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The Priority Areas of the Ninth Phase of the Intergovernmental Hydrological Programme (IHP-IX) as of May 2020

Summary

This document contains the descriptions of the Priority Areas of IHP-IX as designed by the Task Force and Experts of Member States as of May 2020.

Priority Areas
1. Scientific research and innovation
2. Water Education in the Fourth Industrial Revolution
3. Bridging the data-knowledge gap
4. Inclusive water management under conditions of global change
5. Water Governance based on science for mitigation, adaptation and resilience

1. Sciences: Research and Innovation

Scaling and heterogeneity issues in hydrological processes have engendered debate in both the water research and management communities for decades Questions such as what causes spatial heterogeneity in runoff, evaporation, surface and subsurface water and material fluxes are still being debated today. Scientists still cannot fully answer how various physical factors cause spatial homogeneity and heterogeneity in hydrological variables and fluxes. It is also an open question how hydrological principles should be applied at different scales (e.g., point-scale principles, hillslope-scale principles, catchment-scale principles, and continental-scale principles) and further how to relate such data to each other when scales change over space and time.The coevolution of landscape and hydrological processes may provide a clue. It is important to note that the important speed in integration of hydrological and ecological processes form molecular to catchment scale has been provided by ecohydrology initiated in UNESCO IHP-VI and developed further in IHP-VII and VIII. Moreover the principles of ecohydrology provide a framework how to use ecosystem processes as catchement management tools. Further implementation of these principles is required to elaborate their use in various climatic and morphological settings.

Further to the importance of different scales and heterogeneity, the interfaces between systems from the top of vegetation's canopy to groundwater possibly via hillslope and riparian systems and high elevation cold regions, referred to as the "**critical zone**", matters as well. In particular, there is still a significant lack of knowledge on **groundwater** related to its availability, quality and recharge.

By conducting further research within IHP-IX in this area, an improved understanding and predicting the hydrological cycle in an ungaguged basin will be accomplished, as well as for a better understanding of hydrology.

Experimental field hydrological studies at small catchments remain an indispensable source for the development of hydrological knowledge and methods for calculating and forecasting of hydrological, meteorological and biochemical processes in river catchments; for monitoring of natural and anthropogenic changes in hydrometeorological characteristics and hydrometeorological regime including climate change.

Variability and change in the hydrological cycle, including those of **extremes such as floods and droughts,** is a research area which often attacts publicity and where public concern is high. The capacity of forecasting extreme hydrological phenomena and the disasters caused by them, should be further enhanced. Variability and change includes not only natural variability and change, but also those changes induced by anthropogenic activities such as global warming, socioeconomic and landuse changes, and water withdrawal. These areas define future research targets for IHP-IX. Detection, attribution and future projection are imperative components of this research topic, where uncertainty should be considered. Research on melting and reducing snow reserves, mountain glaciers and permafrost should be carried out to provide additional resources of information and to minimize the possibility or avoid disasters.

The results of conducting research in this area within the framework of the ninth phase of IHP will to improve water management, prevention, response and protection from natural hazards, and governance for mitigataion and adaptation under global changes.

Water quality has been deteriorating due to increased volumes of diffuse pollution linked to the hydrological processes; that is mixing fresh water with untreated or inadequately treated wastewater, agricultural drainage, industry cooling water, wastes from fish farms, livestock manures and poultry farms. Water quality from diffuse pollution remains a big probem that is difficult to monitor and to model. Hydrological models are typically not good in representing agricultural processes and practices. There are currently various biological and chemical treatment techniques, but developing countries have insufficient financing, an in cases political will, to assess and address these issues. Research within the framework of IHP-IX will focus on the potentiality and development of low-cost, innovative, and applicable techniques. Most of currently applied water quality monitoring systems utilize chemical and biological analysis, but, they are laborious and costly, and lack real-time data, indispensible for making quick decisions. Therefore, it is envisioned that within IHP-IX, the enabling research environment will be provided for the Internet of Things (IoT)-based sensors and other digital water quality applications to achieve efficient water quality monitoring. Furthermore, Ecohydrology provides all sets of tools (highly efficient land-water ecotones with denitrification and geochemical barriers, sequentional sedimentation-biofiltration systems, hybride systems), which have to be developed and tested in different geomorphological and climate conditions. Thus, further research needs to be conducted that facilitates their development and testing.

Integrated River Research and Management from the watershed to the local scale is needed in order to unify isolated analysis of specific topics such as floods, droughts or sediments. Rivers are the lifelines in the landscape and have a central function in the water-energy-food-nexus as well as the UN SDGs, supplying people with drinking water, renewable energy or transport means but are as well of central importance related to floodrisk and droughts. They form the hotspots of biodiversity and reflect immediately climate and landuse changes. At the same time they are endangered by overuse, interruption of sediment continuity or spatial restriction as well as water quality. IHP-IX will lead an integrated river research focus on the fundamental processes in river hydrology, hydraulics, sediment transport and morphodynamics, water quality and river management (focusing on usages) as well as socioeconomics while maintaining the health of river ecological environment. The outcome of this research will be a global overview of the status and future of rivers as contribution to an improved water management.

The interactions with **nature based solutions (NBS)** and the catchment hydrology is also an important topic that needs further research, e.g. on interactions of trees and wetlands with the hydrological and water quality processes. Previous projects have shown that there is a need for **science-based proof of concept**, in order to enable financing of NBS that could be explored within the IHP-IX framework. Living labs – UNESCO Ecohydrological Demosites (http://ecohydrology-ihp.org/demosites/demosites/list) will provide a platform to monitor and showcase the value of such solutions.

Ecohydrology by deepening of understanding of hydrological and biological processes interplay formulated and provided a framework (Zalewski et al. 1997, Zalewski 2013) for the change of paradigm from mechanistic to **evolutionary/ecosystemic**. Evolutionary – should rise the consciousness of society that biosphere always has been changing and now in the Anthropocene era society consciousness and attitude will determine sustainable future; Ecosystemic – to achieve sustainability, the key reference point should become the understanding of ecological processes – water, carbon, nitrogen and phosphorus cycling. In the new paradigm, every catchment should be considered as the unique "Platonian superorganism" where the combination of geomorphology, climate, ecosystems (human modified and natural patches) and various forms of human activities affects water cycle and good ecological status. This should be considered not only from security and resources perspective but first of all as safeguard of sustainable future, health and quality of life dwellers. Thus IHP-IX will focus on the profound understanding between the hydrological mesocycle and its interplay with ecosystems, as background for enhancement of the multidimentional catchement sustainability potential WBSRC (water, biodiversity, services for socjety, resilience to climate changes and Culture and Education). This will be achieved by applying the three main principles of Ecohydrology, namely quantification of both hydrological and biological processes and caracterisation of threats, as well as harmonization of grey and green infrastructures to achieve sustainability of ecosystems closely related with water to improve Integrated Water Resource Management (IWRM) on specific areas.

We are witnessing new set of questions arising from the human interactions with nature in the context of complex water management problems. These are questions where hydrology can make important contributions, but they cannot be addressed by hydrology alone, and many core issues lie outside of hydrological science (Blochl et., 2019). In this backdrop, Knowledge Systems need to be developed for assessing past, current, and future changes in the Source-to-Sea interconnection trajectory and for developing governance and response options.
UNESCO's Intergovernmental Hydrological Programme through its initiatives provides the knowledge base to develop a comprehensive scientific understanding of the Source-to-Sea phenomena incorporating the cryosphere, the terrestrial hydrological water cycle, water quality, sediment and erosion processes and deposition in littoral zones, deltas and coasts. It also contributes to global knowledge generation on Source-to-Sea interconnections, particularly related to water resources and as well in proposing options for adaptation to the member states.

IHP-IX will cover a time period when the human race is entering an **unprecedented tech-driven and big-data era** for innovation, numerical models (hydro-informatics) of hydrology for simulation, assessment and forecast, which have been developed and used in the "old" era, should be substantially improved or fundamentally remodeled as spatially and temporally distributed huge data will be obtained and machine learning can be incorporated. Concurrently, **new monitoring techniques including optimal estimation techniques such as data assimilation and sparse modeling will be further developed across scales** by utilizing newly developed instruments, the latest ICT technologies, and big-data. This new generation of modeling is at the nexus of geoinformatics, cyberinfastructure in watersheds and remote measurements for scientific studies and water resources assessment.

Socio-hydrology, a marriage of hydrology with humanities, social sciences and behavioral sciences, is also an emerging research direction which deals with the interaction between human and water systems where they could have dynamic coevolving processes. Societal needs and technology, as externalities to the discipline of hydrology, have stimulated progress in hydrology tremendously (Sivapalan and Blöschl 2017), and will likely do so in the forseable future (Blochl 2019).
Considering the coherence of the scientific process in hydrology, and in order to soliciting ideas for a science agenda for hydrology, international associations of hydrological sciences (IAHS), identified The 23 unsolved problems in hydrology (Blochal et.al., 2019).
The unsolved questions are relevant in the context of IHP-IX strategy as those questions are dealing with hydrology's contribution to resolving societal problems and with understanding the dynamics of water–societal interactions, which ranges from " regional acceleration/ deceleration of the hydrological cycle under climate and environmental change to how can we extract information from available data on human and water systems in order to inform the building process of socio-hydrological models and conceptualisations? , furthermore the unsolved problem also questions what is the role of water in migration, urbanisation and the dynamics of human civilisations, and what are the implications for contemporary water management? Bidirectional / aphidromic coupling of human and water systems is going to be taken into account even in numerical model studies. Research on conflicts will be enhanced. By combining this research direction with the research area on variability and change in the hydrological cycle under global changes in IHP-IX, we will have a better foundation for decision-making in the adaptation to more devastating hydrological disasters, better management of water-energy-food-ecosystems nexus, and better management of water scarcity and transboundary water systems.

Citizen science has fast become an important mechanism for hydrological research. Although the definition is often highly discussed, this method enables the combined effort of scientists and the public to collect and interpret data for research and decision making. Advances in technology and the proliferation of data are enabling easy communication, training and online data visualization and collection. When choosing to research specific water issues using citizen science, and therefore doing it together with the public, there are certain 'side benefits' that provide new opportunities for society, like water awareness and education, ownership, unexpeted insights, and support. From a science perspective, citizen science provides a widening of spatial and temporal data collection possibilities. Many citizen science initiatives already exist, and add to the big data available already in the world. Unfortunately, citizen science data is still not accepted fully due to data quality uncertainty and the unfortunate mis-use of the term for biased activists. There is therefore **a need to research how citizen science data quality can be improved or validated.** Furthermore, there is a need to assist citizens, through enhanced water education programs to ensure scientific methods are used when participating in and applying citizen science. Finally, there is a need to research the possibilities that machine learning and big data processing can give to incorporate citizen science data and monitoring in research and governance.

Innovation and use of technologies

Ever-growing innovation and use of **ICT, and AI**-related technologies in particular, will most assuredly impact efficient and effective use of water resources, timely disaster forecast, groundwater governance, evidence based planning, conflict resolution among the actors and trust building, effective decision support systems, optimize use of resources and time and above all achieving sustainable management of water resources under an integrated water resources management framework., which must be attainned to enssure sustainable water security for future generations and the preservation of the resource and related ecosystems.

What will soon be available and accessible to the public in a similar fashion to that of operational weather forecasting, available and accessible for several decades is **operational hydrological real-time forecasting** (i.e., river discharge forecasting) on global and regional scales. This will change the ways of water resources management and flood disaster mitigation in various parts of the world. Similary, information necessary for the **assessment and disclosure of water-related risks** in the changing world needs to be available and accessible for institions, organizations, businesses, municipalities and governments.

A seemingly unending number of **remotely sensed products**, including products of data assimilation, from the next-generation satellites, including CubeSats (nanosatellites) for Earth observation, are going to provide us much more data with greatly improved quality and hence the potential of more and broader applications than ever before.

The inclusion of **sensors to personal mobile devices** and so-called **"Internet of things" (IoT)** enables us to develop and implement a new generation of observation, data-acquisition and data-distribution, networks globally. Hundreds, thousands or even millions of inexpensive small sensors will be deployed and connected along with personal mobile devices and IoT.

Accurate and adequate monitoring of hydrological systems is still lacking in many parts of the world making it hard to perform sustainable planning and equitable sharing of these limited resources. In recent years, great innovation has been made in the field of Internet of things (IoT), especially in consumer, commercial, infrastructure and military applications. Water monitoring has received limited applications but with very promising outcomes that present immense potentials, yet missing, limited or poor data for environmental monitoring at local, regional and global scales remains a challenge in many parts of the world. Limited or non-existent knowledge and awareness on the potentials of IoT applications in environmental monitoring exists. Further, many key sites that require close monitoring are in very remote places with poor communication and transportation infrastructure making it hard to obtain vital environmental measurements in real-time or near real-time for improved monitoring, planning and disaster prevention. Appropriate tools and platforms for improved data visualization, analysis, understanding and communication for improved monitoring and planning are also still lacking making it hard to get valuable insights of hydrological and water quality processes.

In past decades scientists generally protected their data; today transparency, whether desired or not, has all but replaced privacy including that of scientific data. While original data is still considered to be "proprietary" and falling under the "intellectual property" concept in an academic sense, **open source** decision support systems built on **open software** will play an increasingly key role in the future to managing water resources. Information exchanged on social networking services (SNSs) by citizen scientists can also contribute to water resources management, if effective tools are developed to capture, organize, quality control, and make available such data. There is also an urgent need for the development and appliciation of AI techniques that are able to merge different sources of data obtained from IoT, remote sensing, citizen observatories with models.

Since societal problems related to water are becoming ever more complex, streamlining a community science agenda is more important than ever. There is a need for stronger harmonisation of research efforts and clearer articulation of the community's central research questions.
Social sciences that play an increasingly important role for effective deployment of technology and methods involving "co-innovation" and "co-design" are proving to be an effective and appropriate manner to introduce new technologies in less developed regions and smaller villages. Tools should be developed with a focus on meeting user needs in such a way that encourages citizen science and other social applications that can improve water management. Integration of modern science with **indigenous and local knowledge** will be of great use. IHP-IX role will be to facilitate the resolution of water related societal problems, by enhancing the understanding of the dynamics of water–societal interactions, underpinned by scientific findings and by considering that a sustainable society will deliver equitable solutions to achieve water security.

Focus on institutional and legal barriers to the adoption of ICT tools and related technologies for water resources management is needed. IHP-IX strategy will address inter institutional cooperation at all levels (basin, regional, national and international). In addition, new technologies should be effectively utilized in education, capacity building and awareness raising projects and programs, and strong support should be given to increased education in hydro-informatics – fundamental to using AI and a range of ICTs to better manage water resources.

2. Cross-cutting Water Education in the Fourth Industrial Revolution

It is undeniable that the success of the Agenda 2030 for Sustainable Development, the SDGs and targets, depends on a profound transformation in human values and, consequently, human actions. As such IHP-IX will focus on what is feasible and sustainable in today's world to overcome the water crises and particularly what role education will play in that pursuit. Unsustainable decision-making, a lack of political will, inadequate management, poor conservation of water resources together with population growth and massive unplanned migration are undoubtedly driving the water crisis. Water education will elevate the level of understanding and acceptance that our planet is an integrated system and that the equilibrium of the ecosystems is crucial to long-term water security. Achieving that goal will be realized when society reintegrates itself with nature in ways that embrace a common understanding of the importance and limits of our natural resource base to improving the quality of life.

Education is normally delivered in formal and informal settings. Formal settings include traditional primary, secondary and tertiary education curricula as well as structured life-long learning contexts required to maintain a license or ranking, such as in engineering or medical disciplines, among other objectives. Informal education covers a wide range of training with either precise or general goals and delivery modes, and aimed at all sectors of civil society. Regardless of the context, curricula and delivery mechanism employed, in order for water education to have the greatest impact on improving water management, it must be based on quality science and employ the most relevant technology to ensure the quality of outputs as well as reaching all people. It is therefore incumbent on scientists to help interpret their findings so as to be understandable and useful for educators. The linkage between quality science, credible data and technology and the ability of educators/trainers to communicate such information is fundamental for formal and informal education processes. Without such overlap in understanding, the impact of science on decision-making and policy development and the level of understanding and acceptance by beneficiary communities is severely compromised.

The most efficient way to catalyze this evolution in thinking is through education to all sectors of civil society leading to a greater understanding of the role that water plays in every individual's life. UNESCO has a long history in the field of water education including support to Open Educational Resources (OER) programmes as well as in tertiary education and research to garner new water knowledge. Therefore, a broad water education strategy with a strong scientific basis is a determinant factor to shaping a water conscious future for everybody.

Along with this needed transformation, our society is experiencing a fourth industrial revolution, characterized by the emergence of a new broad range of technologies in fields like biotechnology, big data, drones and artificial intelligence, among others, that will reshape the economy, research and professional practice. Hence, water education must use those technologies in order to help prepare professionals and technicians to make the best management decisions and to better focus needed research and capacity-development activities.

To enable this transformation, IHP-IX is recommending a number of different actions which will, in turn, catalyze other parts of UNESCO to become involved, including:

Implementation of Water Education for Sustainable Development in the official development agendas of Member States and alignment of water education programs with formal curricula and informal programs and goals

Since every Member State has different water issues and priorities, the alignment of water education programs with existing curricula should be sensitive to national contexts and local needs. Countries should endeavor to have formal curricula for primary, secondary and tertiary levels to build a water-knowledgeable society.

Water education, in a formal sense, is a prerequisite to implement the development agenda of countries, as it provides a critical mass of informed citizenry and experts that will translate the developmental needs to water sector-related targets and help develop a strategy and action plan to achieve them. In this regard, there is a need to complement tertiary water education curricula with Technical and Vocational Education and Training (TVET) as well as other efforts aimed at improving the understanding on the part of the general public.

Increasing the number and quality of programs and trainers should also be a high priority. Since human resources and the budgets are limited, a strategy in support of this goal needs to rely on creating multipliers resulting in thousands of formal and informal water educators. There are many ways to acquire water-related knowledge: lifelong learning, training in-field workshops, exchange programs, refresher courses, summer schools, graduate degrees, social media, community story-telling as a form of indigenous knowledge, etc.; thus raising awareness for various audiences (community, decision-makers, and experts).

An example that can easily be replicated, even if on a modest scale in nearly any society is the WAMU-NET initiative. It uses museums as hubs for water knowledge generation and dissemination. Furthermore, UNESCO Chairs and Centers will be able to use the WINS effort to broaden support for water initiatives.

A key challenge is to develop international training and sharing of experiences using e-learning, with contributions from experts globally and reaching water professionals, water technicians, schools and the general public. Tools and mechanisms to overcome this challenge could be in the form of short instruction videos, full courses or even evolve entire programs at M.Sc. and Ph.D. levels, particularly those employing an “open-access” philosophy. There are also numerous experts, teachers, young professionals, and government officials who require on-the-job training related to generating public awareness on water-related topics that will improve their skills and enable them to perform their tasks in a more effective manner. Moreover, while good policy requires informed citizens, good decision-making requires sound science, which in-turn requires knowledgeable experts in a range of natural, technical, medical and social science disciplines. The HLPW supported global platform integrating science and policy and could support the formation of experts.

Examples of specific actions in support of this objective include:

- Enhancing train-the-water trainer education programs as well as specific education programs for women and youth; training programs for teachers in primary and secondary education aimed a level-appropriate information about water. Water-related Centers and Chairs will play a pivotal role in this endeavor.

- Encourage IHP-related programs and projects to develop, monitor and report on their water education efforts and specifically in strengthening reciprocal links between targets 6.1, 6.2 and 6.3 with targets 4.1, 4.5, 4.7 and 4a, as part of a joint effort between water science and education within the 2030 Agenda.

- Continue to support UNESCO efforts to enhance K-12 OER UNESCO science programs, particularly those that include water among the topics to be addressed.

- Expand linkages with UNESCO water-related Centers and Chairs, in providing tailor-made refresher courses for water professionals and technicians as well as in undertaking priority research efforts aligned with the SDGs and IHP-IX priorities.

Understanding the value and difficulty of emotional development in the behavioral transformation towards a more eco-conscious society

The proposed solutions will not be effective if they keep arising from the same worldview that caused the problem. For many people it is impractical to care for others or to care for nature, either because they are unwilling to change their life patterns or because of the daily struggle for survival, the latter the case also found within the increasing numbers of environmental refugees and diaspora. When communities or societies are in turmoil they have difficulty in considering the larger environmental impacts that will affect their long-term quality of life. They are dealing with the immediate needs of survival; their values and what they consider priority is very different from people in a stable society. As a result it is crucial that financial resources as well as other types of social and personal support be found to help fortify the needs of providing education for youth and adults as a basis for confronting the daily struggle of, for example, finding clean water and dealing with sanitation issues. It is therefore crucial to emphasize that water education must embrace self-knowledge practices that will support people to expand their consciousness and be able to adopt better practices towards equilibrium in interacting with the natural world.

It is also important to recognize the contribution of youth and young professionals to improving water management by gaining an understanding of the importance of water in their lives through becoming involved in the development of all types of innovative science programs to ensure that future generations of water leaders are in the making. Therefore, the opinions of young people should actively be sought-out as inputs to decision-making processes related to water, such as management or sanitation.

In order for this to become a reality, it is necessary to create programs that support the development of projects, entrepreneurship and partnerships, as well as research and innovation carried out by young people in the water sector (sanitation, distribution and treatment).

Examples of specific actions in support of this objective include:

- Promote understanding of values-based decision-making as it relates to water governance practices and policies.
- Promote self-knowledge practices that support people in better dealing with their own emotions and expand their consciousness and their respect to all other beings
- Promote and advocate for indigenous water knowledge through documentation and information sharing.
- Water education programs for and by youth should be developed. Youth focused activities can include supporting the implementation of local projects through "water clubs, encouraging mentorship of youth through scouting and other sponsored programs, supporting volunteerism, community service and career development about water as a component of science curricula and/or graduation requirements.

Water Education in support of governance success

A number of different strategies need to be implemented to address the needs and interests of all sectors active within any community. This suite of approaches will provide decision-makers and citizens with the necessary tools for boosting the transition from an economy biased solely on consumption to an economy based on stewardship and conservation. In this way, there will be actions corresponding to the underlying causes of priority problems. Decision makers will therefore have the necessary societal support to design and implement policies that will associate economic success with stewardship of the natural resource base, obviously including water resources.

Examples of specific actions in support of this objective include:

- Cultivate opportunities to integrate citizen-science into water research and education by developing methodologies and protocols into water research and education to enhance its validity and acceptance by the scientific community.
- Develop high-level courses (approaches) to support decision-makers to develop holistic and systemic thinking patterns to be able to understand the chain of impacts of each choice they take.

- Support programs related to building a water-wise citizenry as a component in the development of citizen science as a valid input to water science.

3. Bridging the data-knowledge gap

The openness and accessibility of data are among the main pillars that sustain the advancement of open science. Measurements about hydrological systems provide information about the current state of a basin, the main hydrological unit, which is essential for decision-making and sustainable water resources management. The absence or inaccessibility of data about water quantity, quality, distribution, access, risks, use, etc. does not preclude decision-making, yet leads often to partial, ineffective solutions. Therefore, both sufficient data generation and accessibility need to be ensured and in many cases, improved. This was the main recommendation of the UN Mar del Plata conference in 1977; yet the desired status has not been reached ever since.

Notwithstanding other ongoing successful initiatives, the existing global water data centers mandated by different UN organizations and its coordination mechanism GTN-H (Global Terrestrial Network-Hydrology) for improving cooperation and creating common products should play an essential role and have to be better supported by all Member States.

Water data can come from many sources: manual measurements, real-time continuous sensors, as well as new and innovative sources like remotely sensed information (satellites, drones) or autonomous monitoring buoys. Data generators can be public and private institutions, participatory monitoring (citizen science), and social media. However, the difficulty in collecting and understanding raw data and then applying it to a hydrological system in a decision context is often much more complex than initially contemplated. The gap between data and useful knowledge can only be bridged if it is ensured that data is collected in a manner that it can be replicated by other scientists, understood, interpreted and applied at the scale and level of detail required by policy makers. The challenge of data gathering, sharing, and interpretation becomes more complex when a water resource is transboundary and shared by more than one political jurisdiction, even in the same country.

Therefore, there is a need to go beyond the call of promoting data collection. Countries often require assistance in making evidence-based decisions about water, including management and development of water masterplans or schemes for the integrated use and protection of water resources based on the river basin principle. This concept should include developing national policies based on reliable quantitative and qualitative characteristics of renewable surface and underground water resources (formation, exchange across borders, temporal variability, usage). The scope of these policies determines data required to be collected and in many cases how it shold be organised. Considering that water science cannot exist without data, IHP VIII initiated cooperative programs like IHP-WINS, the International Water Quality Platform, the Global Network on Water and Development Information for Arid Lands (G-Wadi) which harvests knowledge and infomation to support science and decission making. UNESCO programs are also making essential contributions to the data platforms from the UN Water Family like GEMS/Water (UNEP), HWRP (WMO) and their global water data centers (like GPCC, GRDC, GWDC, GGWM and IGRAC for its groundwater data platform). The IHP Secretariat has been strengthening these cooperations in recent years and should continue these efforts in institutional outreach. IHP-IX will continue to support capacity building through the FRIEND, ERB, the World Large Rivers, EauMega, and the international Sediment, Drought, and Disaster Initiatives.

To realize the vision of open science, IHP-IX is promoting the following data-related actions:

Improving the quantity, quality, and validation of water data via scientific Organisations in collaboration with other UN Agencies and stakeholders from the academic and private sectors.

Credible data is the most important basis for water resources management; without which management is severely handicapped. All analysis and modeling efforts are dependent on the quantity, quality, coverage, and accessibility of data. Data quantity should not only be maintained by stopping the current decline trend in ground monitoring points and sampling frequencies, but preferably increased by expanding the coverage and resolution of monitoring networks. Data quality determines the quality of scientific research based on the data. The diversification of data sources allows scientific research to be based on larger and more complete data sets, increasing the confidence of results, and researching optimal data collection strategies. Water data should not be limited to physical parameters, water quantity and qualtity. Water use, and other human interactions with surface and groundwater should be monitored as well. It is thus proposed to promote the exchange of experiences and analytical methodologies along with the provision to free access to data to reduce current and future challenges, especially in transboundary water resources, and to create / strengthen new capacities at local, regional and global levels. Metadata are essential for data validation, therefore, databases should be equipped by metadata.

Enabling data accessibility and visibility, comparable and usable data series, and open-access data

Centralized management of data at an appropriate scale to undertake and complete planning and management process is crucial to develop better decision support systems, improve water governance, advance water education and eventually attain sustainable management of water resources. Availability of accurate and credible data in a format that can be easily accessed and understood is fundamental for the sake of any of these interventions. Therefore, this aspect must be placed on highest priority and its maintenance should be a continuous process.

Global access to data is essentially important., Professionals need to be able to access necessary data for their purposes, including validating the data collected for sake of comparison both scientifically and for understanding how such data can be applied in a policy context. Whether this data is collected using traditional field techniques or using state-of-the-art technology, whether it is local data or data on a larger scale, it all needs to be available.

To facilitate data access, the emphasis should be put on connecting existing web databases, developing data access Application Programming Interfaces (API) and removing obstacles to connectivity (incompatibilities between platforms, business and national security interests).

To make water data more accessible and understandable, platforms and quality assurance protocols should be improved or created, depending on the need.

Besides data collection by traditional means, remote collection, Internet of Things sensors and citizen science must be promoted too. Data from these technologies should be placed on globally accessible portals to alleviate the differences between country resources and mismanagement of transboundary water resources, among other issues.

Data collected by citizen science initiatives all over the world infrequently realize their full potential because of their limited reach and comparability problems. Solving these issues, where applicale, would lead to better science and sound policies, which could include such information. To enable the correct professional interpretation of citizen science data, user-friendly platforms, outreach protocols, and capacity building exercises need to be developed.

Data on the operation of the existing water infrastructure for various activities on water and by water reflecting anthropogenic impacts on the water regime are being collected by public and private companies. These data must be collected in a publicly accessible database, at least on the national level, according to open access policies.

Enhance development and use of scientific research methods to correctly analyze, complete, and interpret the data, resulting in better scientific information.

To correctly analyze, complete, or interpret available data, scientific methods like modeling, forecasting, data assimilation, and data visualization need to be thoroughly understood and practised. Method selection and correct use are essential to interpret the data in a way that is understandable by the broad scientific community. There is thus a need for capacity building for professionals of the water community as they participate in planning future water projects and contributing to water-related global and local, goals including the SDGs.

The UN-Water SDG-6 Synthesis Report suggests the need for understanding more innovative scientific methods to enable the use of data from remote technologies and citizen science. Developing new scientific methods to process data and utilizing cutting-edge technologies from other sectors are also needed to help serve the SDGs and beyond. Artificial intelligence and big-data technologies will play a key role in this process. The programme will use multidisciplinary input from other UNESCO departments to combine different natural and social sciences related to Integrated Water Resources Management (social, economic, environmental) with hydrology to include the current influences on water resources in the Anthropocene.

IHP will work as a catalyst for international, inter-disciplinary cooperation in many aspects of water-related disaster risk reduction in collaboration with global and regional programs, networks and initiatives, including the International Flood Initiative (IFI), the International Drought Initiative (IDI), and the International Consortium on Landslides (ICL). Historical data form the basis for understanding trends and rare (extreme) events. Countries and international organizations should collect, digitize and make available on the web historical data, reports, proceedings, and other documentation.

There is a need to incorporate the changes to the hydrological cycle (such as social influences, climate change or others) in different environmental settings (delta, arid, tropical, SIDS, etc.). Thus, a chain of experimental basins could be managed and researched with the help of the UNESCO Water Family as examples for similar basins all over the world. In these basins, methodologies can be developed and tested, and scientific information can be gathered on sustainable management. The basins will be selected based on existing initiatives like HELP and to the extent possible within UNESCO designated sites, like WHS, Biosphere Reserves and Global Geoparks.

To go beyond the basin scale, water processes at the global scale should be analysed, including trade data on food and other products and commodities using the concept of virtual water.

The last mile: Assist in disseminating and developing new interpretation methods of scientific information into a format usable for water education and policy making

Accessibility and visibility of scientific information are prerequisites for open science. Once data has been processed into scientific information and published in journals, it needs to be shared, enabling citizens, professionals, and scientists to use it to further their work. The accessibility aspect of open science should be enhanced as much as possible to support education and policy making.

Scientific information should be combined with or consider indigenous/local knowledge and widely disseminated in both scientific journals, education sources and other widely consulted media and digital outlets.

Current methods for translating scientific information into information for decision making and policy formulation such as visualization methods, roadmaps providing implications for decision making, scenario development, etc. are in general limited and new ones need to be developped. These methods need to be disseminated (via workshops, meetings, trainings, platforms, etc.) to other professionals and stakeholders at catchment level.

4. Inclusive Water Management under conditions of Global Change

Issues the world is facing concerning water management practices

Freshwater sustains life on earth, is a human right and a social need, and underpins economic development. Healthy rivers, lakes, wetlands, aquifers, and glaciers do not just supply safe drinking water and maintain all ecosystems on the planet; they also support agriculture, hydropower, industry, recreation, flood mitigation and transportation of goods across the globe. Water is the driver for many key sectors and in the end for the economy and will remain a crucial element to sustain a healthy ecosystem which eventually affects the well-being of the world's population. In short, all goods and services depend on water. Although water is considered as the core of sustainable socio-economic development this knowledge is often not considered when managing our water resources. Actually, water management is not considered in an integrated, inclusive manner in other sectors and is usually scattered over many different governmental institutions.

Furthermore, the voices of women, youth, indigenous groups, minorities in society, low-educated inhabitants or migrants are not heard, and unsustainable practices of social inclusion and participation are implemented when managing the resource.

Population growth, human development activities, particularly in large metropoles, productive centers, and agricultural latitudes, but most importantly unsustainable decision making, inadequate management, and poor conservation of water resources, result in increasing scarcity of the resource. Economic and demographic growth impact the availability , quantity and quality of freshwater and require deepening and expansion of the knowledge on and management of water, in an integrated manner that can include all sectors of society. However, there is **a continuous lack when it comes to understanding the complete watershed and water cycle while managing our water resources, especially under the challenging conditions of climate change**. Water is a finite resource and it is only renewable if it is managed sustainably, efficiently and equitably. It could play a key enabling role in strengthening the resilience of socio-economic and environmental systems in the light of rapid and unpredictable changes. Furthermore, transboundary management of these resources is a continuously increasing dilemma, where rivers, watersheds and aquifers do not take country borders into account. Losses in centralized water supply systems due to leakage, infiltration and evaporation losses in agriculture, defects, and low maintenance, all are challenges that need innovative solutions that fit the local context. A one size fits all approach is not applicable as technologies used in one country might not be applicable in the other, due to different climatic conditions, finances, human resources capacities etc. .

We are living in a time of unprecedented risk but also an unparalleled opportunity for the future of our planet. We recognize that the natural systems underpinning life are endangered by what many people consider to be the paramount challenge of our times, climate change and the resulting increase in both the frequency and intensity of extreme weather events as well as ocean level rising.,. At the same time, population growth, urbanization, changes in land use and in lifestyles produce increases in water demand, a drop in agricultural yields, disappearance of forests and polluting the once pristine oceans. Groundwater use, (over)abstraction and pollution are globally increasing, while urbanization is decreasing - groundwater recharge in urban areas, which are continuously expanding. In general, variations on the availability of water resources and of water demand of all sectors are highly expected due to climatic, demographic and economic changes. Rapid global changes can easily lead to increased water scarcity and pollution, as well as a higher vulnerability and exposure to hydrometeorological extreme events. Water pollution is drastically increasing worldwide due to impact of agriculture, industry, urban areas and tourism, with climate change further reducing water quality. Water quality degradation is posing threats to human health and jeopardizing ecosystem services and functions, including causing biodiversity loss. **The impacts of these global changes on how we need to manage our water, are scarcely recognized**. To actively plan, develop, distribute, promote, and manage the optimum of our water resources is therefore not only a wish but also a necessity. Water management will have to continue to adapt to the current and future issues facing the water resources and demands while maintaining good water quality. With the growing uncertainties of global climate change and the long-term impact of management actions, the decision-making will be even more difficult.

Ways of action and focus for IHP IX

The aforementioned challenges that are currently practiced while managing water, can be halted when we work towards changing those paradigms.

Using the backbone of Education, Science Research and Data that flow into this pillar of action, IHP should identify, promote and implement innovative solutions that will support Member States achieving the Sustainable Development Goals set in the for 2030 Agenda, as water provides the basis for enhancing the environment potential and the well-being of society.

Increasing inclusive water management

To tackle the ineffective and inefficient water management practices, IHP should first and foremost work towards enhancing **Participatory Management** practices. Future water management efforts should be implemented through inclusive approaches, ensuring that young minds are considered, that indigenous and local knowledge and wishes are the starting point and that all stakeholders are considered and included into the process. UNESCO-IHP has a very strong venture point here, having one of the biggest intergovernmental platforms related to water, and enabling other network initiatives that bring together institutes, scientists, museums, policy makers, governments and others, to share knowledge and integrate different points of view.

The need for social participation as means to enhance water accountability and responsibility is high, and when properly achieved, can lead to a conscious, inclusive management of the resources.
Gender equality should be enhanced, where the strengthening of women in their abilities and roles for water management can be achieved by acknowledging them, offering space in programs and decision making, and where both men and women get offered equal chances.

Participatory management also includes the enabling of citizen science, user-centered design, youth participation, serious gaming, and participatory modelling in water management. Within such approaches, high consideration should be given to leaving no-one behind. The most vulnerable or marginalized who suffer from lack of access, or who do not organize themselves to participate. This can be achieved by, among others, support institutional guarantees for basic rights, and including the non-usual suspects in programs or workshops.

The global consensus for SDGs also led to the creation of SDG17, which focusses on strengthening the means of implementation and revitalizing the global partnerships for sustainable development. By working together in partnerships, greater and more wide-reaching impacts can be achieved.

Furthermore, exclusive water management practices on the intersectoral level can be battled by increased capacity building on the use of **Integrated Water Resource Management.** Successful management of freshwater resources requires extensive knowledge on demand, resources and capacity, available technology, hydrometeorology, social involvement, water governance and political factors. During management processes, the sustainability of water resources and attached ecosystem services must be the starting point. To ensure this, eco-hydrology, ecosystem services, and environmental flow assessments must be performed. Both on the watershed scale, as well as on the urban scale, water management should focus on the sources and its users. Not just quantity, but also the quality of water will influence the amount of fresh water available for use by humans and ecosystems. And when practiced well, it will also include all stakeholders using the water resources, so that all sectors depending on and influencing the watershed are considered for a balanced use of water between sectors.

The use of the **nexus approach** should be further implemented into daily water management practices. Here, there is still much to learn, which we can be linked to the Science, Research and Innovation part of this strategy. to identify synergies and tradeoffs between interdependent sectors to address the complex global development and security challenges and support the implementation of the SDGs in all scales ranging from watersheds to a global scope. This requires capacity building on fluid communication through the interface between different dimensions of science, domestic and international policy, and its regulatory and institutional frameworks. Water management requires a systemic, multi and inter disciplinary approach.

Sustainability of all sectors using water is achieved when water is managed in an integrated manner that is opposed by the complexity and conflict of interests among water sectors (agricultural, residential, and industrial) or sectors only using and not consuming water (hydropower, navigation, fisheries and of course the environment). Moreover, water institutions in many countries are rooted in a centralized structure with fragmented subsector approaches to water management.
The interrelations in the 2030 Agenda show that SDG 6 cannot be achieved independently of the other goals, yet it has been pointed out that most of the others SDGs (e.g. SDG 1, 2, 4, 5, 8, 10, 11, 12, 13, 15 and 16) need sustainable water management. The synergistic relationships between different SDGs and water are case-specific and should be evaluated to design and implement SWM using a nexus approach.

Enhancing water cycle management

For member states to implement a holistic management of their water resources, considering the complete watershed and water cycle, we need to enhance the use of water cycle management by member states. When applying water cycle management (WCM) methods, one can satisfy both human and environmental objectives in a sustainable manner, to in the end achieve sustainable water security.

For member states to start working together over a whole watershed, **the source-to-sea approach** is a particularly useful method that is still not applied sufficiently. The source-to-sea approach reflects an inclusive water management under conditions of global change in several dimensions. First, water, pollutants and sediments are transported by rivers from the mountains to the coasts and any spatio-temporal change affects the river systems fundamentally. Most pollution in ocean originates from land-based activities, with pollutants and debris (such as plastics and microplastics) transported through rivers and waterways to the seas and coastal areas. In this way, freshwater bodies serve as the means for the transport of pollutants to ocean. Therefore, improving understanding and knowledge on pollutants' fate and transport in freshwater systems underpins water resources management strategies based on the source-to-sea approach, which is critical to not only for the sustainability of freshwater resources but also for healthy oceans. Some rivers don´t even flow to the sea anymore or a sediment transfer reduction leads to river bed and coastal erosion. Glacier and permafrost melting as well as landuse changes affect the hydrology and sediment regime, where only a source-to-sea approach – longitudinal dimension – leads to inclusive and sustainable management. Secondly, we need a lateral inclusion between the river and its floodplain in order to minimize floodrisk, allow groundwater recharge or keep the biodiversity of wetlands. Thirdly, a vertical inclusion between river flow, soil water and groundwater is important, with all related processes. A fourth inclusion is a temporal one, where we need to understand trajectories of change over time e.g. in water, pollutants and sediment flow from source-to-sea. Finally a fifth dimension of inclusion is the upstream – downstream integration of river usages and socioeconomical and ecological consequences with respect to energy (hydropower), transport (navigation) or floodrisk management. IHP should built capacity on the use of this approach and perform fundamental research using existing IHP initiatives with the aim to provide a scientifically sound and practically usable method. IHP will enhance it by helping to create organizations that govern complete transboundary watersheds. Workshop and best practices can be shared between countries, to encourage the use of a source-to-sea approach in order for transboundary water management and address linkages between land, water, delta, estuary, coast, nearshore and ocean ecosystems in support of holistic natural resources management and economic development.

Water can only be managed well when we acknowledge that it is a finite resource. By enhancing and improving **water engineering practices,** member states can succeed to provide clean water and with that water security. Water engineering has until now focused mainly on using grey infrastructure which has had vast consequences for the environment. Focus should be turned in the future not only on grey infrastructure, but to include Nature Based Solutions whenever possible. This not only holds for static structures mostly used for water safety, but also for water and sewage treatment to improve the quality of water. A combination of decentralized engineered and ecosystem based, flexible adaptive systems should be explore and provide a paradigm shift needed.

Local solutions that fit local needs and capacities, that are low maintenance and using sustainable materials are an essential aim. In order to achieve effective water engineering solutions, it is therefore important to build an adequate understanding of the local systems and circumstances.
Non-conventional Water Resources (NCWRs) such as wastewater reuse, desalination and rainwater harvesting provide opportunities to augment water supplies and meet water demands. The most widespread use of NCWRs is using treated wastewater for agricultural irrigation. The safe and

beneficial use of treated and untreated wastewater offers an alternative non-convention water resource, while reducing water pollution and allowing for the recovery of useful by-products such as nutrients and energy. Yet, there is a need to improve knowledge and management practices in order to ensure safe water reuse, in particular with regard to health and environmental risks of pollutants. Desalination provides a constant source of water in countries that face extreme scarcity and have access to the most abundant form of water found in seas and oceans.

To enable sustainable management of demand and availability, and to thus ensure that not only humanity, but also ecology is served in the watershed, better **water conservation** is needed. IHP should therefore focus on enhancing the rationalization and optimization of existing water resources. **Protecting and improving water quantity and quality** is essential for water security and sustainability. Long-term strategies are needed protect water resources from pollution from different sources and restore water quality to a sufficient level for all human uses and ecological needs The principle of “what you do not put in, does not have to be removed”, holds for all waterbodies. Avoiding the decline of water quality is thus better than treatment afterwards. Action to improve and restore water bodies need to be prioritized at all scales. The prevention and control of water pollution also need to be integrated into other sectors’ policies such as agriculture and industry. Emphasis should be given to groundwater, the hidden resource, which due to its nature is not well understood. Information gaps in water quality assessment at the national and global scale need to be filled to allow evidence-based policy making and management priorities. Changing the current situation to reflect this type of thinking and sharing it between the member states should be a key-role for IHP.

Managing Water Resources while recognizing global change

For managing our water resources, not only now, but also in the future, we will need a high understanding, acknowledgement, and inclusion of the influences of global changes on our water management plans, using tools like scenarios development.

To ensure that member states and their experts start responding effectively to these global changes, **awareness** among their inhabitants and experts should be raised to ensure acknowledgement of future changes and propose elements for managing them.

Socio-hydrology is providing an insight on how the human population and its activities influence the water cycle and watershed. IHP should built capacity within the member states on the results of such research, to enable member states to consider the human influence on the watershed in water management plans.

Demographic growth and rapid urbanization issues, urban – rural dynamics and other related issues will be tackled. Understanding the change in water demand in all sectors and in land use and how these can challenge and inclusive IWRM needs to be explored.

The IPCC has been very clear that with a global warming of 1.5 degrees Celsius, mean temperatures, hot extremes, droughts and heavy precipitation will increase, and there is high confidence that the probability of drought and precipitation deficits in some regions will also increase. If global warming is limited to 1.5 degrees Celsius, the impacts on freshwater ecosystems and the retention of their services to humans will be lower. Therefore, we need to both focus on mitigating global warming, as well as on adapting to it and increase resilience. When doing this, risk sensitive areas such as SIDS, semi-arid regions, coastal hinterlands and mountainous areas should be receiving extra attention.

Mitigative water management can be achieved by among others utilizing water’s energy capacity in innovative ways, by for example using tidal changes and small sustainable hydropower dams, decreasing the water use which will decrease energy need for supply and treatment, considering NBS which need less energy and possibly transport of construction material, decrease of bottled water use and transport and so on. This will in the end also add to the implementation of both SDG7 on sustainable energy, as well as on SDG13

Adaptive water management should consider extreme conditions to occur more often and with higher intensities. This does not only mean that one should focus on how to limit the effects of extreme conditions on the populations (flooding, drought mitigation), but also on how to built a resilience framework on these flood and drought events to optimize water management. To enable adaptive water management will in the end also add to the implementation of SDG11.5 on water-related disasters and SDG13.1 to strengthen resilience and adaptive capacity to climate-related hazards.

5. Water Governance based on science for mitigation, adaptation and resilience

Water governance refers to the political, social, economic, legal and administrative systems in place that influence water's use, protection from pollution, and management in general. It determines the equity and efficiency in water resource and services allocation and distribution, and balances water use between socio-economic activities and ecosystems. It includes formulation, establishment and implementation of water policies, with clear and practical standards based on science and water democracy, including water ethics, legislation and institutions, and roles and responsibilities of all stakeholders.

The UN-Water SDG-6 Synthesis Report suggests that adequate or good governance is essential for sustainable water management focusing on a bottom-up framework with multiple stakeholders. Water governance is understood as a cornerstone to enable Member States and the multiple stakeholders in water to adopt and implement decisions based on information and knowledge to build more resilient and peaceful communities and governance structures, without leaving anyone behind, therefore the need to develop and put in place good water governance structures.

Water resources availability and protection of water quality pose an interesting and complex challenge globally due to their hydrological characteristics, scarcity due to global change, uneven distribution and land use changes, in addition to unsustainable decision-making, inadequate management, and poor conservation policies, combined with climate changes and local water culture that are altering the water map. These factors therefore translate into various managerial challenges. Water governance is a long-term activity that calls for water master plans and implementation projects based on science. Good governance thus is a prerequisite in addressing most of the aforementioned challenges, building a successful implementation of SDG 6 of the 2030 Agenda.

One of UNESCO's priorities is to ensure that decisions and actions on water, (surface and groundwater), are made on the basis of scientific, multidisciplinary and accessible information, and this is why we insist on promoting water education and research as the best tools to understand water and manage it.

Water governance requires the ability to understand what happens to the water resource in a basin or aquifer, both in terms of the hydrological cycle (of precipitation, evapotranspiration, infiltration and runoff flows) and where and how the main modifications of ecosystems take place in order to address those hot spots (human settlements, agricultural use, industrial activity, etc.) and to intervene to avoid unwanted modifications or to rehabilitate ecosystems to a suitable state.

Decisions to deal with water challenges require a holistic, coherent and inter-sectoral vision as well as science-based policies in order to address all aspects of water uncertainty. The sound scientific underpinning of water management decisions needs to become common practice globally. Water use, protection, mitigation and adaptation measures are considered to underpin the sustainability of societies. Building resilience to uncertainty and future risks requires a continuous partnership of all stakeholders in member states, working within an enabling legal, scientific, and institutional framework.

Although groundwater governance forms part of overall water governance, the characteristics of groundwater as an 'unseen', largely open-access resource, extremely vulnerable to contamination from many diverse sources, and usually developed and used in an unregulated way (private, unregistereed exploitation is predominant), and the comparatively very slow processes (leading to very large groundwater system reaction times) merit specific attention and governance provisions. Groundwater still lags behind surface water with respect to effective governance and therefore great efforts are still required to close this gap.

Economic development, population growth, urbanization, the evidence of cvariations and climate Change <u>and the further deterioration of the environment</u> have become the main challenge for water governance at different spatial scales and time periods, significantly increasing water-related risks, compromising the availability and the quality of water and, in general, the sustainability of the resource. Inadequate management skill can further compromise the implementation of adequate water governance.

The high increasing rate of urban population and development of megacities and massive migration is a challenge in the achievement of SDG 6, and thus jeopardizes governance. There is a need to develop and implement new paths to achieve sustainable urban water management that needs to go beyond physical engineering and implement IWRM, ensuring conservation of the resource and protection of watersheds, raising awareness for the reduction of water consumption, ensuring compliance with the law, promoting water reuse, managed aquifer recharge, and recycling of stormwater and wastewater, providing circular economy incentives, especially in megacities, which can be achieved with the cooperation of the national governments, local authorities and non-governmental organizations, with well coordinated efforts.

Resource mismanagement, corruption, inappropriate and malfunctioning legal and institutional arrangements, non-convergence between hydrographic boundaries andiadministrative boundaries, bureaucratic inertia, insufficient human capacity[1], and a shortage of funding for investments all undermine the effective governance of water in many places around the world.

An additional important challenge is to define how to use previous work, transparency and participation as a basis for further improving water governance based on science for climate mitigation, adaptation and resilience.

[1] Knowledge, technical [...]

Governance addresses the role of institutions and relationships between organisations and social groups involved in water decision making, both horizontally across sectors and between urban and rural areas, and vertically from local to international levels.

Therefore, governance needs to be adaptive, context-dependent and location-based in order to take into account historical and territorial specificities and challenges. Governance is much broader than government as it also seeks to include the private sector, civil society and the wide range of stakeholders with a stake in water use and management (OECD)[2]

It's necessary to improve better decision-making through public participation that "can ensure that decisions are soundly based on shared knowledge, experiences and scientific evidence, that decisions are influenced by the views and experience of those affected by them, that innovative and creative options are considered and that new arrangements are workable, and acceptable to the public"[3] (EEA, 2015, 12). Understanding and ensuring the role of accountability, transparency and participation all stakeholders, including those vulnerable groups (women, indigenous communities, youth and children, refugees, immigrants, and disabled groups) whose opinions are often sidelined, is core for effective and equitable water governance.

Tackling problems due to the mismanagement of water requires two areas of action: adaptation to global changes and mitigation of environmental degradation. Adaptation measures for a resilient water sector require the participation of multiple actors, political will and a sound scientific framework including strategic, tactical and operational decisions. This can be addressed by supporting knowledge development and dissemination on resilience, which is extremely important for socio-economic development and potential investments. Linking resilience-promoting activities with community livelihoods and encouraging community participation in resilience assessments are indispensable for the spreading and effectiveness of these measures.

The mitigation of environmental degradation should be supported by the enhancement of legal, policy and institutional frameworks for improved water quality and quantity management and the understanding of water-biota interplay for mitigation of intermediate impact (non-point source pollution) from agricultural land and urban stormwater. It is also necessary to develop robust analytical techniques and methodological standards across sectors in support of integrated decision support systems that can be adapted to a variety of environments and political contexts.

Good water governance also requires the promotion of additional research to address the challenges of food security and adaptation to climate change as well as on the recycling and re-use of wastewater, managed aquifer recharge, and to develop affordable technologies for water desalination, by developing research for renewable energy utilization. Improving scientific research, knowledge and data on risk assessment, regulations, and pollution control/attenuation, and linking water quality and quantity with economic approaches; advancing socio-ecological system approaches; and identifying feedback between water and society are some of the good actions to water governance taking into account how to face Climate Change

Climate Governance is essential for Water Governance just as water governance is essential for climate governance. The Intergovernmental Panel on Climate Change (IPCC) has reflected on the need

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[2] OECD (2015), OECD Principles on Water Governance, www.oecd.org/governance/oecd-principles-on- water-governance.htm; OECD (2011), Water Governance in OECD Countries: A Multi-level Approach, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264119284-en.

[3] EEA (2014), Public participation: Contributing to better water management, Experiences from eight case studies across Europe, Luxembourg, https://www.gwp.org/globalassets/global/toolbox/case-studies/asia-and-caucasus/eea-03-2014-public-participation.pdf

to understand this concept from a broader and different perspective that allows addressing solutions to climate change based on the constant changes that are carried out at a scientific technological and social level.

Water Governance should not only incorporate a cooperative framework but should also make use the tool of open access internet-based databases that can enhance cooperation and shed light on water-related conflicts among users and user sectors in any one country, and among countries that share transboundary waters. As local demand for water rises above supply in many regions, the effective governance of available water resources will be key to achieving water security, fairly allocating water resources and settling related disputes.

The value of water and the services that freshwater ecosystems provide in all affected sectors should be stressed. Coherent policies, legal frameworks, planning, partnership adequate financing and justice are fundamental to achieving the SDGs, and thus are required for good governance. This must include ethics[4] creating effective, accountable and transparent institutions, to ensure responsive, inclusive, participatory and representative decision-making, at all levels. The elements of coherence and integration also need to be stressed avoiding the silo approach. A multi-stakeholder platform can work effectively to realize such institutions.

After 28 years of the Dublin principles where experts recognized the critical situation of world water resources and the interdependence of all countries, water hasn't yet reached the highest level of governance. However, there is a growing understanding and recognition that the scope and complexity of water-related challenges extend beyond national and regional boundaries and therefore, cannot be adequately addressed solely by national or regional policies. This is especially true, as widespread water scarcity and lack of access to water supply and sanitation threaten socio-economic development and national security for countries throughout the world.

It is important to strengthen the cooperation and the leadership IHP as an Intergovernmental Programme provides, with an emphasis on transboundary water resources based on principles of water diplomacy, but without neglecting domestic water resources, not only in terms of negotiation and cooperation, but via a concrete mechanism, capable of leading to:

- Management of domestic and transboundary water resources, recognizing asymmetries as well as interdependencies , underlining the need for integrated management of these resources within a solid and just legal framework which will guarantee attaining sustainable water security.
- Joint basin and aquifer-wide approaches for water resources assessment, management, and prevention of water conflicts.
- Provision of diagnostic analyses based on scientific information for both surface and groundwater.
- Advice on appropriate and minimum institutional requirements, mandate/roles, establishment of standardized protocols and strategies; and provision of expertise in mapping, analysis, stakeholder participation, in policy formulation and decision making;
- Advancing work on policy and legal frameworks at domestic and international level;

[4] Managing water effectively entails addressing the complex range of cultural, social, and psychological values embedded in water policies, projects, and investments. Ethics refers to the broad value principles that provide guidance about the proper course of action. The topic of Water Ethics takes on a fundamental importance in dealing with the ethical principles underlying the use and protection of the essential basis of life itself: water.

- Creating binational or multinational groups and international scientific networks capable of sharing and generating knowledge for decision-making in transboundary water management in a fair and ethical manner.

Faced with climatic instability and the effects of demographic and economic growth on the world economy, the global landscape and biodiversity, it is necessary to reverse the degradation of water resources and halt the decline in biodiversity and carbon storage. Water governance should facilitate adaptation, mitigation and resilience processes including, through ecohydrology[5], theregulation of the hydrological and nutrient cycles in ecosystems altered by the human factor. Ultimately, adequate water governance should be a fundamental and solid pillar to guarantee sustainable water security for all.

[5] Ecohydrology, is the integration of hydrology and ecology to make possible the sustainable management of water resources, at the basin scale to improve the potential of the ecosystem and achieve the sustainability of those ecosystems