actual examples:

The ratio of water resource to total water flow is a function of the hydrologic regime

A water flow can only be accounted as a resource if it can be used by man, i.e. if it occurs at the right time. Naturally, what is the right time for flow depends on the type of use: for irrigation, the right time will be the summer; for hydroelectricity, the right time will be the peak hours of electrical consumption, etc. Since groundwater flows are much more regular than surface water flows, this notion of right time mainly applies to river flow. It is interesting to note here that floods should not be accounted as water resources, unless a river has enough dam storage capacity to regulate them and store the water.

The ratio of water resource to total water flow can be increased by construction of storage reservoirs

Man has the possibility to manipulate the natural variability of river flows, by building reservoirs to store water: they represent the only possibility to transform a larger part of river flow into a usable water resource. It is interesting to note here that because of the unavoidable evaporative losses caused by reservoir lakes, increasing the ratio of water resource to total water flow has a water cost.

Environmental constraints imply a reduction on exploitable water resources

Environmental law prescribes to maintain or reserve Minimum River flows to protect river ecosystems. These environmental constraints (which are naturally beneficial to the ecosystems they are deemed to protect) reduce the availability to other users.

Transboundary Rivers and aquifers imply a reduction on exploitable water resources (and incidentally, this means that international statistics overestimate world water resources)

Rivers and aquifers do not respect state boundaries: they flow through them. Unless specific treaties have been signed to detail how transboundary flows are to be shared, each of the neighbour states usually counts the entire amount of transboundary flow as its own water resource. This is for example the case in FAO's AQUASTAT database. This means that international statistics overestimate world water flows and thus world water resources. Even if water flow figures are right, water resources account can be wrong.

Potential climatic changes hold the potential to reduce exploitable water resources even if they do not modify total water flows

Future climatic changes may or may not change precipitation amounts and river flows. Predictions are still quite uncertain. However, trends in temperature are extremely trustworthy, and they imply that in mountainous and northern regions, less snowfall and more rainfall will occur. This will have a definite impact on the seasonality of river flows, and potentially reduce water resources even where total water flows are not modified.
The green water–blue water distinction must be handled with caution in water security computations, due to the fundamental asymmetry that exists between the two categories. Falkenmark and Rockström (2006) proposed to distinguish "Green" water which corresponds to the part of precipitation stored in soil on arable lands and subsequently transpired by vegetation from "Blue" water which corresponds to the part of precipitation that flows in rivers and aquifers. Although it was a tradition to only account for "Blue" water in water resources statistics, some authors have recently started to present figures for both "Blue" and "Green". We consider this to be potentially misleading: while it is easy to convert "Blue" water into "Green" water, the opposite is impossible. Rainfed agriculture (based on "Green" water) and irrigated agriculture (based on a mix of "Blue" and "Green" water) both contribute to food security. We would argue that water security issues are restricted to "Blue" water availability.

REFERENCE

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“Water and energy are inextricably linked. Water is essential for the production, distribution and use of energy. Energy is crucial for the extraction and delivery of safe drinking water – and for the very safety of water itself. People everywhere – but especially the most vulnerable and marginalized – face great risks when access to water either is limited or compromised.” (Ban Ki-moon, WWDR 2014)

As the first of a new series of theme-oriented reports to be released on an annual basis, this fifth edition of the United Nations World Water Development Report (WWDR) “Water and Energy” marks a pivotal new direction for the WWDR series, the World Water Assessment Programme (WWAP), and the many partner agencies that work with us in the production of the flagship report of UN-Water. Comprised of two volumes (comprehensive overview and case studies/data-indicators annex), the Report provides a comprehensive and up to date overview of the impacts of ever-increasing energy production on water resources and water users, including agriculture, rapidly expanding cities, expanding industry and the environment.

Water and energy are tightly interlinked and highly interdependent. Choices made in one domain have direct and indirect consequences on the other, positive or negative. The form of energy production being pursued determines the amount of water required to produce that energy. At the same time, the availability and allocation of freshwater resources determine how much (or how little) water can be secured for energy production. Decisions made for water use and management and for energy production can have significant, multifaceted and broad-reaching impacts on each other – and these impacts often carry a mix of both positive and negative repercussions.

The challenge today: Extending services to the unserved. Worldwide, an estimated 768 million people remain without access to an improved source of water – although by some estimates, the number of people whose right to water is not satisfied could be as high as 3.5 billion and 2.5 billion remain without access to improved sanitation. More than 1.3 billion people still lack access to electricity, and roughly 2.6 billion use solid fuels (mainly biomass) for cooking. The fact that these figures are often representative of the same people is evidenced by a close association between respiratory diseases caused by indoor air pollution, and diarrhea and related waterborne diseases caused by a lack of safe drinking water and sanitation.

The challenge to come: Meeting growing demands. Demands for freshwater and energy will continue to increase significantly over the coming decades to meet the needs of growing populations and economies, changing lifestyles and evolving consumption patterns, greatly amplifying existing pressures on limited natural resources and on ecosystems. The resulting challenges will be most acute in countries undergoing accelerated transformation and rapid economic growth, or those in which a large segment of the population lacks access to modern services. Global water demand (in terms of water withdrawals) is projected to increase by some 55% by 2050, mainly because of growing demands from manufacturing (400%), thermal electricity generation (140%) and domestic use (130%). As a result, freshwater availability will be increasingly strained over this time period, and more than 40% of the global population is projected to be living in areas of severe water stress through 2050. There is clear evidence that groundwater supplies are diminishing, with an estimated 20% of the world’s aquifers being over-exploited, some critically so. Deterioration of wetlands worldwide is reducing the capacity of ecosystems to purify water. Global energy demand is expected to grow by more than one-third over the period to 2035, with China, India and the Middle Eastern countries accounting for about 60% of the increase. Electricity demand is expected to grow by approximately 70% by 2035. This growth will be almost entirely in non-
Organization for Economic Co-operation and Development countries, with India and China accounting for more than half that growth. Approximately 90% of global power generation is water intensive.

The International Energy Agency estimated global water withdrawals for energy production in 2010 at 583 billion m³ (representing some 15% of the world’s total withdrawals), of which 66 billion m³ was consumed. By 2035, withdrawals could increase by 20% and consumption by 85%, driven via a shift towards higher efficiency power plants with more advanced cooling systems (that reduce water withdrawals but increase consumption) and increased production of biofuel. Local and regional impacts of biofuels could be substantial, as their production is among the most water intensive types of fuel production. Despite ongoing progress in the development of renewables, the overall evolution of the global energy mix appears to remain on a relatively fixed path: that of continued reliance on fossil fuels. Unconventional oil and gas production is generally more water intensive than conventional oil and gas production.

The different political economies of water and energy should be recognized, as these affect the scope, speed and direction of change in each domain. While energy generally carries great political clout, water most often does not. Partly as a result, there is a marked difference in the pace of change in the domains; a pace which is driven also by the evolution of markets and technologies. Unless those responsible for water step up their own governance reform efforts, the pressures emanating from developments in the energy sphere will become increasingly restrictive and make the tasks facing water planners, and the objective of a secure water future, much more difficult to achieve. And failures in water can lead directly to failures in energy and other sectors critical for development.

The post-2015 Sustainable Development Goals (SDG) are likely to include increased access to water and energy services. WWDR2014 aims to contribute to the ongoing international process, by informing the decision-making about the interlinkages, potential synergies and trade-offs as well as by stressing the need for appropriate responses and regulatory frameworks that account for both water and energy priorities. Furthermore, the 2014 edition provides a comprehensive overview of major and emerging trends from around the world, with examples of how some of the trend-related challenges have been addressed, their implications for policy-makers, and further actions that can be taken by stakeholders and the international community.

**REFERENCE**

Capacity building for hydrological change – using a Blended Learning approach

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INTRODUCTION

Extreme hydrological events have always been a challenge to societies. There is growing evidence that hydrological extremes have already become more severe in some regions. The Middle East and North Africa (MENA) region is characterized as one of the world’s most water-scarce and driest regions; with a high dependency on climate-sensitive agriculture.

There is an urgent need for capacity building programs that prepare water professionals and community to deal with the expected hydrological changes and extremes. The most successful capacity building programs are the country driven ones which involve a wide range of national stakeholders, have a high degree of in-country ownership and have an applicability character. The method of choice to set up such capacity building programs will be through blended learning.

WATER SCARCITY

Since the mid-1990s Integrated Water Resource Management (IWRM) is targeted by national and international water organisations and water politics. The second UN world water development report (UNESCO WWAP 2006 1) states that sharing the water resources and ensuring at the same time the sustainability will be our problem of the future.

"There is enough water for everyone. The problem we face today is largely one of governments: equitably sharing this water while ensuring the sustainability of natural ecosystems" (UNESCO WWAP 2006 2).

Is it really true that there is enough water for everyone in the MENA region? Let’s have a closer look at the facts and figures. All in all water seems to be an unlimited resource for John Q. Public when it comes to the 1.4 billion km³ of water that our earth is supplying us with. But 97,5 % of this amount is salt water and can only be made available for human beings through the use of high energy rates (e.g. desalination).

Most of the remaining 2,5 % of fresh water on our earth is stored in glaciers and perpetual ice so that in the long run there are just 14,000 km³ that we can make use of (some hydrologists even take a total budget of 9,000 km³ into account when it comes to integrated water resource management for mankind). So out of each 100,000 litres of water only 1 litre can be used for public water supply, food production and industry.

As the world population is still increasing and world-wide production is still on the rise (with non-sustainable consumption patterns), integrated water resource management will face severe circumstances within the next decades.

CAPACITY DEVELOPMENT

By no means can we change these physical constraints. So we will very much have to focus on teaching and training sustainable ways of water use and management in the process of capacity building related to the hydrological change and water management.

The United Nations Development Programme (UNDP) defines capacity and capacity development as follows: “Capacity is the ability of individuals, institutions and societies to perform functions, solve problems, and set and achieve objectives in a sustainable manner. Capacity Development (CD) is thereby the process through which individuals, organisations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time.” (see: http://www.capacity.undp.org/)

This capacity building will be very much based on knowledge transfer from specialists to dedicated members of water related organisations as well as to the wide public. A targeted approach to enhance this
The process of knowledge transfer is by making use of blended learning concepts.

**BLENDED LEARNING APPROACH**

Let us focus on the didactical structure of Blended Learning courses and the design patterns. You should start by unitizing the content into well-defined topics. Within each topic, the first step will be a knowledge transfer which is realized by so called knowledge objects. These knowledge objects could be your aural presentations, videotaped lectures or webinars. A knowledge object has the task to transfer all the necessary information to the attendee. Again, one should be aware of dual coding all the information. When you stick to the assumption that your knowledge transfer is realized primarily by aural coding, sequences should not be longer than approximately five minutes (the reason for that is that attendees will lose their attention after a while, when looking at a monitor where nothing is visually changing). If for the knowledge transfer it is necessary to have longer sequences, you should add a video stream of the speaker which the attendee can visually concentrate and focus on.

The second step of the didactical structure will be an assessment. With that the attendee can really proof whether the knowledge transfer has been successful and he or she did acquire the knowledge, skills and competencies, which the first step did allocate. Most often this step is done in form of a quiz (using true-false, single-choice, multiple-choice, short answer, numerical or matching questions). Best practice will be the use of the Question and Test Interoperability Specification (IMS QTI standard, see www.imsproject.org/question). The assessment (as well as the knowledge transfer) should be designed in such a way, that it motivates, incentivizes and encourages the attendees. Moreover the design of the eLearning module should take into account the fact, that giving learners more than one method to solve a problem or show them multiple approaches to solve a task, will greatly raise the efficiency and the impact of your knowledge transfer.

The first two steps are always mandatory, whereas step three is optional and will offer additional, advanced knowledge contents to the attendees. This can be any further information on the selected topic, a series of links to internet pages with topic related information or any other add-on.

You can easily link different topics (steps 1–3) in a linear chain, where every topic has to be followed one after the other (often called a program flow model). Another possible design pattern would be the presentation of these topics and offering different entry points for the attendees (so that they can choose which contents they would like to follow). If you choose this design pattern, it could be a good idea to start each topic with an assessment to find out whether the attendee knows all the basics necessary for this topic. Depending on the result of the assessment, the attendee will be allowed to go on with a topic or will possibly be redirected to the topic he needs to repeat before starting the new subject.

The future of capacity building through Blended Learning looks bright and promising; we do have the tools and technologies to support us and know the design patterns. It is just up to us, to make the best of it.

**REFERENCES**

