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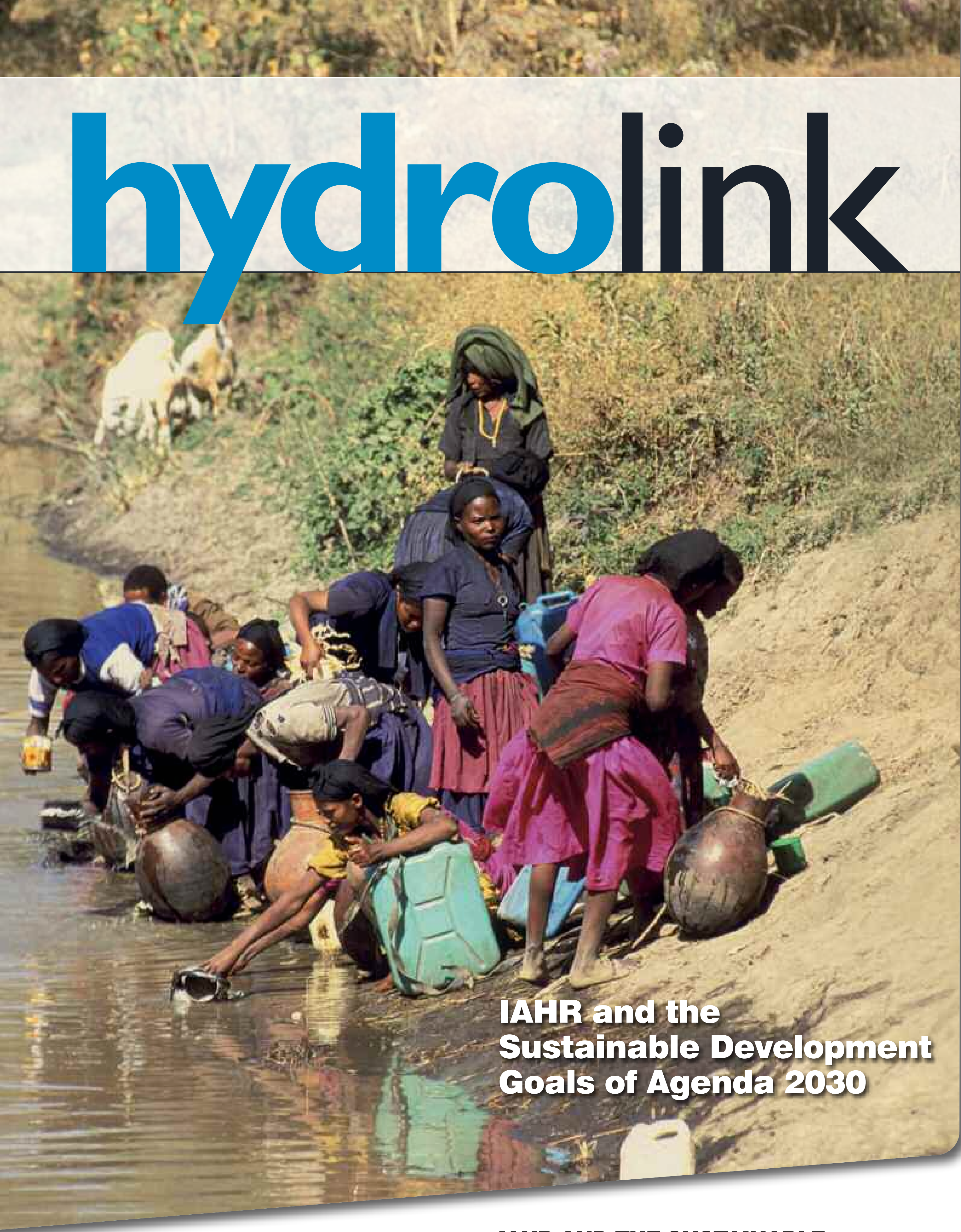

IAHR and the Sustainable Development Goals of Agenda 2030

IAHR AIRH
International Association for Hydro-Environment Engineering and Research

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LOOKING AT WAYS TO EXPAND IAHR'S SUPPORT TO THE GOALS OF AGENDA 2030

EDITORIAL BY ANGELOS N. FINDIKAKIS

Angelos N. Findikakis
Hydrolink Editor

This issue of Hydrolink focuses on the Sustainable Development Goals (SDGs) of Agenda 2030 for Sustainable Development adapted by the United Nations in 2015. It includes an article that provides an overview of how the IAHR technical committees support the SDGs, and several articles that describe in more detail the contribution to the SDGs by some of these committees.

Seeking ways to expand its support to the SDGs, IAHR organized on August 14, 2017 a special Forum on the subject, as part of its 37th biennial Congress in Kuala Lumpur. The Forum included a panel of three invited speakers, Roger Falconer, Professor at Cardiff University and Past President of IAHR, Ms. Sushmita Mandal, Asia Program Manager of the International Water Association (IWA), and Dr. Anton Schleiss, Professor at the Ecole Polytechnique Fédérale de Lausanne, President of the International Commission on Large Dams (ICOLD) and Past Council Member of IAHR. The Forum produced several ideas which are summarized next.

A major theme of the Forum was the need for collaboration between water associations (e.g. IAHR, IWA, ICOLD. ICID, IWRA) to develop a common voice on water-related issues of the SDGs and provide advice to policy makers, development banks, and other organizations. It was noted that unlike the energy sector, which in many countries has a single entity for policy makers to consult on energy matters (e.g. the International Energy Agency), the water sector is fragmented. It was suggested that a first step in the direction of developing such a common voice would be to establish an agreement between the leadership teams of these associations.

At the technical level, IAHR is already working together with IWA through two joint technical committees, and there are more opportunities to expand this collaboration to other areas of importance for the SDGs. Besides focusing a good part of its activities on wastewater treatment, IWA is also working on the human right to have clean water for WASH (water, sanitation, hygiene), water scarcity and water governance issues, subjects that need more attention, especially in many developing countries.

There are also opportunities for collaboration between IAHR and ICOLD in supporting multidisciplinary research and sharing of knowledge contributing to the development and management of dams in a manner consistent with the SDGs. This is especially important in Africa, where substantial activity is under way to plan, design and construct new dams, which in many countries are viewed as essential for economic development and food security.

Among the initiatives that could be undertaken by IAHR in collaboration with other water associations is an effort to educate the general public and raise awareness about limitations in the available water resources in many parts of the world and the need to manage them sustainably. It was suggested that publicizing the water footprint of different products could help highlight the international connections in water use for the production of consumer goods. For this purpose, IAHR could collaborate with the Water Footprint Network. Also, it is worth exploring whether different companies producing consumer goods would be willing to voluntarily include information on the water footprint of their products on its packaging, or in the case of clothing, on its labels. Another way to raise awareness about the water footprint is to post every month on the main IAHR webpage information on the water footprint of a different product. In addition, IAHR could organize special sessions on the water footprint at IAHR Congresses and possibly at other events.

IAHR should make an effort to inform policy makers and the general public about the findings of research and other work reported in its journals, or presented in its congresses and symposia, especially findings that could contribute to the SDGs. This could be accomplished by producing brief summaries of selected papers, to explain in simple language the relevance of this work to the SDGs. These overview summaries could be distributed to policy makers, international development organizations and the general public through the press.

Another theme in the discussions at the Forum was capacity building, emphasizing the need to support the education and training of hydraulic engineers, hydrologists and other practitioners in developing countries working on different aspects of the water related SDGs and especially SDG 6, which addresses drinking water and sanitation, pollution reduction, water use efficiency, water resources management, and the protection and restoration of water-related ecosystems. For this purpose, IAHR could work with other associations to offer workshops and training courses, and develop educational material outlining best practices on selected topics such as monitoring and water reuse. This will be especially important for Africa, parts of which face serious challenges in their effort to achieve the SDGs. IAHR should expand its presence in the continent by increasing its membership, organizing local or regional events and being creative in finding ways to ensure the participation of African delegates in the association's Congress and other major international meetings, who otherwise may not be able to attend because of the lack of financial support from their home countries.

IAHR could also be more active in providing technical advice and reviews to development banks and other organizations funding water projects to ensure that these projects are consistent with the SDGs. It can also contribute to developing guidelines for specific issues, such as guidelines for assessing inter-basin water governance and standardizing the monitoring and quantifying of facts supporting the SDGs.
It was suggested that IAHR should try to establish contacts with those working on the ground to achieve the SDGs, such as different Non-Government Organizations (NGOs) focusing on safe drinking water supply, sanitation, pollution reduction and other water-related issues. IAHR should support them and work with them to identify problems that the hydraulic research community should be paying more attention to. In addition, members of IAHR's Young Professional Network (YPN) could get directly involved in the water-related work of NGO's and groups like Engineers without Borders.

I would like to encourage the readers of Hydrolink to contact us if they have any suggestions on other activities or initiatives that IAHR could undertake in support of the effort to achieve the SDGs by 2030.

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Cover picture: Women fetching water from a dam in Asella, Ethiopia. Source: Alamy Stock Photo

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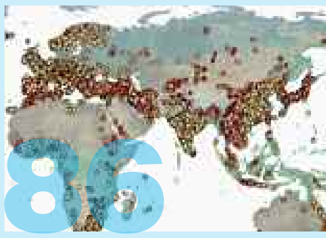


ERRATUM

In the Council Elections candidates article in Issue 2, page 60, where it was written Prof. Vladimir Nikora, National University Singapore, Singapore it should have been Prof. Vladimir Nikora, University of Aberdeen, UK

IAHR AND THE SUSTAINABLE DEVELOPMENT GOALS

BY ANGELOS N. FINDIKAKIS

The International Association for Hydro-Environment Engineering and Research (IAHR), as a worldwide independent organization of researchers and practitioners working on hydraulic engineering projects and environmental problems in a variety of water bodies, is conscious of how the work of its members can contribute to the welfare of people around the globe. For this reason, IAHR is committed to work for the success of Agenda 2030 of the United Nations for Sustainable Development.

To understand how IAHR contributes to efforts to achieve the goals of Agenda 2030, it is instructive to review how these goals are related to several water issues and then examine how the work of the IAHR technical committees supports the effort to reach these goals.

The role of water issues in Agenda 2030

In September 2000 the General Assembly of the United Nations adopted a resolution known as the Millennium Declaration which set several goals aimed at improving the welfare of people around the world within the following 15 years [1]. These goals, termed the Millennium Development Goals (MDGs), covered a broad range of subjects, including significant poverty reduction, improved public health, and ensuring environmental sustainability. Explicit references to water in the Millennium Declaration included the resolution *"to halve the proportion of people who are unable to reach or to afford safe drinking water"* by 2015, and *"to stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies"*. Even though not all the specific targets within the framework of the MDGs were met, the mobilization to reach these goals had a positive impact on many social and environmental problems and contributed to improvements in the lives of billions of people.

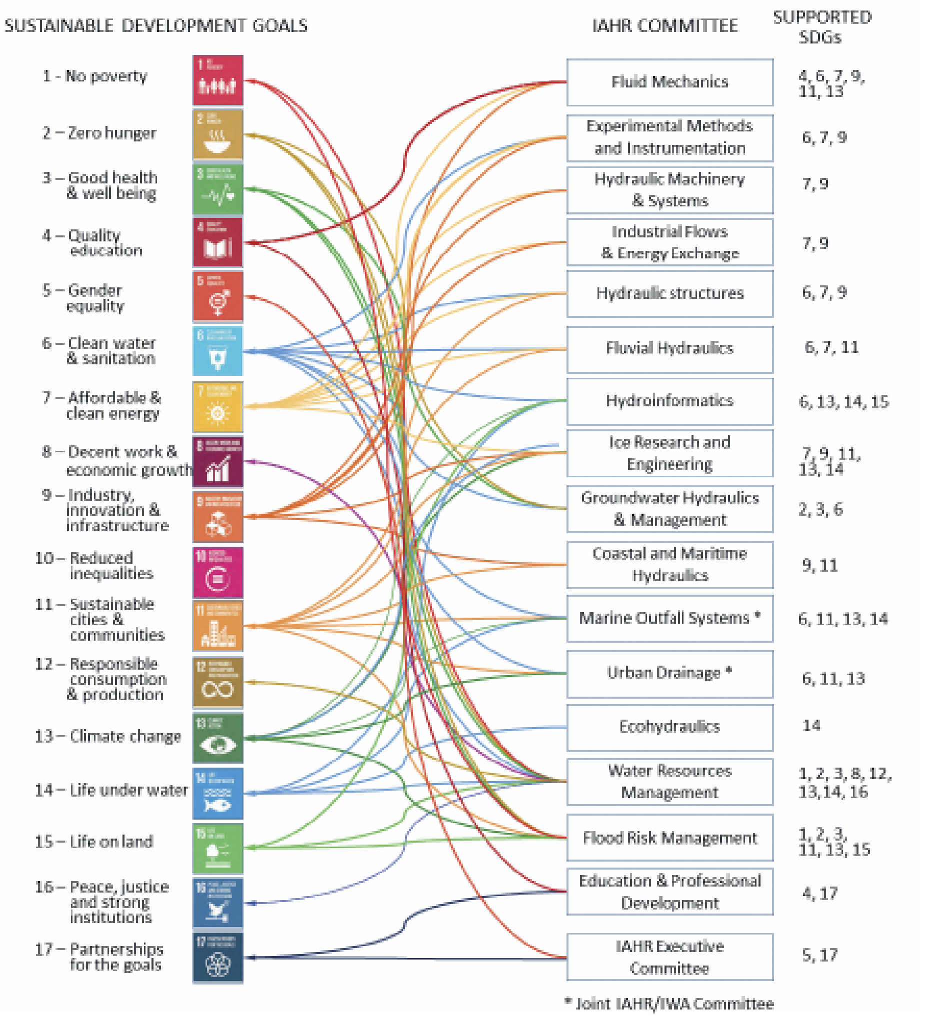
Following the success of the MDGs, the General Assembly of the United Nations adopted a broader and more ambitious action plan for the next 15 years, the Agenda 2030 for Sustainable Development, which included 17 Sustainable Development Goals (SDGs), each of which had several specific targets [2]. A total of 169 targets were set for the 17 SDGs. To monitor progress towards the SDGs and inter-agency and expert group developed 232 indicators designed to provide quantitative assessment of the status of the specific targets of the SDGs [3].

Water is at the center of SDG 6. Its targets for the year 2030 include achieving universal and equitable access to safe and affordable drinking water, sanitation and hygiene for all, improving water quality by reducing pollution, substantially increasing water use efficiency across all sectors and ensuring sustainable withdrawals, implementing integrated water resources management, protecting and restoring water-related ecosystems, expanding international cooperation in water issues and capacity building support to developing countries, and supporting and strengthening the participation of local communities in improving water and sanitation management. UN Water (of which IAHR is a partner) has prepared guidance proposing specific methodologies that can assist national governments in monitoring each of the 11 global indicators under SDG 6 [7].

Besides SDG 6, water and especially its management, has a direct effect on several SDGs and affects indirectly others. As pointed out in another article published earlier in Hydrolink[4], Agenda 2030 includes explicit references to water in SDG 3.3 (end water-borne diseases), SDG 3.9 (reduce the number of deaths and illnesses from water contamination), SDG 11.5 (reduce the economic losses and the number of people affected by water-related disasters), SDG 12.4 (sound management of chemicals and waste to reduce their release in to water, and SDG 15.1 (conservation, restoration and sustainable use of inland freshwater ecosystems). Besides these explicit references to water in different SDGs, there are many other interlinkages between SDG 6 and several other SDGs.

The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) developed a matrix identifying all the direct and indirect relationships between the eight targets of SDG 6 and the individual targets of all other SDGs, and providing the rationale for the characterization of each relationship [6]. The UNESCAP matrix describes a large number of interrelationships between individual targets. As an example, SDG 6, target 5, the implementation of integrated water resources management (IWRM), directly supports and benefits the following SDG targets:

SDG 1, target 1.3 - social protection systems and measures for all
SDG 1, target 1.5 - resilience of the poor and reduction of their exposure and vulnerability to climate-related extreme events
SDG 2, target 2.4 - sustainable food production systems
SDG 6, target 6.6 - protection and restoration of water-related ecosystems
SDG 8, target 8.4 - resource efficiency in consumption and production; decoupling of economic growth from environmental degradation
SDG 9, target 9.1 - reliable, sustainable and resilient infrastructure
SDG 11, target 11.3 - inclusive and sustainable urbanization
SDG 11, target 11.4 - protection and safeguarding of the world's cultural and natural heritage
SDG 12, target 12.2 - sustainable



management and efficient use of natural resources
SDG 13, target 13.1 - resilience and adaptive capacity to climate-related hazards and natural disasters
SDG 13, target 13.2 - integration of climate change measures into national policies, strategies and planning
SDG 14, target 14.1 - reduction of marine pollution
SDG 14, target 14.2 - sustainable management and protection of marine and coastal ecosystems
SDG 15, target 15.1 - conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems
SDG 15, target 15.2 - sustainable management of forests, afforestation and reforestation
SDG 15, target 15.3 - combatting desertification and restoring degraded land and soil
SDG 15, target 15.4 - conservation of mountain ecosystems, including their biodiversity

The UNESCAP matrix also shows that several SDG targets have a direct positive impact on the effort to implement IWRM (SDG target 6.5), including the following targets:

SDG 4, target 4.7 - knowledge and skills needed for sustainable development
SDG 6, target 6.a - international cooperation and capacity-building in water- and sanitation
SDG 6, target 6.b - participation of local communities in improving water and sanitation management
SDG 7, target 7.b - infrastructure and technology for modern and sustainable energy services for all in developing countries
SDG 11, target 11.a - positive economic, social and environmental links between urban, peri-urban and rural areas
SDG 13, target 13.3 - awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
SDG 15, target 15.9 - integration of ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts
SDG 15, target 15.b - financing of sustainable forest management and provide adequate incentives to developing countries for conservation and reforestation
SDG 16, target 16.6 - effective, accountable and transparent institutions at all levels
SDG 16, target 16.7 - responsive, inclusive, participatory and representative decision-making at all levels
SDG 17, target 17.4 - long-term debt sustainability in developing countries
SDG 17, target 17.5 - investment promotion regimes for least developed countries
SDG 17, target 17.7 - development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries
SDG 17, target 17.8 - science, technology and innovation capacity-building for least developed countries

In addition to these direct relationships, the UNESCAP matrix identifies several indirect relationships between SDG 6.5 and other SDG targets.

Another recent study identified interlinkages between the SDG targets and used data from nine Asian countries on the proposed indicators for 108 out of the 169 targets to quantify the strength of the relationship between individual targets. The analysis of these data helped distinguish between positive and negative linkages, i.e. those where achieving a target contributes to or conflicts with the achievement of another target [5]. An online tool for the visualization of the interlinkages identified in this study is available at https://sdginterlinkages.iges.jp/visualisationtool.html. It is noted that some of the linkages that the study concluded that indicate negative relationships are counterintuitive, which suggests that the indicators used to describe the status of the targets involved may not capture the true essence of these targets.

The work of the IAHR Technical Committees in support of the SDGs

IAHR promotes and facilitates the advancement and exchange of knowledge through 17 Technical Committees (TCs) supported by its Council, Executive Committee and Secretariat. Key activities are specialty symposia, conferences and congresses, the publication of five journals, one magazine, and monographs on selected topics. Each of the TCs focuses on a sub-discipline of hydro-environment engineering and research. Because of the important role of water in many SDGs the work of each TC supports several SDGs. Figure 1 shows the relationship between the work of the IAHR TCs and the 17 SDGs.

The **Fluid Mechanics Committee** focuses on fundamental and applied environmental fluid mechanics, leading to better understanding of fluid processes and their interaction with the natural and human-made environment. This contributes to the solution of problems related to several SDGs including clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), industry and infrastructure (SDG 9), sustainable cities and communities (SDG 11), climate change (SDG 13) and quality education (SDG 4). More on the work of this committee can be found in the article by Harindra Joseph Fernando included in this issue.

The **Experimental Methods and Instrumentation** Committee works to promote new experimental methods, instruments, measurement techniques, and data analysis routines for both laboratory and field hydro-environment studies. Remote and in-situ measurement techniques, including real-time data acquisition, provide the means to monitor the condition of different water bodies to ensure that it is safe to use them and develop proper management strategies (SDG 6), but also improve and monitor the performance of hydropower (SDG 7) and other water infrastructure including those that serve cities and other communities (SDG 9). The use experimental methods and different types of instrumentation contributes also to SDGs 2, 12, 13, 14. An article by Alessio Radice, Rui Aleixo and Rui Ferreira that discusses the work of this committee will be published in the next issue of Hydrolink.

The Committee on **Hydraulic Machinery and Systems** deals with the advancement of technology associated with steady and unsteady flow characteristics in hydraulic machinery and conduit systems connected to the machinery. This work helps improve the performance of hydraulic machinery and systems, contributing this way to more clean hydroelectric energy production (SDG 7) and more efficient energy use in several industries (SDG 9).

The **Industrial Flows and Energy Exchange** Committee works to advance the knowledge of fluid behavior and thermal transfer in industrial facilities, and especially in power generation stations to ensure their economical and safe operation, contributing this way to SDGs 7 and 9.

The **Hydraulic Structures Committee** facilitates the sharing of new knowledge between researchers and practitioners related to the planning, designing, construction, and life cycle maintenance of hydraulic structures. Hydraulic structures play an important role in water supply, energy production and general hydraulic infrastructure. Current research is related to dam rehabilitation under changing hydrological conditions and the sustainable design of eco-friendly structures among other topics. Given these focuses, the work of this committee contributes to SDGs 6, 7 and 9.

The research agenda of the **Fluvial Hydraulics** Committee includes topics related to flow and transport processes in rivers, risk analysis and mitigation in fluvial systems. The work of the committee contributes to the protection and restoration of water-related ecosystems (SDG 6), sustainable management and efficient use of natural resources (SDG 12), resilience and adaptive capacity to climate-related hazards and natural disasters (SDG 13) and conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems (SDG 15)

The IAHR/IWA Joint Committee on **Hydroinformatics** focuses on the synergy, between information and communications technologies and water science and technologies with the objective of satisfying social requirements. As among other topics, Hydroinformatics deals with the interpretation and availability of knowledge and results for non-specialist stakeholders, its work relates to the topics of several SDGs, including water supply and water resources management (SDG 6), climate change (SDG 13), aquatic ecosystems (SDG 14) and terrestrial ecosystems dependent on water (SDG 15).

The efforts of the **Ice Research and Engineering** Committee are mainly directed toward advancing the understanding of ice and how best to manage it, and includes research topics such as the formation and evolution of

Special session on the SDGs during the 37th IAHR Congress in Kuala Lumpur various types of ice, the movement and accumulation of ice in surface waters and around structures (SDGs 7, 9, 11), and the effects of ice on the environment and ecology, in particular life under ice (SDG 14). This work can contribute to the development of climate change mitigation measures in parts of the world (SDG 13). More on the work of this committee can be found in the article by Matti Leppäranta included in this issue.

The scope of the **Groundwater Hydraulics and Management** Committee includes a broad range of subjects including the monitoring and management of aquifers, groundwater remediation, and coupled flow, transport and bio-geochemical processes. Because of the wide use of groundwater for irrigation and domestic and industrial water supply, the work of this committee is important for food production (SDG 2), public health (SDG 3), water, and sanitation (SDG 6). More on the work of this committee can be found in the article by Zhongbo Yu and Alberto Guadagnini included in this issue.

The **Coastal and Maritime Hydraulics** Committee covers all aspects of maritime, coastal and estuarine problems including coastal morphology, waves, tides, currents, sedimentation, and pollution. Its work contributes to the design of resilient maritime infrastructure (SDG 9) and the sustainability of coastal cities and communities (SDG 11).

The work of the IAHR/IWA Joint Committee on **Marine Outfall Systems** and its contribution to the SDGs is discussed in detail in the article by Phil Roberts, Jim Bradley, Robin Morelissen, Daniel Botelho included in this issue. Outfalls play a role in all targets of SDG 6, but also in energy production (SDG 7), sustainable cities (SDG 11), climate change (SDG 13), and sustainable use of the oceans, seas and marine resources (SDG 14).

The work of the IAHR/IWA Joint Committee on **Urban Drainage** is mainly carried out by its nine working groups (Data & Models, Real Time Control; Sewer Processes; Source Control; Urban Rainfall; Cold Climate; Water Sensitive Urban Design; Urban Streams; Stormwater Harvesting). These groups develop, provide and apply tools and concepts that improve urban stormwater and wastewater drainage, thus contributing to better access to sanitation (SDG 6, target 2), to improved water quality by reducing pollution (SDG 6, target 6.3), to the restoration of water-related ecosystems (SDG 6, target 6.6), to international cooperation, capacity building, and the strengthening of local community participation (SDG 6, targets 6.a and 6.b). Their work also helps reduce the effects of water-related disasters leafing to more sustainable cities and communities (SDG 11). The activities of most of the working groups of the Joint Committee are closely related to climate change (SDG 13).

The **Ecohydraulics** Committee works on different problems of aquatic ecosystems involving hydraulics, such as the hydraulic modelling of aquatic ecosystems, fish passes, and eutrophication in lakes and reservoirs. Its work is important for ensuring the health of aquatic ecosystems (SDG 14).

The members of the **Water Resources Management** Committee are involved in interdisciplinary research, management under increasing uncertainty, conflict resolution in water management, and non-structural water management. As discussed earlier, integrated water resources management, which is part of the scope of this Committee, has a direct impact on specific targets of several SDGs, including SDG 1, 2, 6, 8, 9, 11, 13, 14 and 15. More on the work of this committee can be found in the article by Carlos Galvão, Young-Oh Kim, Elpida Kolokytha, Arpita Mondal, Pradeep Mujumdar, Daisuke Nohara, Satoru Oishi, Roberto Ranzi, and Ramesh Teegavarapu included in this issue.

The research agenda of the **Flood Risk Management** Committee includes a range of issues related to floods, such as damage prevention, protection from flooding through both structural and non-structural measures, preparedness, emergency response, recovery and resiliency of communities and ecological systems. This Committee is integrating hydraulic processes with many other areas involved in defining risk and vulnerability to flooding, helping reduce vulnerability of the poor to climate-related extreme events such as flooding (SDG 1, target 5), and supporting sustainable food production systems (SDG 2, target 4) and the goal of achieving a land degradation-neutral world (SDG 15, target 3). Considering flood risks is critical for the sustainability of many cities and communities (SDG 11) and the health and safety of their people (SDG 3), and should be assessed in the context of climate change (SDG 13).

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The Committee on **Education and Professional Development** works to enhance knowledge sharing through technology transfer (SDG 17). Its activities include the IAHR Media Library which contributes to SDG 4, IAHR's Young Professionals Networks and online collaboration with HydroWeb. More on the work of this committee can be found in the article by Michael Tritthart included in this issue.

Finally, the IAHR Executive Committee develops partnerships in support of the goals (SDG 17) through collaboration with other sister water associations (e.g. IWA, IAHS, IWRA, ICOLD) and involvement in international programs (e.g. UNESCO, WMO, IDNDR, GWP, ICSU). It also works to increase the representation of women in the leadership of the association (SDG 5).

Closing remarks

The intent of this article has been to raise awareness about the relevance of the work of IAHR to sustainable development as defined in Agenda 2030. It is important to recognize that academic researchers and practicing engineers, who are members of the Association, do not work in isolation from society. They care deeply for the well-being of humanity and all life on the planet and try through their work on different water-related issues to contribute to this end. ■

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SUBMARINE OUTFALLS AS PART OF THE SOLUTION TO ACHIEVE SDGs

BY PHILIP ROBERTS , JAMES BRADLEY, ROBIN MORELISSEN & DANIEL A. BOTELHO

Central to the task of achieving Sustainable Development Goals (SDGs) is the provision of potable water, sanitation, and economic development to the poorest. According to the United Nations, half of the world's population lives within 60 km of the sea and three-quarters of all large cities are located on the coast. Many cities in developing countries lack adequate sanitation. Sewage may run untreated in the streets into lakes or rivers, contaminating local water supplies. The rivers ultimately flow to the ocean, causing pollution as they enter the local coastal environment. Even in cases where wastewater is collected it is often discharged right at the shoreline resulting in contamination and potential health risks to bathers.

According to the World Health Organization (WHO), even advanced treatment does not mitigate this health risk. Inevitably, drinking water production, collection of domestic and industrial effluent, as well as increased demand for energy will result from efforts to reach SDGs and will lead to increased pressure on marine ecosystems, as much of the produced effluent will be discharged in the ocean. In this regard, submarine outfalls will form an essential part of a sustainable and environmentally sensitive wastewater management strategy for coastal regions.

Before discussing how marine outfalls can assist in reaching SDGs, it is of benefit to define outfall systems, as many readers may be unfamiliar with their characteristics and purpose. Put simply, an outfall system is an engineering structure designed to convey domestic and/or industrial effluent into ambient waters as a means of reducing the impact of (treated or untreated) anthropogenic waste to acceptable levels. Outfalls, however, do not work in isolation and need to be seen in the context of a broader treatment system quite often necessitating considerable capital investment. For example, domestic effluent requires a sewerage system for wastewater collection and conveyance to a treatment plant, and a means of ultimate discharge in receiving waters. For relatively large discharges in a coastal setting, this means of discharge commonly consists of an outfall. More specifically, the outfall comprises a pipeline or tunnel, or combination of the two, which terminates in a diffuser (Figure 1). Outfalls typically range from 1 to 4 km long and discharge into waters 20 to 70 m deep, although they may be longer or shorter if the seabed slope is unusually flat or steep.

Because they convey the effluent to the ocean, outfalls are frequently (and erroneously) perceived as the source of pollution. However, extensive experience around the world has shown that disposing of properly treated wastewater through well-designed ocean outfalls is an economical and reliable strategy for wastewater disposal with acceptable environmental effects [1].

Outfalls and SDGs

Given the definition and aspects of outfalls provided above, a discussion of how outfalls can support achievement of SDGs is provided below.

Goal 6.1 Universal and equitable access to safe and affordable drinking water for all

Marine outfalls for wastewater discharge remove the need for discharge/disposal into inland waters and/or land application where there is the possibility of water supply contamination. Marine outfall systems therefore play an important role in protecting freshwater systems and are crucial to meeting this goal. Seawater

Figure 1. Underwater Picture of the Alkimos Sewerage Outfall in Perth, Western Australia. In detail, one of the diffuser ports in operation. Photo courtesy of BMT Oceanica

desalination and water reclamation also rely on outfalls for discharge of the return brine effluent. Effective outfalls are crucial components of these water supply options.

Goal 6.2 Access to adequate and equitable sanitation and hygiene for all

Effective sanitation requires considerable capital investment, and advanced treatment requires expertise that may be beyond the capabilities and resources of developing countries. Therefore, it is important that the level of treatment and the disposal method be chosen appropriately and together to ensure efficient allocation of resources with a technology that is sustainable, reliable, and protects the receiving water environment and human health.

Noting the above, the adoption of an effective outfall can often be achieved by relinquishing onerous advanced wastewater treatment and be implemented at lower cost than higher technology and nutrient removal and disinfection before discharging to inland waters and/or land. This is especially the case when considering the ongoing operating costs of advanced treatment plants, sludge management, and expertise required for plant operation.

An effective outfall is one that discharges far from shore into relatively deep water that results in high dilution, thus reducing concentrations of contaminants to safe levels with minimal effects to primary and secondary recreation, fisheries, and the local ecosystem. In practice, outfalls separate people and fragile ecosystems from effluents. The disposal options are sometimes posed as a dichotomy between advanced treatment or an outfall, but in fact an outfall will still be needed even with advanced treatment. As financial availability for capital expenditure are quite often restricted, it is often desirable to ensure the construction of an outfall as early as possible in the overall implementation of sanitation planning.

Current technological advancements allow outfalls to be implemented relatively quickly following a proper design process, and with lower costs than other solutions. New methods of outfall construction, especially the increasing use of HDPE (high density polyethylene) pipe and prefabricated treatment units means that systems can be readily put together in developing countries at reasonable cost. An example of such systems ready for installation is the Mar del Plata sewerage outfall in Argentina (Figure 2). Furthermore, outfalls, when properly designed and installed, require little maintenance over their lifetime. In this context, outfalls are likely to be more practical and affordable than higher cost solutions such as advanced treatment.

Outfalls are not only required for effective domestic sewage discharge. Noting that food production and economic development are essential requirements to achieving SDGs, adequacy and cost efficiency in terms of equitability are also important considerations for many industrial wastewater discharges. In this respect, high organic strength (Biological and Chemical Oxygen Demand) wastes from industries such as food and meat processing, are more amenable to discharge into the marine environment, where the assimilative capacity is much greater than for inland waters. Appropriate outfall design can efficiently guarantee hygienic conditions for coastal populations.

Figure 2. HDPE pipes comprising the manifold of the Mar del Plata (Argentina) sewerage outfall ready for installation. This photo was taken during a technical visit at the International Symposium on Outfall Systems in Mar del Plata Argentina, 2011

Goal 6.3 Improve water quality by reducing pollution, halving the proportion of untreated wastewater and sustainably increasing recycling and safe reuse

Outfall systems provide flexibility in terms of reducing pollution and facilitating increased recycling and safe water reuse. Specific mechanisms and infrastructure arrangements that can be used to facilitate these objectives include:

- Appropriate control of industrial wastes at their source that adopt cleaner technologies and recycling of pre-treated wastewater schemes
- Separate collection, conveyance and treatment before combined discharge through an outfall, thereby facilitating recycling and reuse of one or the other wastewater streams. For example, combination of fresh and saline (i.e. brine) effluent can be used for energy recovery as a means of reducing energy requirements for desalination.
- Use of multi-port outfall diffusers that can be operated in various modes to accommodate variable discharge flow rates that may result from recycling and reuse of variable amounts of the treated wastewater.

Goal 6.4 Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals of freshwater to address water scarcity

Measures can be imposed and adopted in voluntary ways in any reticulated wastewater collection system and also in on-site wastewater systems to increase water use efficiency.
In the urban/domestic systems measures of water conservation and demand management, such as universal water supply metering and associated cost charging, water efficient plumbing and other water saving devices, water pressure management in the water supply network, consumer education and stewardship all available to achieve various degrees of water efficiency.

In industrial wastewater management appropriate controls at the industry promise cleaner technology with or without water reuse and pretreatment of pollutants in the wastewater, all forming parts of water efficiency measures.
The adoption of such water efficiency measures

can result in significant cost and infrastructure efficiencies, reducing the requirements for wastewater outfall systems. These include:

- The collection, conveyance, treatment and outfall infrastructure does not need to be as large as wastewater volumes are reduced thereby reducing capital and ongoing operating costs
- Pre-treatment of industrial wastes at the source (at the industrial premises or at joint industry pre-treatment plants) reduces the pollutants requiring treatment in the outfall treatment plant, thereby reducing treatment infrastructure needs and ongoing operation costs
- With less industrial wastewater pollution outfall systems may be able to discharge nearer to the shoreline and accordingly be shorter and at lower cost.

Goal 6.5 Implement integrated water resources management at all levels

Outfall systems provide a wide range of integrated water resource management needs. These for example include procedures for reduction of domestic and industrial wastewater at the source, flexibility and modular development of treatment facilities, and beneficial reuse of treated wastewater and other residuals, particularly sludges and biosolids. A further key approach in terms of integration is the efficient use of the assimilative capacity of the receiving marine environment to ensure that a long term sustainable solution is attained.

Goal 6.6 Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

Marine outfall systems for treated wastewater discharges obviously provide a high degree of protection of fresh water ecosystems by removing the discharges from rivers, lakes, wetlands, aquifers or land areas where contamination could occur.

If treated wastewater discharges are diverted from inland waters, aquifers, wetlands, and land to the marine environment through a marine outfall, this would result in some restoration (depending on the impacts of the former discharge) of the freshwater, aquifer, wetlands and land into or onto which the discharge was previously made.

Goal 6.6.a Expand international cooperation and capacity-building support of development countries in water and sanitation related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

The sharing of outfall case histories, including investigations, design, construction and operating experience can expand international co-operation and capacity building and are all vital planks in advancing the sustainable development goals for water that are included in the United Nations 2030 Agenda. The existence and activities of the IAHR-IWA Joint Committee on Outfall Systems play an important role in this respect. The Committee's activities, including the regular Outfall Symposia, provide a sound vehicle that covers many of the sustainable water management topics covered in the above goals.

Goal 6.6.b Support and strengthen the participation of local communities in improving water and sanitation management

One of the IWA's Joint Committee on Marine Outfall Systems initiatives is to develop activities that promote local communities who are closely involved in outfall system projects being planned or already functioning in their locales. Local communities play an important role in providing knowledge of their local marine water body and other environmental factors to those designing outfalls, outfall owners, and regulatory authorities. Local groups can also be closely involved in the ongoing performance monitoring of outfalls.

In order to facilitate such local involvement it is not uncommon in some countries, such as New Zealand, for the regulatory authorities to include conditions on the outfall permits that require the outfall owners and operators to regularly involve local communities. Such involvement can include the establishment of local liaison and monitoring groups.

These local groups can also have ongoing involvement in assessing the outfall systems' monitoring results, of input into (any) future outfall system and treatment upgrades, and in assessing the appropriateness and updating the monitoring and reporting procedures. The latter activity is important as advances in technology and understanding of the marine environment continue and it is appropriate to adopt technologies and monitoring procedures that ensure long term sustainable approaches.

Goal 7 Energy (affordable, reliable, sustainable and clean energy)

Outfall systems, particularly those that do not require advanced wastewater treatment often result in lower overall energy usage. Accordingly, they can be more affordable, reliable and sustainable, particularly if the energy comes from clean renewable sources.

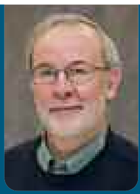
Further, substitution of coal-fired by less carbon-intensive gas-fired thermal power plants are likely to be an important step in the transition to cleaner energy production. The use of outfalls will still be required to properly discharge cooling water to acceptable levels of impact in the receiving environments (both freshwater and marine).

Goal 11 - Cities – (safe, resilient and sustainable)

The maintenance of safe, resilient and sustainable cities will be bound by water security, economic activity and energy requirements.

The establishment of Industrial Coastal Cities should be carefully considered by both developed and developing nations noting that the ocean is a vital transport route for manufactured products, has a much larger pollution-absorbing capacity compared to inland waters, and is often suited to both water and energy production. Thus, it is not unrealistic to link these industrial hubs to potential wealth creation and economic health of nearby urban populations.

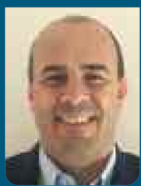
Whilst the creation of these Industrial Cities is intended to optimize land use, there is a potential for the release of multiple marine discharges within close proximity to each other, which may lead to unintended environmental outcomes. Outfalls can help mitigating these unintended environmental impacts by combining the discharge of different wastewater streams to a specific area (e.g. an area that has been identified as having low ecological risk or possessing suitable mixing characteristics). It is recognized that the implementation of such resilient Industrial Cities would face many challenges (e.g. careful planning from project conception, regulatory oversight, clean and transparent information sharing, stakeholder engagement and coordination, etc.). However, identifying the design and operation of outfalls as a means of conciliating these competing interests can be used as an opportunity for a more sustainable implementation of Industrial Cities.



Philip Roberts **is Professor Emeritus of Civil and Environmental Engineering at the Georgia Institute of Technology. His professional interests are in environmental fluid mechanics, particularly its application to the engineering design of water intakes and ocean outfalls for disposal of wastewaters and desalination brine, and density-stratified flows in lakes, estuaries, and coastal waters. He is an authority on the fluid mechanics of outfall diffuser mixing and the development and application of mathematical models of wastewater fate and transport. He has extensive international experience in marine wastewater disposal including the design of ocean outfalls, review of disposal schemes, numerical modeling, and the design and analysis of oceanographic field study programs. Phil is a Past-Chair of the Joint IAHR-IWA Leadership Committee on Marine Outfall Systems.**

James (Jim) Bradley**, Senior Principal at Stantec, New Zealand, has a long distinguished 47 year professional career in the fields of civil, environment and public health engineering in New Zealand, particularly active in serving local authority clients in the three waters sector specialising in wastewater management. Jim has given over 80 national and international papers and presentations, and has participated in a number of national and international advisory groups, technical committees, and industry associate boards. Jim is a Distinguished Fellow of the Institute of Professional Engineers, a Diplomat of the American Academy of Environmental Engineers, and the inaugural winner of the William Pickering Award for Engineering Leadership at the New Zealand Engineering Excellence Award. Jim is also a Member of the Joint IAHR-IWA Leadership Committee on Marine Outfall Systems.**

Robin Morelissen **– Vice Chair - Joint IAHR-IWA Leadership Committee on Marine Outfall Systems, has over 15 years experience in multi-scale numerical modelling of coastal hydrodynamics, dredge plumes and outfalls and is working at Deltares, The Netherlands. His research focuses on the coupling of near field and far field models used in recirculation studies for (seawater) intakes and outfalls and dredge plume studies and on advanced modelling techniques used in engineering practice. Mr Morelissen had a key role as a project manager in (multi-disciplinary) projects concerning studies for new reclamations, flushing studies, dredging (sediment dispersion) impact studies and recirculation studies. Within Deltares, Mr Morelissen also works on new business development and innovation focusing on collaborative innovation. Furthermore, Mr Morelissen is currently Vice Chair of the IAHR/IWA Marine Outfall Committee.**



Daniel A. Botelho **– Chair - Joint IAHR-IWA Leadership Committee on Marine Outfall Systems, is the Principal Engineer at the Catchments and Receiving Environments at BMT WBM in Brisbane, Australia. His expertise lies in the understanding of hydrodynamic processes and how they drive the ecology and water quality of freshwater and marine environments. Adequate and sustainable use of marine outfalls for effluent discharges is one of his main technical pursuits. Of particular relevance, Dr. Botelho has developed advanced numerical tools to support reliable assessments of the impacts of existing and proposed outfall systems. Over the last 6 years, Dr. Botelho has actively contributed to the activities of the Joint IAHR-IWA Leadership Committee on Marine Outfall Systems.**

Additionally, resilient cities require alternative water sources such as desalination and water reclamation. The resulting return brine effluent will require disposal through an efficiently designed outfall. Recent technological developments such as pressure retarded osmosis (PRO) and reverse electrodialysis (RED) are being investigated to aid in energy recovery. While the adoption of these new technologies would contribute to the resilience and sustainability of coastal cities, changes in physico-chemical characteristics of the brine stream will demand more flexibility in outfall designs.

Goal 13 Climate change

Appropriately sized outfall systems can accommodate the results of climate change that may lead to prolonged wet periods and high intensity rain that may partially enter the wastewater systems. As mentioned previously, water security will rely more and more on desalination, as droughts are expected to last longer and the world's population is expected to grow. Properly designed outfalls will be needed to effectively dispose the brine resulting from water desalination.

An efficient outfall can obviate the need for advanced wastewater treatment that can be a significant source of greenhouse gases such as methane.

Goal 14 Oceans (conserve and sustainably use the oceans, seas and marine resources)

Suitably located outfall discharges, with the appropriate level of treatment, can achieve long-term sustainable solutions for domestic and industrial wastewater discharges. The matching of the receiving environment's assimilative capacity to the quantity and quality of the discharges is key to the achievement of such sustainable solutions. It is imperative that siting and design of outfalls are undertaken within the broader context of coastal zone and ocean management so that human recreation, fisheries, and ecosystem health are preserved. Inherently, the design of an efficient ocean outfall is a multi-disciplinary endeavor requiring expertise in oceanography, mathematical modeling to predict the fate and transport of wastewater, water quality and water microbiology, hydraulic engineering, coastal engineering, geotechnical engineering, and environmental engineering. Integration of these disciplines is one of the principal remits of the Committee on Marine outfall Systems.

Proposed Actions – Guiding principles for development of sustainable outfall systems

Noting the above, submarine outfall systems have an important role in helping the achievement of SDG's. It is clear that technology advancement, stakeholder engagement, and a multidisciplinary approach will be pivotal for effective implementation of outfalls within the context of SDGs. With this in mind the Leadership of the Committee on Marine Outfall Systems promotes the adoption of a few guiding principles for the design and implementation of outfalls.

For developing countries that lack clean drinking water, one of the challenges is to separate the wastewater streams from the water sources. When the wastewater and drinking water source mix, this could seriously impact the health of the population or animals (e.g. cattle) in that region. It is therefore essential to develop infrastructure that can separate wastewater from drinking water sources.

Sustainable development ideas can be implemented in the design of such infrastructure. The design philosophy starts from the existing situation and the various functions it serves, such as residential functions, agriculture, industry, etc. By understanding the needs of these existing functions, as well as the problems they face, infrastructure design options could be developed that not only mitigate the negative effects that wastewater could have if not properly handled, but at the same time create opportunities for the existing functions. Furthermore, since in developing countries, resources to develop such infrastructure are typically scarce, a wise combination of functions could lead to a more sustainable design for the overall water infrastructure. This provides interesting opportunities to minimise outfall impacts with opportunities for innovative and sustainable designs.

The following design steps, adopted from Vriend et al. [2], could be applied to the sewage and outfall system design process:

Step 1: Understand the system
This step aims at gathering the main characteristic of the wastewater collection and outfall system. It includes a solid understanding of the natural environment and existing functions and the ecosystem services that the system provides to the local population and industry. It also includes understanding the cultural vocation of the region and its relationship with nature. This step identifies:

- the physical and ecological environment in which the wastewater collection and the outfall will be placed;
- the values and interests the local community places on available freshwater and marine ecosystems;
- stakeholders that need to be involved to advance the sustainable solution development process; and
- coarse screening of potential alternatives and prioritising for maximising the services and functions to be provided to the local community.

Information about the system at hand can be derived from various sources, including historic documentation, academic research, but also fundamentally from local knowledge and its cultural practices. Analysis of this information will form the principles for the identification of the functioning of local communities and how ecosystem services beyond those relevant for the primary objective (i.e. separation of water and wastewater) can be developed and harvested.

Step 2: Identify realistic alternatives that use and/or provide ecosystem services.
In this step, realistic alternatives for wastewater collection and the outfall are developed. To identify feasible solutions, it is important to involve academic experts, business owners, decision makers and other stakeholders in their formulation. The approach in identifying the alternatives should proactively seek for options to utilise and/or provide ecosystem services. In other words, it should not only minimise possible impacts but should seek opportunities to improve existing services and functions. Such opportunities could be created in different ways, such as:

- Creating opportunities for nature (e.g. habitats) with the outfall system
- Using the natural processes and system in the project area to optimise the functioning of the outfall system
- Combining the design with other functions or operations in the project area

In addition to the above ways of creating opportunities with the outfall design, these systems have a number of characteristics that could create opportunities, such as:

- High kinetic energy of the outfall flow
- Density differences between effluent and ambient water
- Nutrients contained in the effluent
- Discharge-induced residual flow

Some initial examples of such sustainable design options for wastewater infrastructure could be:

- Reuse of wastewater for aquaculture, e.g. using a wastewater outfall as nutrition for (coastal) aquaculture with proper management of health risks [3].
- Using fresh wastewater in combination with saline marine water to generate energy [4]
- Use the kinetic energy of a wastewater outfall to generate energy [5]
- Wastewater channels with levees that double as flood protection
- Collection of wastewater and reuse as irrigation water
- Reuse of wastewater for industrial use
- Use natural options to treat wastewater before reuse (e.g., filtering by duckweed widely applied in Asia), which could again be used as food for fish or livestock, or as fuel.

Step 3: Evaluate the qualities of each alternative and preselect an integral solution.
This step requires the adoption of conceptual and pre-feasibility studies to test whether the potential of each of the alternatives selected in Step 2 can be realised. This step should be undertaken by a team of experts using suitable methodologies for assessing whether the intended outcomes can be achieved. As practicable as possible, these assessments should contemplate engineering, economical, environmental, and social aspects of the proposed solutions.

The merits and shortcomings of each solution should be discussed with stakeholders for valuation and selection of preferred solutions.

Step 4: Fine-tune the selected solution (practical restrictions and the governance context)
After selecting the optimal solution, its design must be refined and detailed. This will typically be done by a team of engineers, but a close connection should be kept with experts in the fields of economics, environment, and governance to ensure the feasibility of all aspects of the selected solution. It is particularly important to involve the stakeholders in this step, who need to support the eventual solution and can assist in overcoming restrictions. This is especially important in the implementation phase.

Step 5: Prepare the solution for implementation
Finally, the solution needs to be prepared for implementation and construction using a suitable approach (e.g. by involving local work force). It is important to keep the stakeholders involved at this stage in the operational phase to maintain support for the development. Furthermore, it is important to secure a solid knowledge transfer about the wastewater collection and outfall system to the local stakeholders. This way, a feeling of ownership of the development is promoted, which helps in a long-term, sustainable operation and maintenance of the system. ■

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THE CONTRIBUTION OF IAHR'S COMMUNITIES OF WATER MANAGEMENT AND CLIMATE CHANGE TOWARDS THE SDGs

BY CARLOS GALVÃO, YOUNG-OH KIM, ELPIDA KOLOKYTHA, ARPITA MONDAL, PRADEEP MUJUMDAR, DAISUKE NOHARA, SATORU OISHI, ROBERTO RANZI & RAMESH TEEGAVARAPU

Integrated and adaptive management can foster more equitable, efficient and sustainable access and use of water resources, and in this way address the specific needs of the SDGs. These principles must be the core concept of societal and human development.The perception of endless resources exploitation should be replaced by resource efficiency. End of poverty, suffering, hunger, inequalities and injustice must be considered as core objectives of water management. IAHR is committed to create interest for all communities and stakeholders involved in development of sustainable and climate-change sensitive and risk-informed water resources management, thus contributing to the achievement of the SDGs.

IAHR's communities of water resources management and climate change

IAHR's Committee on Water Resources Management, and Working Group on Climate Change have promoted the discussion of sustainability. Recent activities of these communities are the publication of a book on "Sustainable Water Resources Planning and Management under Climate Change" published in 2017 and a Hydrolink article on "Summary of recommendations for policymakers on adaptation to climate change in water engineering" (Issue 2015/3) Among IAHR's journals, the Journal of River Basin Management, the Journal of Applied Water Engineering and Research and the Revista Iberoamericana del Agua (RIBAGUA) include the topic of Water Management in their scope. 37th IAHR World Congress' sessions on Water Resources Management hosted some 98 papers, most of them related to the SDGs. Among these, 55 addressed Integrated Water Management, including reservoir, drought, flood, groundwater and demand management; 15 presentations addressed climate change impacts on water and 15 wastewater treatment and pollution control. These numbers show the strong commitment of the members of these IAHR communities to ground-based research aimed at sustained and inclusive global and regional development. In the next paragraphs, we show some examples on how IAHR is developing state-of-the-art knowledge and methods for policy-makers to achieve the SDGs considering water as main resource under threat.

Figure 1. Kamafusa Reservoir, a multi-purpose reservoir operated for flood control, water supply and power generation in the Natori River basin in Japan. The reservoir provided enhanced capability for flood protection by introducing prior release operation considering real-time hydrological predictions while river levees in the downstream were damaged by the great earthquake and tsunami in 2011

Green economy and water resources management

A holistic approach to water resources management needs to incorporate all drivers of change. Integrated and adaptive management, where decisions are made taking into account space and time variations and where adjustments are to be made according to specific needs can foster more efficient and sustainable use of water resources. SDGs mainly consider the use of resources and the way human activities affect the natural and built environment. The sustainable use of natural resources and the environment has to be the core concept of economic growth while the perception of endless resource exploitation should be replaced by resource efficiency. The use of improved technology lowers inputs of material and energy, which in turn reduces pollutants, resulting in this way to higher environmental protection. In this sense, green economy and green development provide a core concept for sustainable water management.

Water needs to be seen as an integral part of the ecosystem and as such, solutions should revolve around maintenance of ecosystem services, reallocation among sectors, true cost pricing and public engagement in all stages of decision-making. Using water efficiently, making it available to all at a reasonable cost and ensuring environmental sustainability of ecosystems constitutes the “puzzle” of sustainable water management. Water and water management is essential in combating poverty, enhancing economic development, ensuring food security and sustainable agriculture, allowing for sustainable production and consumption. Water management is also essential in promoting sustainable cities and securing peace.

Water management under climate change

Decision makers need to recognize that new types of decisions are needed under climate change. Modelling and analysis needs to take these, often unclear, factors into account including making allowances for greater fluctuations in available water resources. The problems of climate change are global and where water sources overlap national boundaries, water managers should transcend those boundaries.

Traditional estimates of hydrologic risk and infrastructure design principles are based on the notion of stationarity that can be challenged by global warming and associated changes in the coupled natural and human systems. Comprehensive methods have been developed for investigating climate-change-induced non-stationarity in hydrologic extremes and how it can affect hydrologic risk estimation for infrastructure design and hazard mitigation. New approaches and principles address the effect of non-stationarity and also the associated uncertainties, with the aim to aid practitioners and policy makers in developing water infrastructure to ensure equitable and universal distribution of water resources. These principles are generic and apply to all environmental systems undergoing change, thereby aligning to achieve the SDGs.

Adaptive reservoir management

Novel and holistic approaches for the adaptive operation of reservoirs considering real-time hydro-meteorological predictions can enhance the significance of reservoirs by integrating operations for achieving different objectives related to the SDGs, such as flood and drought management, municipal and agricultural water supply, and power generation.

Reservoirs play a significant role in mitigating water-related disasters such as floods or droughts, which may become more severe under a changing climate. Development and implementation of the integrated operation of reservoirs are therefore important to reduce

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Arpita Mondal **serves as Assistant Professor at Indian Institute of Technology (IIT) Bombay. She is a recipient of the prestigious INSPIRE Faculty Award (2015) and the Early Career Research Award (2017) by the Govt. of India.**

P. P. Mujumdar **is Professor and Chairman of Interdisciplinary Centre for Water Research at Indian Institute of Science (IISc), Bangalore. He is a fellow of the Indian Academy of Sciences and is a recipient of the Alexander von Humboldt Medal of the European Geosciences Union (EGU), the Distinguished Visiting Fellowship of the Royal Academy of Engineering, UK.**

Daisuke Nohara **is Assistant Professor at Disaster Prevention Research Institute of Kyoto University, Japan. His field of expertise includes optimal management of water resources systems, operational hydrology, and assessment on applicability of hydrological predictions.**

Satoru Oishi**, Professor, is the Director of Research Center for Urban Safety and Security, KOBE University, Japan, and also the Leader of Computational Disaster Mitigation and Reduction Research Unit, Advanced Institute for Computational Science (AICS), RIKEN, Japan.**

Roberto Ranzi **is Professor of Hydraulic Structures and of Hydro-meteorological monitoring and river basin restoration at the University of Brescia, Italy. He chairs the Climate Change Working Group of IAHR.**

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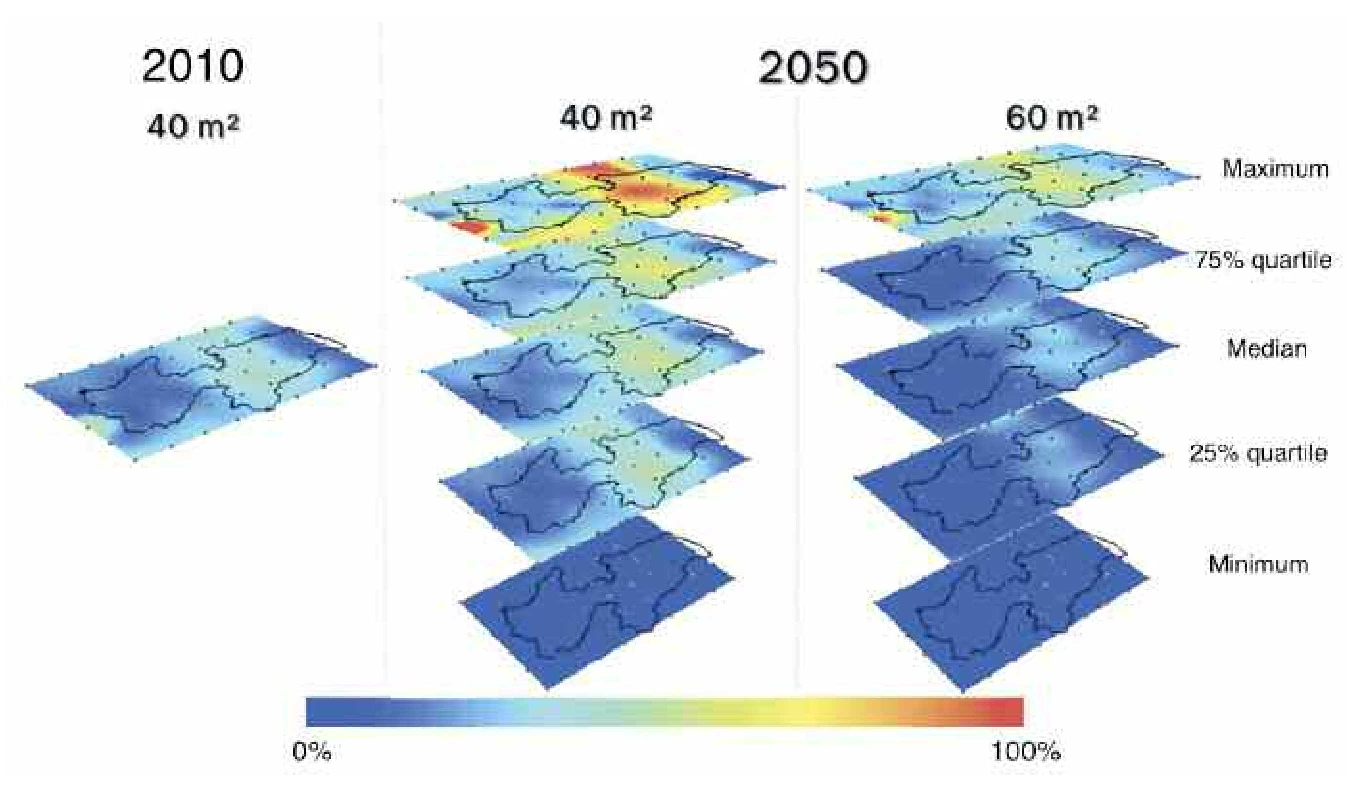

Figure 2. Current (2010) and future (2050) values of water scarcity (expressed as the water supply deficit as % of annual domestic water demand) of rainwater systems for water harvesting surfaces of $40m^2$ and $60m^2$ in the Brazilian rural semi-arid in the State of Paraíba derived from projections by 19 climate models. The quantiles refer to simulations of water scarcity from model projections of rainfall. For example, the second plane from the bottom, labelled 25% quartile, represents predictions of 25% of the models showing the smallest deficit, i.e. the lowest water scarcity. Risk of future scarcity can be minimized through larger water harvesting areas. Approximately one million of such small rainwater systems supply safe water for small communities in the whole Brazilian semi-arid region (courtesy of Marilia Dantas, of the University of Campina Grande, Brazil)

vulnerability and exposure of people to those disasters, which can contribute to building the resilience of the poor for sustainable development. The methods of adaptive reservoir operation provide an effective approach to increase the ability of reservoirs to control those water-related disasters in an integrated manner utilizing advanced real-time hydrological forecasts for more adaptive and resilient water resources management under climate change. An example of this approach is the operation of the Kamafusa Reservoir in Japan (Figure 1) following the Tohoku earthquake of 2011, when real-time predictions of hydrologic conditions were used to adjust water releases from the reservoir in order to provide adequate flood protection downstream where the river levees had been damaged by the tsunami that was caused by the earthquake.

Many reservoirs supply water for irrigation, contributing to enhanced food production. Introducing a sophisticated operation of reservoirs is therefore important for more sustainable food production systems under changing climate. One of the common purposes of reservoirs is hydropower, which is considered as renewable energy. It is therefore important to optimize reservoir operations for power generation in order to increase the amount of renewable energy generation.

Water governance for the SDGs

SDGs-related challenges are so great that they may require substantial adaptations and even transformations in social organizations and the use of their resources. In the context of climate change, uncertainties associated with climate variability in the future are even more striking and complex towards this end. An example, of the magnitude of such uncertainties is shown in Figure 2 which shows the range of predictions of future water scarcity in a semi-arid rural part of Brazil.

To know more

From the perspective of the integrated and adaptive management of water resources, it is important to understand its aspects relevant to water governance, considering the adaptation measures that promote the SDGs. In this sense, new approaches have focused on the following questions:

- in what aspects will water governance, through its policies, plans and management systems, need to adapt to better cope with the new development goals?
- how to generate strategies to meet the requirements of this adaptive governance?

It is essential that no group of people, independent of race, ethnicity or socio-economic class, should suffer alone the negative impacts resulting from industrial, agricultural, commercial and infrastructure activities or government programs and policies. The concept of equity should, therefore, be a key criterion of sustainable water management. As an example, inefficient water resource management has caused unequal access to water by different social groups or unequal exposure to water-related disasters in many regions of the world. ■

THE IAHR ICE RESEARCH AND ENGINEERING COMMITTEE AND THE SDGs

BY MATTI LEPPÄRANTA

The mission of the IAHR Ice Research and Engineering Committee is to promote research towards a better understanding of ice properties and processes, and related environmental and ecological issues on rivers, lakes, and the ocean, and to develop knowledge for water resources problems in cold regions, including natural and anthropogenic ice-related challenges. The Ice Committee has established working groups and organizes biennial Ice Symposia. A recent effort was to provide a set of articles on ice topics to the UNESCO EOLLS (Encyclopedia of Life Support Systems)[1]. The next symposium organized by the Committee will be held in Vladivostok, Russia, in June 4-8, 2018. Proceedings of earlier symposia (held 23 times in 1971-2016) are available in electronic form in the IAHR web site [2].

Figure 1. The zone of seasonally freezing lakes in the northern hemisphere and the 0°C January climatological isotherm. The contours 100 and 180 refer to the mean length of the ice season (days) [4].

The region where river and lake ice occurs covers in fact a large part of land areas is located north of 45°N (Fig. 1). In oceans sea ice forms above latitudes 60°N and 60°S except in the northeast Atlantic where the Gulf Stream keeps the sea open up to 75°N. In northern Eurasian and American continents, the annual ice season is even longer than the open water season. However, ice research has been under-represented in many science, engineering and environmental programs concerning surface waters. The IAHR Ice Committee has tried to take care of this field within the IAHR community. Ice management is connected to the Sustainable Development Goals (SDG) as it affects the ecology in natural waters and human life in cold climate conditions. Due to links between ice and liquid water resources, more collaboration between the Ice Committee and other committees is needed in order to increase IAHR's contribution to the efforts to achieve the SDGs.

The effects of ice on human activities can be either harmful or beneficial. Problems caused by ice are floods induced by ice jams [3]. See Fig. 2. Also clogging of water intakes and trash racks by frazil ice, severe impediment to winter navigation, and damage to coastal and offshore structures by moving ice are important issues of concern. On the positive side, stable ice covers have extensively been used for traffic and transportation, recreational activities, landing of aircrafts and working platforms, and also ice is a source of clear drinking water. In earlier times, ice was stored to be used for cooling in summer. At times, however, mishaps during these activities have resulted in loss of life.

Figure. 2. Ice jamming in the Yellow River, China. Photograph: Xinlei Guo.

Figure 3. Ice road maintainance in Lake Pielinen, Finland. Photograph: Maritta Räsänen

The presence of ice cover has a major impact on the circulation of water below ice. Diffusion and dispersion of pollutants is different in ice-covered waters from those in ice-free waters. Oil spills are a major issue in ice-infested waters due to difficulties to detect and predict oil movement and to remove oil. The effects of ice on stream ecology and the presence of an ice cover in lakes influences the level of dissolved oxygen. Ice control techniques may also affect the stream habitat. These are all emerging areas of research. To provide safe and economical vessels is an essential goal for investigators. Exploitation of petroleum and other natural resources in polar regions requires ice navigating vessels to transport massive amounts of products. Ship operators strongly request vessels that can safely and effectively navigate in ice-covered waters. The presence of an ice cover is not only a severe impediment to winter navigation in inland waters, but also affects ships and barges passing through locks and dams. Coastal regions and harbors have to be protected from ice forces.

About 77% of the fresh water of the world is stored in glaciers and ice sheets, mostly in Antarctica and Greenland. Possible global warming will affect these ice massifs, resulting in a global change of the sea level. Regionally, the formation of ice on water bodies strongly affects human activities in countries located at higher latitudes. In a moderately cold climate, the existence of ice is limited to short periods of a few weeks per year, but unexpected winter conditions can cause severe ice-related problems, such as interruption of navigation, ice-jam induced floods, ice damage to bridges, coastal structures, hydropower plants and other hydraulic structures, ice blockage of water intakes, etc.

***Matti Leppäranta* is the Chairman of the IAHR Ice Committee, which has 16 members from most countries of the regions where world's surface waters freeze seasonally. He joined the Ice Committee in 2008 and organized the 20th IAHR Ice Symposium in Lahti, Finland. He works as a professor of geophysics in the University of Helsinki. His research has focused on physics of sea ice and lake ice.**

Ice research and engineering efforts are mainly directed toward better understanding of ice and how best to manage it. Research topics include ice formation and evolution, physical properties of ice, movement and accumulation of ice in surface waters and around structures, inter-action between flow and ice cover, effects of ice on the environment and ecology, and ice control and use. Ice engineering deals with ice formation, ice movement, the thermal regimes of rivers, lakes and seas, and the development of methods to alleviate the harmful effects of ice. Research should aid in the solution of ice related problems affecting strong economic and environmental interests, such as hydropower production, navigation in ice-infested waters, water transfer in cold regions, mitigation of ice-jam floods, effects of ice on hydraulic structures, and exploitation for petroleum and other natural resources in polar regions. The effects of global climate change need to be assessed with respect to the ice regimes of rivers, lakes and seas. Active co-operation exists between the research community and industry in ice hydraulic engineering.

A major goal of ice research and engineering is to protect life and property against the harmful effects of ice by understanding ice phenomena and processes. Therefore, the activities of the Ice Committee strongly support the SDGs, in particular Life under ice and Climate change and they are also linked to several other SDGs in high latitudes, where the life and society are closely connected to the seasonal presence of ice. Also in lower latitudes better understanding of ice helps to prepare for extreme cold events. In the field of education, producing the article collection "Cold Regions science and marine technology" for EOLLS [1] was a major effort. Developing countries have free access to this electronic encyclopedia, but elsewhere UNESCO requires a fee. ■

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GROUNDWATER AND ITS MANAGEMENT AS CRITICAL COMPONENTS OF SUSTAINABLE DEVELOPMENT

BY ZHONGBO YU, ALBERTO GUADAGNINI & DANIELE TONINA

Groundwater is a key component of the hydrologic cycle. The documented increasing scarcity of fresh water and the degradation of its quality place groundwater resources under pressure. Monitoring groundwater dynamics and improving the ability to interpret groundwater processes is a critical challenge for transformative practices in water resources management. Feedbacks between global drivers, such as climate change, and anthropogenic actions, including population dynamics, tend to affect hydrological systems on multiple spatial and temporal scales. Water security in a rapidly changing environment is a critical issue attracting international attention. The United Nations Agenda 2030 for Sustainable Development addresses three aspects on sustainable development, i.e., society, economy and environment. Many countries currently face major challenges in the implementation of national water security strategies and in their effort to achieve sustainable development at a time of intensive environmental changes. To fully assess the consequences posed on water resources by climate change, society and technological progress, requires profound understanding of a variety of processes and the ability to properly interpret signals embedded in the available data. Examples include contamination processes, potential risks linked with conventional or unconventional energy sources, excessive water drawdown, the effect of droughts, or groundwater-related feedbacks from flooding events in urban environments.

In broad terms, groundwater hydraulics is concerned with the analysis of flow and transport processes in porous and fractured geologic formations. Water management and its effect on the environment are main topics of concern. Groundwater possibly constitutes the most valuable freshwater resource on Earth, representing a resource which is as much as two orders of magnitude larger than the total water volume associated with rivers and lakes.

Groundwater systems vary greatly, depending on their geological signature, e.g. sand and gravel aquifers, fissured rock aquifers, karstic aquifers). The hydraulic behavior of such systems is characterized by large water volumes and generally low flow velocities, typically resulting in markedly long residence and exchange times. Transport at regional scales is affected by heterogeneities of the geological formations, in terms of the spatial architecture of hydrofacies and their attributes, which still poses significant challenges to modeling and providing risk-based decision metrics. Bio-geo-chemical reactions take place at the pore scale and their effects propagate to a variety of spatial and temporal scales. Key drivers of groundwater recharge include rainfall, infiltration and the interaction with surface waters, and involve a variety of processes in variably saturated soil environments.

The protection of groundwater quality is a major environmental issue in most countries. Instances of groundwater pollution by diffuse or concentrated sources, resulting from accidental or poorly planned activities at the ground surface, are quite common. Industrial, domestic and agricultural contamination sources include waste disposal sites, accidental spills, leaking septic tanks, fertilizers, herbicides and pesticides. Air pollution contributes to groundwater pollution via atmospheric the deposition of contaminants at the ground surface that eventually make their way into the groundwater. Contaminants which are not miscible with water can also be found in the subsurface as a non-aqueous phase, as well as dissolved in the water, or adsorbed onto the solid phase.

Research agenda: The IAHR Groundwater Hydraulics and Management Committee serves as a platform for interested parties around the world to share their vision on research as well their approaches to addressing challenges in groundwater-related environmental and societal needs. Activities promoted by the IAHR Groundwater Hydraulics and Management Committee include studies on a variety of subsurface processes, remediation and water management. Problems in these subjects are tackled in an integrated way within an operational framework for risk assessment under uncertainty. This work directly supports SDG 2 (food production) as groundwater is a major source of irrigation around the world; SDG 3 (public health) by developing methods to identify, contain, remediate and prevent ground-

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water contamination; and SDG 6 (water, and sanitation) by helping development of drinking water sources and ensuring that the use of proper sanitation prevents the the pollution of groundwater. The work of members of the Committee has also implications for the development of policies and best practices for sustainability of cities and communities (SDG 11) as well as for responsible consumption and production (SGD 12). In this broad context, effective monitoring of aquifer bodies should include appropriate design of future monitoring networks and sampling frequency of target environmental variables to increase certainty and maximize the value of collected data. Adoption of goal-oriented monitoring practices can allow early recognition of chemical plumes and biological activities. It can also enhance the effectiveness of timely countermeasures as well as provide fundamental data to advance our ability to represent the subsurface environment through models with diverse degrees of fidelity. Studies on flow and transport of partially saturated regions, which are also part of critical zones where there is a delicate feedback between anthropogenic and geogenic components, provide fundamental understanding of the subsurface processes and their interaction with surface water and ecobiological systems. Restoring water quality in polluted aquifers involves clean-up operations in the saturated and unsaturated regions. major issues of concern in the context of integrated groundwater management include aquifer overexploitation, changing groundwater levels, water deficits, and soil and water pollution. Risks associated with groundwater pollution are ubiquitous and their assessment should always take into account uncertainty. These risks must be recognized and properly addressed, managed, and communicated. In this context, the evaluation and effective design and implementation of sustainable water resources policies remain important topics for groundwater management. Dealing with them requires continuous improvement of our ability to assess the vulnerability of groundwater resources. Studies on coupled flow, transport and bio-geo-chemical processes along with proper accounting for the spatial variability properties and processes, and the way information content can be transferred across scales remain fertile research topics.

What lies ahead: the IAHR Groundwater Hydraulic and Management Committee has promoted and supported the organization of a series of international groundwater symposia, including a major event planned for Water Security and Sustainability conference in Nanjing, China in 2018. This conference will be a forum where scientists and stakeholders from the industry and public administration will have the opportunity to share their recent research and application-oriented results and vision, to discuss and promote strategies for addressing global change challenges. The major theme of the conference will focus on “Global Change Challenges: Water Security and Sustainability” with six focused topics on hydrologic processes, modeling, groundwater protection, new approaches for monitoring, sustainability of water

THE FLUID MECHANICS COMMITTEE AND THE SDGs

The focus of the Fluid Mechanics Committee is on fundamental and applied environmental fluid mechanics in support of hydraulic research. Particular emphasis is on the fundamentals of transport and mixing phenomena in turbulent flows such as contaminant transport processes in rivers, lakes and coastal regions, anthropogenic influences (e.g., heat, dissolved and suspended organic/inorganic material) and sediment dynamics.

The activities of the committee are summarized in its website (https://www.iahr.org/site/cms/contentviewarticle.asp?article=646).

Mostly the committee’s involvement in these topics comes from hosting summer schools, workshops and symposia that cut across above topics. For example, its educational mission is largely covered by the Gerhard Jirka Summer School, which is rotated around the globe at various international destinations. The Jirka School emphasizes theory, experiments and applications, with focus on basic theoretical principles (and their mathematical description), as well as consideration of examples of engineering design and environmental applications. Formal in-class lectures as well as informal out of class excursions and visits are part of the school. This approach represents the vision of the committee to help develop fundamental understanding on fluid processes (air and water), as well as the interaction of fluids with natural, factitious and biological elements. Climate change and how it affects water resources, run off, urban heat island, natural disasters, green infrastructure, air pollution and human health are addressed in various conferences, and in some cases the conference themes or special sessions are dedicated to this purpose. Sustainable development is considered in the framework on development through a thematic area called Urban Fluid Mechanics. The fluid mechanics committee hosts four regular conferences: the International Symposium on Environmental Hydraulics (ISEH), Stratified Flows (ISSF), and Shallow Flows (ISSF) and supports two symposia, Ultrasonic Doppler Methods (ISUD) and Hydrodynamics (ICHD). The committee hopes to initiate a workshop series dedicated to the sustainable development of cities.

Harindra Joseph Fernando **is currently the Wayne and Diana Murdy Endowed Professor of Engineering and Geosciences at University of Notre Dame. He is a Fellow of the American Society of Mechanical Engineers, American Physical Society, American Meteorological Society and the American Association for the Advancement of Science. He was elected to the European Academy in 2009. He received docteur honoris causa from the University of Grenoble, France, in 2014 and Doctor of Laws Honoris Causa from University of Dundee, Scotland in 2016. He is the Editor-in-Chief of the Journal of Environmental Fluid Dynamics and an Editor of the journals Theoretical and Computational Fluid Dynamics and Non-Linear Processes in Geophysics. He chairs the IAHR Fluid Mechanics Committee.**

The fluid mechanics committee contributes to the sustainable development goals of clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), industry and infrastructure (SDG 9), sustainable cities and communities (SDG 11), climate change (SDG 13) and quality education (SDG 4) ■

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FOSTERING GLOBAL PARTNERSHIPS BY EDUCATION AND PROFESSIONAL DEVELOPMENT

BY MICHAEL TRITTHART

The mission statement of IAHR's Education and Professional Development (EPD) Committee targets regional and world-wide activities promoting education and professional development. Regional activities in that field are linked to world-wide activities. This overall mission of the EPD Committee contributes therefore to Sustainable Development Goal (SDG) 17, Global Partnerships, which calls for "cooperation on and enhance knowledge sharing (…) through a global technology facilitation mechanism" (United Nations, 2015). Moreover, SDG 17 calls for "implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals". Thus, SDG 17 can be viewed as auxiliary goal, which provides mechanisms to support the implementation of the SDGs in general. Besides contributing to the development of new mechanisms to achieving this goal, the EPD Committee particularly focuses on further developing a number of already existing activities within IAHR, including the IAHR Media Library, the Young Professionals Networks of IAHR, and the HydroWeb international online course.

Knowledge sharing through the IAHR Media Library

The IAHR Media Library (www.iahrmedialibrary.net) provides a web resource for the storage and dissemination of photographic, animated and video material relating to hydraulics, hydrology and water resources (including photos and films with brief technical descriptions). Moreover, teaching tools in hydraulics are provided, such as slides of class lectures and seminars, didactic computational software or e-learning tools. The Media Library thus provides a general mechanism for knowledge sharing as defined in SDG 17, giving easy access to teaching material particularly also to teachers and students in the Global South. This way the EPD Committee contributes to SDG 4, which among its targets has the goal of ensuring equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.

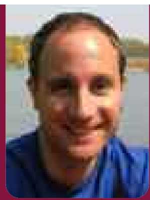
Networks for IAHR's Young Professionals

A typical challenge for students is to get into contact with their future profession in practice in a relatively early stage of their education, in order to learn from experienced engineers and create a network for their future careers. By establishing the Young Professionals Networks (YPN), which have evolved in the past few years from the original IAHR student chapters, IAHR has created a common platform to tackle this challenge in the hydraulic engineering and research community. YPNs carry out different water-related activities, projects and educational programmes; they also conduct special activities in the scope of the biennial world congress. The fact that the community of YPNs is ever growing, with several new YPNs being established around the globe every year, shows that the strategy is successful and young professionals can draw an added value from their networks, just as aimed for by the SDGs.

Online collaboration with HydroWeb

HydroWeb was first established as an educational initiative in 1999. After running successfully for many years within the scope of the EuroAquae joint Master programme on European level, in 2014 it was extended to become available to IAHR's YPNs. It deals with web-based collaborative engineering in hydrosciences. The idea of HydroWeb is that participants from different universities are forming teams to run online a river modelling project via the internet within a time window on a shared web-based project platform. Key focus in this initiative is not so much the learning of technical skills but rather the development of a "technical culture" for online team work using web technology and information sharing principles in engineering projects (Tritthart and Molkenthin, 2015). To date, young professionals from Austria, Brazil, China, Germany, Spain and the US have taken the opportunity to participate in the HydroWeb experience under the umbrella of IAHR, and their reports overwhelmingly indicate that they have learned collaboration skills far beyond what is available to them at their respective universities.

"The sharing of knowledge, the creation of networks and online collaboration assist in reaching the SDGs"



Michael Tritthart graduated in civil engineering from the University of Innsbruck, Austria, in 2000, and obtained a doctorate in technical sciences at Vienna University of Technology in 2005. He then joined the University of Natural Resources and Life Sciences, Vienna as a senior scientist, where he obtained a post-doctoral lecture qualification (habilitation) for hydroinformatics and river engineering in 2013. Throughout his career, he has developed various numerical models in hydrodynamics, sediment transport and ecohydraulics. He is Chair of the IAHR Education and Professional Development Committee.

Conclusions

These three examples of activities coordinated by the EPD Committee show how the sharing of knowledge, the creation of networks and "hands-on" learning by online collaboration assist in reaching the UN's SDGs. The committee aims to implement new activities and further develop the existing ones in the years to come. ■

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BETTER WATER INFRASTRUCTURES FOR A BETTER WORLD –
THE IMPORTANT ROLE OF WATER ASSOCIATIONS

BY ANTON J. SCHLEISS

History shows that the economic prosperity of a society and its cultural wealth has always been closely related to the level of development of its water infrastructure. In view of climate change, especially dams and reservoirs, but also other water infrastructure will and has to play an even more important role than in the past as part of mitigation and adaptation measures that are necessary in order to satisfy vital needs in water, renewable energy and food worldwide.
International organizations and national governments have shown that there is political will to improve water, energy and food security at a global level through the so-called NEXUS approach that integrates management and governance across sectors and scales.
Nevertheless, these political intentions must be translated into concrete actions for the urgently needed enhancement of the worldwide water infrastructure including reservoirs and dams. To gain wide acceptance and to obtain a win-win situation for all stakeholders, such large water infrastructure projects must be designed as multi-purpose projects by multidisciplinary teams recognizing the complexity of these systems and adhering to the principles of sustainable development as expressed in Agenda 2030 of the United Nations. This calls for excellence in engineering, sciences and management. All water associations should contribute with concerted actions to the worldwide vision "better water infrastructure for a better world".

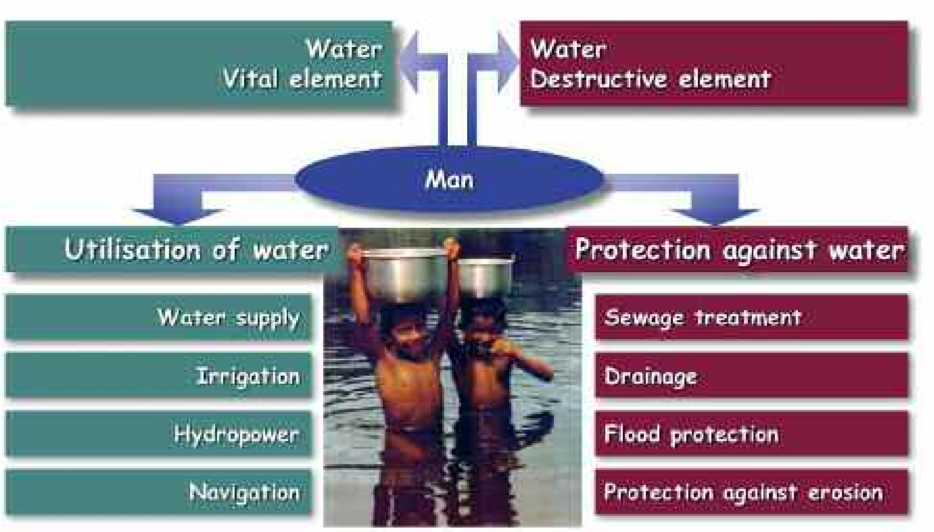

Figure 1. Application of water infrastructures [1]

Vital water infrastructures for reaching the sustainable development goals (SDG)

For thousands of years, humankind has continuously developed techniques to use water and at the same time to protect itself against water. The term «hydraulic schemes" or "water infrastructure» covers all measures and human interventions aiming at controlling parts of the water cycle. A vital element of our environment, water also has great destructive potential. Thus, the water infrastructure projects can be divided, according to their objectives, into two groups (Figure 1) [1]:

- schemes for water utilisation
- schemes for protection against water.

The hydraulic structures or water infrastructure designed for water utilisation are often multipurpose projects providing water supply, irrigation, hydropower production and navigation. The structures designed for protection against water hazards include, besides flood control reservoirs, also sewage treatment facilities (hydraulic structures to eliminate pollution), drainage, flood protection and erosion protection measures.
Today large water infrastructure projects should be designed as multipurpose schemes in order to benefit from synergies between different objectives of use and protection and to gain wide acceptance from all stakeholders.

Dams and reservoirs as key water infrastructures

According to the ICOLD register, today more than 58000 large dams – often called the useful pyramids [1] – are satisfying the worldwide vital needs for water, energy, food and flood protection (Figure 2). The total storage volume of all reservoirs registered by ICOLD is about 6700 km^3, of which about 4000 km^3 can be used directly. To put the magnitude of useful storage of these reservoirs in perspective, it is noted that all the water stored at a certain instant in all rivers worldwide, is between 1000 and 2000 km^3, which shows clearly that the reservoirs can significantly influence the water cycle. This is, above all, of highest importance for food production around the world, a good part of which depends on irrigation.

The major problems of the world population in this century will be without doubt the safe supply of ecological and renewable energy, as well as the supply of water of good quality and sufficient quantity in order to eliminate famine, poverty and disease in the world. Still today water supply and sanitation services leave much to be desired; 40% of the global population suffer from water scarcity, which is projected to rise, and almost 800 million people do not have access to clean water. Furthermore, an important part of the world population is still threatened with famine. This risk could be considerably lessened by irrigation to produce food in arid areas, which are not cultivable today. Thus, in many countries, especially in Africa, there is still an urgent need for increased development of water and energy resources as the basis for the economic prosperity and cultural wealth of these societies.

Figure 3 shows where the new large dams have been built since the beginning of this century [2]. Thanks to these new water infrastructures, a security belt is formed around the world to ensure water, food and energy. The zone of high density of new dams extends from Southern Europe over to the Middle East, to Central and

East Asia. It covers the area of high water stress in arid and semi-arid regions, as well as the Monsoon- exposed regions with extremely high population density. The belt of new dams shown in Figure 3 is less apparent across North America over the World's most productive crop growing region, where only a few dams have been built this century. This is due to the fact that significant dam development took place in this region in the last century. It must also be noted that the regions along this belt are already affected perceptibly today by climate change, whose effects are expected to become even more dramatic in the future, according model simulation predictions. The existing dams and reservoirs, as well as future projects will play a key-role in the mitigation of the effects of climate change [3]. The belt of dams and reservoirs which covers these threatened and very vulnerable regions around the world will help provide food security, water and energy. Therefore, it can be called a security belt. Figure 3 illustrates another worldwide problem addressed through the construction of new dams, which is the huge economic gradient from the global North to the global South, i.e. from the developed countries to the emerging and developing countries The trend for more new dam construction in the South compared with the North can be seen clearly in South America, as indicated by the arrow attached to the security belt mentioned earlier. The same cannot be said for Africa. In this part of the world, the security belt has to be fixed with extensions to the South in order not only to secure food, water and energy but also equitable worldwide wealth for all countries. Dams and reservoirs are a major part of the water infrastructure, which strengthens the security belt and its extensions.

Important role of water associations

Among the 16 sustainable development goals (SDGs), water associations should at least promote the following goals in their activities which are strongly related to the worldwide development of water infrastructure:

- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

How can this be achieved? First the members of the water associations have to be aware of the importance of the SDGs and of how they can contribute through their research and development activities to achieve them. One possible suggestion could be to require that any paper submitted to an IAHR Congress include a short paragraph, if applicable, explaining in two to three sentences how it contributes to the SDGs. Furthermore, a new best ***SDG paper award*** could be set-up. This could be used as a vehicle to publicize to a broader audience outside IAHR the most relevant three papers contributing significantly to the SDGs. A next step could be to extend this initiative to papers published in IAHR journals. This would greatly increase the awareness of the SDGs among the authors and readers of Congress and journal papers. Most of the water associations are fighting today alone to promote and communicate their viewpoint on social-political issues related to or affected by water. To be heard really, they would have to unite their voices in such communications. A significant platform is the World Water Council (WWC) with its globally known communication and promotion vehicle the World Water Forum (WWF). In order to have an influence on the water themes to be treated and discussed during the WWF it is important to be elected on WWC's Board as a Governor. For single water associations, such as IAHR or ICOLD, it is very difficult to be elected alone in WWC's Board as a Governor. Thus, all water associations having several votes should unite their forces to get one of the associations elected to represent and defend the common interests of all water associations. In addition, the water associations could also prepare together a declaration to publicize issues of common interest and/or concern. ■

Prof. Dr. Anton J. Schleiss **obtained his PhD at ETH Zurich in 1986 and worked then for 11 years for Electrowatt Engineering Ltd. in Zurich (now Pöyry) and was involved in the design of many hydropower projects around the world as an expert. In 1997 he was nominated full professor and became Director of the Laboratory of Hydraulic Constructions (LCH) of the Swiss Federal Institute of Technology Lausanne (EPFL). In 2015 he was elected president of the International Commission on Large Dams (ICOLD). For his outstanding contributions to advance the art and science of hydraulic structures engineering he obtained in 2015 the ASCE-EWRI Hydraulic Structures Medal.**

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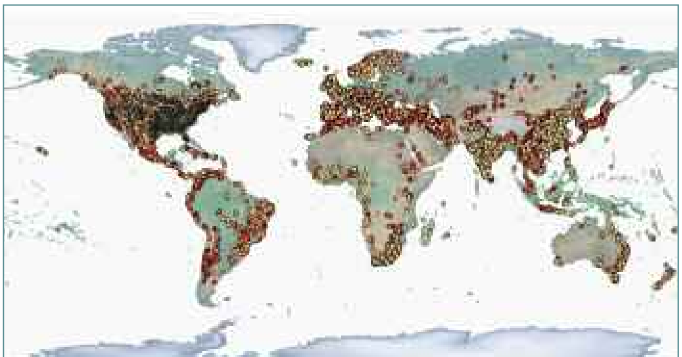

Figure 2. Location of the 58'000 large dams according to the ICOLD register ranging from medium size dams (up to 50 m high, shown in yellow) to very high dams (above 150 m, shown in red)

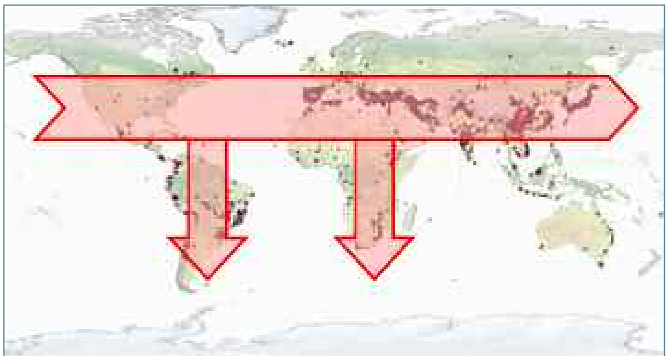

Figure 3. New dams and reservoirs commissioned since 2000 creating a security belt around the world to ensure water, food and energy [2], [3]

MONITORING SDG PROGRESS FOR WATER AND SANITATION: CHALLENGES AND OPPORTUNITIES

BY CARTER BORDEN, DARREN SWANSON & WILLIAM YOUNG

The 2030 Agenda for Sustainable Development represents an historic agreement among all Member States of the United Nations [1]. Never before have all nations of the world, developing and developed alike, held a common vision for the future. The 2030 Agenda officially came into force in January 2016 along with its 17 global Sustainable Development Goals (SDGs). The SDGs, supported by 169 targets and 232 indicators, are described in the Agenda as "integrated and indivisible, global in nature and universally applicable" as well as being "aspirational and global, with each government setting its own national targets guided by the global level of ambition but taking into account national circumstances." This article provides an overview of the SDG 6 on Clean Water and Sanitation along with a brief discussion on limitations and opportunities for its implementation.

Water in the SDG Framework

Water and sanitation are at the core of sustainable development, and water quality and quantity are critical to ensure healthy freshwater ecosystems that provide important ecosystem services (including flood and drought mitigation) that are resilient in the face of global environmental change. These issues are addressed in Clean Water and Sanitation (SDG 6) and Sustainable Cities and Communities (SDG 11). SDG 6 aims to "ensure availability and sustainable management of water and sanitation for all" and "ensure availability and sustainable management of water and sanitation for all" [2]. SDG 6 builds on the MDGs in improving water for drinking water (6.1) and sanitation and hygiene (6.2) (Table 1). The 2030 Agenda for Sustainable Development expands the scope of monitoring to additional elements of the hydrologic cycle that influence human and ecological well-being. Thus, SDG 6 addresses water quality and wastewater (6.3), water use and scarcity (6.4), water resources management (6.5), ecosystems (6.6), and international cooperation and stakeholder participation (6.6). Furthermore, SDG 11.5, evaluates water-related disasters impacting human lives and property.

The SDG 6 Indicators are explicitly connected to 11 other SDGs, having indicators that use the same monitoring for SDG 6 and for some, rely on the same analysis. These SDGs include No Poverty (SDG 1), Zero Hunger (SDG 2), Good

Table 1. Indicators for SDG 6 and SDG 11.5 targets. Affected Targets are those where the SDG 6 and 11.5 targets are drivers for change

SDG 6 and 11.5 Indicators	*Tier**	*Affected Targets [3] [4]*	*Custodian*** [5]*
6.1.1 Proportion of the population using safely managed drinking water services.	I	1.2, 1.4, 2.2, 3.2, 3.8, 3.9, 4a, 5.4, 11.1	WHO, UNICEF
6.2.1 Proportion of the population using safely managed sanitation serves includes a hand washing facility with soap and water.	I	1.2, 1.4, 2.2, 3.2, 3.8, 3.9, 4a, 5.4, 11.1	WHO, UNICEF
6.3.1 Proportion of wastewater safely treated	II	3.3, 8.4, 11.5, 11.6, 12.4, 14.1, 14.2, 15.1	WHO, UN Habitat, UN DESA
6.3.2 Proportion of bodies of water with good ambient water quality	III		UNEP
6.4.1 Change in water use efficiency over time	III	1.1, 1.2, 2.1, 2.2, 2.4, 5.4, 5.a, 8.4, 9.4, 12.2, 12.3	FAO
6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	II	1.5, 2.4, 11.5, 15.3	FAO
6.5.1 Degree of integrated water resources management implementation (0-100)	II	1.4, 2.3, 4.7, 5.5, 7.1, 8.5, 10.2, 11.3, 13.2, 15.9, 16.3, 16.5-16.7	UNEP
6.5.2 Proportions of transboundary basin area with an operation arrangement for water cooperation	II		UNESCO, UNECE
6.6.1 Change in the extent of water-related ecosystems over time	III	11.5-11.7, 12.2, 13.1, 14.2, 14.5, 15.1, 15.3, 15.5	UNEP
6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government coordinated spending plan	I	7.a, 13.b, 15.9	WHO, UNEP, OECD
6.b.1 Proportion of local administrative unites with establish and operational policies and procedures for participation of local communities in water and sanitation management	I		WHO, UN Environment, OECD
11.5.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population	II	1.5, 2.4, 3.6, 3.9, 3.d, 4.a, 6.6, 9.1, 9.a, 11.1, 11.3, 11.5, 11.b, 11.c, 13.1, 13.2, 13.3, 13.a, 13.b, 14.2, 15.1, 15.2, 15.3, 15.9.	UNISDR
11.5.2 Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters	II		UNISDR

* Tier classification by the Inter-Agency Expert Group on the SDGs (IAEG-SDG) at 5th meeting March 2017 [5]
- Tier I: Indicator is conceptually clear, has an internationally established method and standards are available, and data are regularly produced by countries for at least 50 per cent of countries and of the population in every region where the indicator is relevant.
- Tier II: Indicator is conceptually clear, has an internationally established methodology and standards are available, but countries do not regularly produce data.
- Tier III: No internationally established method or standards are yet available for the indicator, but method/standards are being (or will be) developed or tested.

** Acronyms used in Table 1: WHO: World Health Organization; UNICEF: United Nations Children and Education Fund; UN DESA: United Nations; UNEP: United Nations Environment Program; FASO: Food and Agriculture Organization; UNECE: United Nations Economic Commission for Europe; OECD: Organization for Economic Cooperation and Development; UNISDR: International Strategy for Disaster Reduction.

Health and Well-Being (SDG 3), Quality Education (SDG 4), Gender Equality (SDG 5), Decent Work and Economic Growth (SDG 8), Industry, Innovation, and Infrastructure (SDG 9), Responsible Consumption and Production (SDG 12), Life Below Water (SDG 14), Life on Land (SDG 15), and Peace, Justice, and Strong Institution (SDG 16) [3], [4] (Table 1).

Understanding these inter-indicator connections reduces the cost and effort of monitoring and data analysis as common data is required for each. For example, SDG 3.2, mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene, relies on statistics on WAter, Sanitation and Hygiene (WASH) services in SDGs 6.1, 6.2 and 6.3 as well as data on deaths [3]. SDG 12.2, achieve the sustainable management and efficient use of natural resources, requires input from 6.4 and 6.6. During initial implementation of SDG monitoring, it is important for countries to map data sources to identify inter-indicator connections for efficient monitoring and reporting.

Implementation

Implementing the SDGs requires multifaceted development at both global and national levels. The UN and other international organizations need to work with nations to develop standards and methods for national monitoring, quality assurance, and reporting, as well as providing technical and institutional support to member states [5]. Since 2014, IAEG-SDG has been developing standards and methods that are repeatable, cost efficient, credible (nationally and internationally), comparable between countries and regions capitalize on existing national data sets and do not require extensive national capacity building [6]. Indicators have been defined to be relevant and actionable with respect to policy and operations and for some, the data collected will support disaggregation in order to evaluate differential impacts (e.g. by gender, ethnicity, region, sector, economic status).

Custodian agencies organize data from member states and report progress toward SDGs nationally, regionally, and globally (Table 1). For SDG 6, the custodian agencies are clustered under three complimentary initiatives [5]. SDGs 6.1 and 6.2 fall under the WHO/UNCEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation, which builds upon the MDGs for drinking water and sanitation. SDGs 6.3-6.6 data are within the Integrated Monitoring of Water and Sanitation-

Table 2. Summary of definition, data sources, and disaggregation for SDG 6 Indicators [3], [4], [11]

SDG Indicator	*Definition*	*Data Sources*	*Disaggregation*
6.1.1 Proportion of the population using safely managed drinking water services.	Population using an improved drinking water sources located on premises, available when needed, and free of faecal (and priority chemical) contamination. Improved water sources: piped water into dwelling, yard or plot; public taps or standpipes; boreholes or tubewells; protected dug wells, protected springs and rainwater.	Household surveys provide data on improved water on premises as well as availability when needed and free from contamination via direct water quality testing. Administrative sources including drinking–water regulators can provide data on compliance with standards for water quality and availability	• Urban/rural • Wealth • Affordability
6.2.1 Proportion of the population using safely managed sanitation services includes a hand washing facility with soap and water.	Population using an improved sanitation facility that is not shared with other households and where excreta is safely disposed in situ or treated off–site.	Household surveys provide types of sanitation facilities and disposal in situ. Administrative, population and environmental data is used to estimate safe disposal/treatment of excreta	• Urban/rural • Wealth • Affordability • Household onsite/offsite
6.3.1 Water quality and wastewater-Proportion of wastewater safely treated	Wastewater safely treated is calculated by combining the percentage of household (sewage and faecal sludge) wastewater and the percentage of wastewater from hazardous industries treated	Household data: see 6.2.1. Industrial wastewater can be estimated from an inventory of industries through International Standard Industrial Classification (ISIC). Per industry, water extraction from municipalities, boreholes. Given economic production, compute wastewater generated.	• See 6.2.1 • Industrial, per sector
6.3.2 Proportion of bodies of water with good ambient water quality	Proportion of water bodies with good ambient water quality compared to all water bodies in the country. "Good" indicates an ambient water quality that does not damage ecosystem function and human health according to core ambient water quality indicators. Parameters: total dissolved solids (TDS); percentage dissolved oxygen (DO); dissolved inorganic nitrogen (DIN); dissolved inorganic phosphorus (DIP); and Escherichia coli (E. coli).	Existing data (in situ and modelled values) are available from UNEP's Global Environmental Monitoring System (GEMS) Water and OECD. Additional information on optical water properties from remote sensing can be used as proxies for sediments and eutrophication/nutrient loading.	• River basins
6.4.1 Change in water use efficiency over time	Output from a given economic activity using ISIC categories, per volume of net water withdrawn by the economic activity. Economic activities include agriculture (excluding rain-fed agriculture), manufacturing, electricity, and water collection, treatment and supply (looking at distribution efficiency and capturing network leakages).	Existing datasets and new data to be collected during country updates from FAO–AQUASTAT on water withdrawals in different sectors, together with datasets on value generation from other sources. United Nations Statistics Division (UNSD), Environment Statistics Section collects data from official national sources for water abstraction by ISIC activity. Modelled data can be used to fill in possible gaps	• Industrial, per sector
6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	The ratio between total freshwater withdrawn by all major sectors and total renewable freshwater resources, after having taken into account environmental water requirements. Main sectors can include for example agriculture; forestry and fishing; manufacturing; electricity industry; and municipalities.	National ministries and institutions having water–related issues in their mandate, such as ministries of water resources, agriculture, or environment. Data are mainly published within national water resources and irrigation master plans, national statistical yearbooks and other reports	• Industrial, per sector • Hydrological units (river basins, aquifers)
6.5.1 Degree of Integrated Water Resources Management (IWRM) implementation (0-100)	National surveys are structured in 4 components: policies, institutions, management tools, and financing. Within each component there are questions with defined response options giving scores of 0–100. Questions scores are aggregated to the component level, and each component score is equally weighted to give an aggregated indicator score of 0– 100.	National surveys for all UN member states (one per country) in the form of a score–based questionnaire completed by the government ministries. Regional and global estimates are aggregated from national data.	IWRM Survey address: • gender, • governance, • ecosystems, • expenditures, and • human capacity
6.5.2 Proportions of transboundary basin area with an operation arrangement for water cooperation	Calculated as the percentage that the total surface area of transboundary basins that have an operational arrangement for water cooperation makes up of the total surface area of transboundary basins.	GIS data on the extent and location of transboundary basins facilitates the spatial analysis, corresponding datasets available globally.	• Hydrological units (river basins, aquifers) • Country level
6.6.1 Change in the extent of water-related ecosystems over time	Estimate percentage change in each major ecosystem present in a country. Wetland extent is computed through the existing Living Planet Index method for data collection and analysis. It consists of a number of stages including harvesting of time series data, codification and database entry, aggregation into sub–indices to reduce sampling bias, and further aggregation to create sub–global (ecologically and regionally specific) and global indices.	Biophysical data on extent, volume and quantity are available for the majority of freshwater systems listed in the majority of the countries but with temporal gaps; in some cases there has been no access to national data. It is proposed to estimate percentage change in each major ecosystem present in a country using a mixture of ground data and earth observations.	• Water related ecosystem
6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government coordinated spending plan	Amount and percentage of Official Development Assistance (ODA) that is included in a government coordinated spending plan, whether: (1) on treasury or (2) on budget.	Creditor Reporting System (CRS) of the OECD, in particular the reporting on "Water Supply and Sanitation".	ODA CRS Purpose Codes
6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	Percentage of local administrative units within a country with established and operational policies and procedures for participation of local communities in water and sanitation management. Local administrative units: subdistricts, municipalities, communes or other local communities. Policies and procedures define a mechanism by which individuals and communities can meaningfully contribute to decisions and directions on water and sanitation management.	UN–Water GLAAS surveys and the IWRM surveys for SDG target 6.5, with ground truthing from household surveys, census data, and information on regulated water supplies collected for SDG target 6.1.	• Subnational regions • Rural/urban • Sanitation, drinking water, hygiene promotion

related SDG Targets, new Global Environmental Management Initiative (GEMI): an initiative to expand existing efforts on water, wastewater and ecosystem resources. SDG targets 6.a/b are within the UN-Water Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS).

The custodian agencies, along with other UN agencies, provide support to nations implementing SDG 6 by providing tools and guidelines as well as conducting training and capacity building workshops. For example, the SDG Policy Support System (SDG PSS) assists countries in collaboratively creating one authoritative, national-level evidence base to define policy on the water-related issues with respect to SDG 6 [7]. The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) used systems-thinking to map inter-linkages across different sectors to SDG 6 Targets [8]. UN affiliated organizations are organizing national inception workshops to introduce SDG monitoring systems to countries [9]. At a broader level, the UN Development Group (UNDG) is providing guidance to UN Country Teams on good practices for mainstreaming SDGs into national strategies and planning, including monitoring and reporting [10].

Countries are responsible for national reporting of progress on the SDGs to custodian agencies. Countries are thus responsible for assessing current data sets and developing roadmaps for augmenting monitoring networks; collecting, managing, and analyzing monitoring data; computing and reporting indicators; funding monitoring efforts; building and maintaining institutional capacity; developing agency and stakeholder collaboration; and developing political support for the use of the data in policy making, and to ensure the sustainability of the monitoring programs. To support this, methods and tools developed by custodian agencies are being contextualized and adapted to fit country requirements and priorities. Countries are also being encouraged to establish National Statistical Offices to organize and report the data as well as Technical Teams to collect data and compute indicator values. Finally, countries are implementing Inter-sectoral Monitoring Teams for planning and coordinating monitoring across the SDG framework.

Monitoring

Monitoring, analysis, and reporting are being conducted in accordance with methods developed by the IAEG-SDG. Generally, these standards include definitions of indicators, computational methods, data sources, definitions of terms, comments on disaggregation and gender relevance, cross-link connections to other SDG targets, limitations, and recommendations on scaling monitoring efforts as capacity and resources increase [3], [4]. Table 2 provides abridged definitions, data sources and disaggregated categories for the SDG 6 Indicators.

Challenges and Opportunities

The large number of sectors covered by the SDGs framework has created monitoring challenges in terms of cost and resource requirements, understanding cross-cutting relationships, data handling and reporting, and technical and decision making capacity. In 2016, the draft monitoring methodologies for SDG 6 were piloted in five countries (Jordan, Netherlands, Peru, Senegal, and Uganda). The pilots recommended that (i) SDG 6 methodologies be improved with more comprehensive instructions, better defined terminology and greater clarity on the process and frequency of reporting, (ii) monitoring across multiple sources requires contributions from multiple ministries, and (iii) capacity building be provided for decision makers was needed [12]. Scientists and engineers involved in water and environmental disciplines can significantly contribute to implementation of the SDG 6 monitoring through:

1. *SDG 6 Indicator Methodologies:* While many SDG monitoring, analysis, and standards are well established, some are still being developed and tested. The IAEG-SDG classifies indicators as Tier I, II, or III (Table 1). Tiers I and II have clearly defined indicators with international methods and standards, while Tier III methods and standards are under development. Even for well-established methods, improvements can address known limitations. For example, SDG indicators 6.1.1, 6.2.1, and 6.3.1 rely on household surveys and censuses that employ methods that can lead to discrepancies between observed and self-reported data, that likely overstated MDG progress [13]. The IAEG-SDG is working with agency experts, researchers, academics, and stakeholders to further refine the methods and standards for computing the indicators.

2. *Monitoring Networks and Data Management:* As SDG 6 addresses water issues beyond

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***Darren Swanson* is Director of the Canadian-based consultancy Novel Futures Corporation and an Associate of the International Institute for Sustainable Development. He is lead author of the United Nations Reference Guide for Mainstreaming the Sustainable Development Goals (SDGs) and coordinated the creation of the UN's new SDG Acceleration Toolkit. With master's degrees in Public Administration from Harvard University's Kennedy School of Government and Geo-environmental Engineering from the University of Saskatchewan, Darren draws from a diverse science-policy knowledge base when assisting organizations in the collective pursuit of sustainability, accountability and adaptability.**

***Dr William (Bill) Young* is a Lead Water Resources Management Specialist with the World Bank, based in Washington DC. He leads water resources management and hydromet lending operations in South Asia. He also leads analytical studies on national water security and on river basin planning. From 2013-2016 he was Program Manager for the South Asia Water Initiative – a multi-donor trust fund supporting transboundary water cooperation in the Himalayan river basins of South Asia. Dr Young is the World Bank's technical liaison to the UN High Level Panel on Water and is a member of the GEMI inter-agency Working Group for SDG 6.4.**

water for drinking and sanitation, the monitoring and reporting for the indicators increase the data collection burden on countries. Existing monitoring networks and data sets from a variety of agencies, organizations, and stakeholders need to be evaluated for sufficiency in supporting SDG reporting, and expanded to account for deficiencies. Countries vary in their capacity and resources to collect, manage, and analyze SDG data. Opportunities exist to support the national technical teams and key stakeholders in evaluating existing data sets, developing roadmaps for monitoring, augmenting and expanding data collection, and data analysis for SDG 6.

3. Innovative Technologies/Methods: New technologies and methods can enable more timely and detailed information while decreasing cost of monitoring. However, countries need to be made aware on these areas of innovation, including:

a. Updating monitoring equipment. Older monitoring equipment can be updated with more accurate, less expensive, and more reliable sensors. For example, implementing telemetry into a stream gauge network reduces staff effort, increases frequency of reporting, and can also be used to support real-time water management such as reservoir operations. Hydrometeorological data directly supports SDG 6 indicators 6.1, 6.2, 6.3, and 6.6.
b. Earth observations toolsets can support broad spatial analysis. For example, METRIC (Mapping EvapoTRanspiration with Internalized Calibration), a method of using satellite data to map evapotranspiration, is being used to quantify evaluate agricultural efficiency (6.4). Experimental Advanced Airborne Research Lidar (EEARL), a method of surveying stream bathymetry, is being linked to aquatic habitat modeling for evaluating ecosystems across watersheds (6.6, 14). The United States National Aeronautics and Space Administration's (NASA's) twin GRACE (Gravity Recovery and Climate Experiment) satellites measure shifts in earth's gravity field to determine change of groundwater availability in aquifers (6.4).
c. Crowdsourced data: Information and Communication Technologies (ICTs), such as mobile phones, internet, and satellite systems, provide citizens and communities with greater access to data and a means of communication that allows for more informed decision making. In hydrology, mobile apps are being used to support household surveys, collect water quality data, report staff gauge heights, and collect data on ecological conditions. Mobile apps can provide cheaper and more extensive data, and can be used to educate citizens on water issues.

4. Decision Making. In addition to reporting SDG progress, indicators and the data used in their evaluation can be used to guide policy and operations. The SDG 6 pilot studies reported that further capacity building is needed on how SDGs can be used to guide water management decision-making [9]. Capacity building could usefully encompass training in available decision support software and participatory planning processes.

Conclusions

The broad and ambitious scope of SDG 6 has created challenges in monitoring with respect to methodologies, cost and resources requirements, understanding cross-cutting relations, data handling and reporting, and capacity amongst technical and decision makers. Scientists and engineers have great opportunities to help countries achieve the SDG targets. ■

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Interested in hosting the IAHR 2023 World Congress?

IAHR Members are cordially invited to submit expressions of interest to host the 40th IAHR World Congress which will be held in 2023.

Expressions of Interest should be submitted to the IAHR Secretariat before December 1st and prospective applicants are strongly recommended to contact IAHR Executive Director, Dr Christopher George, for an informal discussion as a first step.

The IAHR Council will select the Congress venue at its meeting in summer 2018. The forthcoming world Congress will be in Panama in 2019 and in Granada, Spain in 2021.

REPORT FROM THE KUALA LUMPUR WORLD CONGRESS, AUGUST 13-18TH 2017

BY NOR AZAZI ZAKARIA, CHUN KIAT CHANG & CHRISTOPHER GEORGE

Kuala Lumpur World Congress News
Every two years our community gathers together at the IAHR World Congress, and in August 2017 around 1200 participants from 61 countries met at the Putra World Trade Center in Kuala Lumpur, Malaysia. Some 911 full papers were accepted out of 1324 abstracts submitted. The congress covered seven main themes comprising:

- River and Sediment Management
- Flood Management
- Environmental Hydraulics and Industrial Flows
- Coastal, Estuaries and Lakes Management
- Urban Water Management
- Water Resources Management
- Hydroinformatics/Computational Methods and Experimental Methods

Our Congress opened on Monday 14th August by The Honourable Deputy Prime Minister of Malaysia. There were a total of 12 keynotes during the week involving leading specialists in the hydro environment domain from around the world. Dr Tyler Erickson, Senior Developer Advocate at Google gave a fascinating opening lecture on democratising access to global water information with cloud technologies (see Hydrolink 2, 2017, page 36-37), and the second opening keynote was given by the Minister for Natural Resources and Environment of Malaysia. The Congress closed on the Friday after the Malaysian Deputy Minister for Science, Technology and Innovation gave a highly personal talk about his education, and the differences between public perception of water and the environment and that of scientists.

Around the congress a series of side events took place. Workshops were held on Google Earth Engine, a Master Class on Hydroinformatics and Water Management, a Forum on Practice and Challenges on Integrated Operation of Hydropower Stations and Reservoirs, and Environmental Decision Support for Hydromet cloud based systems.
A special Forum on the UN Sustainable Development Goals took place in collaboration with other associations including ICOLD, IWA and WASER. A special meeting for Water Research Institutes was organised on Managing Change.
The congress was organised by the Ministry of Natural Resources and Environment, The National Hydraulics Research Institute of Malaysia (NAHRIM), Department of Irrigation and Drainage Malaysia (DID) and the River Engineering and Urban Drainage Research Centre (REDAC) of Universiti Sains Malaysia (USM). The congress was sponsored by China Three Gorges Corporation (CTG) (platinum) and the Prince Sultan Bin Abdulaziz International Prize for Water (platinum), together with DHI (gold) and four silver sponsors including HR Wallingford, ADASFA, TCK SCADA and Embassy of the Kingdom of the Netherlands. The congress had a uniquely large exhibition with 40 exhibitors present.

A special reception hosted by Taylor and Francis took place on the Tuesday of Congress to celebrate the development of our portfolio of five IAHR Journals. A range of specialist meetings of IAHR technical committees and regional groups (Asia Pacific, Latin America and Africa) took place during the congress including a special session on the UN Sustainable Development Goals, and a meeting on managing change for the Water Research Institutes which was chaired by Prof. Dr. Shahbaz Khan, head of UNESCO Jakarta.

IAHR News: General Members Assembly

Opening
The IAHR Annual General Members Assembly was chaired by the IAHR President Peter Goodwin during the IAHR congress at the Putra World Trade Centre on Thursday 16th August at 16:00-17:00 with around 60 members present. The minutes of the 2016 General Members Assembly in Colombo, Sri Lanka were circulated to those present and were unanimously approved.

Council Elections
The results of the 2017 Council Elections organised by the 2017 Election Nominating Committee chaired by Prof Bruce Melville were announced. Please find a list of the complete council including the newly-elected members on page 90.


Deputy Prime Minister during the Opening Ceremony


Congress Dinner


IAHR Asia Pacific Division Leadership


IAHR President Peter Goodwin and Azazi Zakaria, Deputy Chair of the LOC


Opening Keynote Speaker Tyler Erickson, Google

	2016	2015
Revenue from continuing operations	299,707	291,098
-from members and users	179,584	181,098
-from promotions, sponsors and associates	9,844	-
-Operating grants, donations and bequests	110,279	110,000
Monetary and other aid	(3,428)	(1,932)
-Expenses for collaboration and governing bodies	(3,428)	(1,932)
Sales and other ordinary income	188,169	147,511
Cost of sales	(86,351)	(86,903)
Other operating income	4,717	4,735
-Supplementary and other operating revenue	4,717	4,735
Personnel expenses	(288,229)	(275,825)
Other operating expenses	(104,144)	(105,800)
Depreciation and amortization	(9,782)	(9,782)
Other results	(10,287)	(10,994)
SURPLUS (DEFICIT) BEFORE TAX	2,971	(78,190)

ASSETS	2016	2015
NON-CURRENT ASSETS	106,340	103,921
Intangible assets	44,922	53,907
Tangible assets	1,347	2,143
Financial investments	80,071	47,871
CURRENT ASSETS	194,993	236,184
Inventories	-	-
Trade and other receivables	97,368	100,255
Financial investments	2,294	2,927
Prepaid and other current assets	4,317	2,798
Cash and cash equivalents	91,014	130,204
TOTAL ASSETS	301,333	340,105

2016 Financial Report

The 2016 financial report was presented by Prof Arthur Mynett, Chair of the Finance Committee. The results, which have been audited by Ernst & Young, show a net surplus for the year of 2,971 Euros which compares with a loss of 78,190 in the previous year.

Although the 2015 loss has been reversed, Prof Mynett expressed the Task Force concern that the reserves of the Association need to be higher, and that efforts should be made by the Association to rebuild them.

The Finance Task Force recommends:

- to continue monitoring of IAHR operations,
- that the budgeting process should be improved,
- efforts should be made to replenish reserves by for example, increasing membership, and more fund-raising.

IAHR is very grateful for the continuing support of Spain Water, both financial and in kind, which is fundamental to our operations in Spain, and for the support of IWHR for our operations in China.

Secretariat Report

Dr George reported the long-term growth trend in membership of IAHR which in mid-2017 has reached a level of 4565, with a strong development of the Young Professional membership to 1933. He also reported that around 20% of our membership at this time is estimated to be female.

During 2017 IAHR for the first time collaborated with a major trade fair (IFEMA – which is the largest trade fair in Spain) to organise the first HydroSenSoft exhibition and conference aimed at showcasing innovation in rapidly evolving sensor technologies for the hydro-environment, and in data analysis and management. This was the first conference of our Experimental Methods and Instrumentation Technical Committee, and a second event has already been confirmed for 26 Feb-1 Mar 2019. Progress in the development of a new internet member management system for the Association was reported. The new system will be platform independent and will include a much improved repository for conference papers, and a special module for conference management available to all IAHR sponsored events.

Publications

IAHR Vice President James Ball, who has council member responsibility for publications, reported on recent special issues of our Hydrolink magazine, and presented news that two of our journals have recently been accepted for indexing in Thomson's ESCI, and another, JAWER, in Scopus.
The new Journal of Ecohydraulics was successfully launched during 2016 edited by Christos Katopodis and Rob Kemp, and with the with the invaluable support of IWHR in China.
Prof. Ball also reported on important new IAHR Monographs which have just been published in the T&F IAHR Book Series called "Experimental Hydraulics: Methods, Instrumentation, Data Processing and Management", and a new Edition of the highly-popular "Fluvial Hydraulics".

Town Hall Meeting: Futuring IAHR

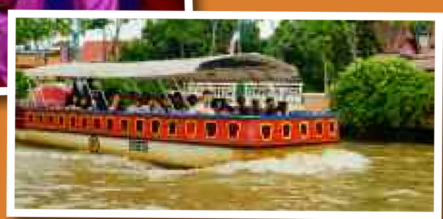
IAHR President Peter Goodwin reported to the GMA that the Council has established a specific Task Force to look at the future of IAHR. The Council sees a wide range of issues affecting the future viability of our association: Employers expect more return on investments, professionals expect value, there is more competition with for-profit programmes and services, members have less time to participate in meetings and committees, the younger generation has different expectations, to name but a few.
The Task Force invites all Technical Committees, Divisions and all members to share thoughts on these issues, and how IAHR should adapt.
Vice Presidents Arthur Mynett and James Ball kicked off this process by inviting the audience to make suggestions. Ideas and suggestions will be reported in a later issue of Hydrolink. ■


Opening Ceremony


Congress Dinner


Technical Visit to Smart Tunner


YPN Technical Tour to the Putrajaya Lake


Technical Visit to Melaka River

NEW IAHR COUNCIL FOR 2017-2019

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Dr. Peter Goodwin
President of University of Maryland
Center for Environmental Science
UNITED STATES OF AMERICA

(elected until 2019)

Executive Director (ex-officio)
Dr. Christopher B George
IAHR Secretariat
Madrid Office
Beijing Office

Vice Presidents
Prof. James Ball
University of Technology Sydney
Faculty of Engineering
School of Civil and Environmental Engineering
AUSTRALIA

(elected until 2019)

Prof. Arturo Marcano
CVG EDELCA
Hidroeléctrica Macagua
Departamento de Hidráulica
VENEZUELA

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Prof. Silke Wieprecht
Universität Stuttgart
Department of Civil and Environmental Engineering
Institute of Hydraulic Engineering
GERMANY

(elected until 2019 R)

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China Institute of Water Resources and Hydropower Research
CHINA

(NB R* means eligible for re-election for a second term)

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Dr. José N. de Piérola C.
Chair of the Latin American Division
Southern Peru Copper Corp
PERU

Prof. David Stephenson
Chair of the Africa Division
BOTSWANA

Prof. Corrado Gisonni
Chair of the Europe Division
2nd University of Naples
Department of Civil Engineering
ITALY

IAHR AIRH

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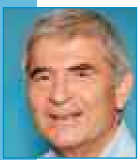
2017 AWARDS AT THE 37th IAHR WORLD CONGRESS IN KUALA LUMPUR

Honorary Membership

Roger Falconer, UK
In recognition of his outstanding contribution in promoting the development of computational modelling in hydro-environment engineering and research, and for his devoted service to IAHR in various capacities and, especially, as President of the Association during the period 2011 and 2015



Jörg Imberger, Australia
In recognition of his outstanding contribution in establishing the field of physical limnology, and as a founder member of the IAHR ecohydraulics community

Zhaoyin Wang, China
In recognition of his outstanding contribution in the field of sediment transport and river dynamics, and for his devoted service to IAHR in various capacities including most recently service as Vice President during the period 2011-2015

6th M. Selim Yalin Lifetime Achievement Award

Marcelo H. García, USA
In recognition of outstanding contributions in the field of numerical morphodynamics and especially in the excellence of his teaching and mentorship of young professionals as well as contribution to applied projects

20th Arthur Ippen Award

Qiuwen CHEN, China
In recognition of outstanding contributions in the field of environmental hydroinformatics and ecohydraulics

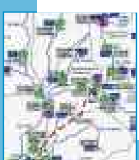
13th John F. Kennedy Student Paper Competition

The following two students win the JFK Student Paper Competition award, as their papers and presentations are of equal, first-place merit:

Isabella Schalko (ETH-Zurich)
for her paper Large wood accumulation probability at a single bridge pier

Sabine Chamoun (EPF-Lausanne)
for her paper Venting of turbidity currents: when to act?

2nd Hydro-Environment Industry Innovation Award



Stormwater Management and Road Tunnel (SMART), Malaysia
Article "Stormwater Management and Road Tunnel (SMART) Flood Detection System, Operation and Performance" published in Hydrolink 2, 2016

20th Harold Jan Schoemaker Award

Bernhard Vowinckel, UC Santa Barbara
for the most outstanding paper published in the Journal of Hydraulic Research during the period 2014-2016
"Entrainment of single particles in a turbulent open-channel flow: a numerical study" J. Hydraul. Res., 2016, 54(2), 1578-171

Ramandeep Jain, TU Dresden
for the most outstanding paper published in the Journal of Hydraulic Research during the period 2014-2016
"Entrainment of single particles in a turbulent open-channel flow: a numerical study" J. Hydraul. Res., 2016, 54(2), 1578-171

Tobias Kempe, TU Dresden
for the most outstanding paper published in the Journal of Hydraulic Research during the period 2014-2016
"Entrainment of single particles in a turbulent open-channel flow: a numerical study" J. Hydraul. Res., 2016, 54(2), 1578-171

Jochen Fröhlich, TU Dresden
for the most outstanding paper published in the Journal of Hydraulic Research during the period 2014-2016
"Entrainment of single particles in a turbulent open-channel flow: a numerical study" J. Hydraul. Res., 2016, 54(2), 1578-171

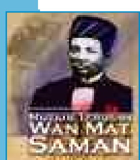
2017 Willi H. Hager JHR Best Reviewer Award

Claudia Adduce, Università RomaTre
For outstanding reviews in the Journal of Hydraulic Research during the period 2015 - 2016

Koen Blanckaert, The Hong Kong University of Science and Technology
For outstanding reviews in the Journal of Hydraulic Research during the period 2015 – 2016

Sk Zeeshan Ali, Indian Institute of Technology Kharagpur
For outstanding reviews in the Journal of Hydraulic Research during the period 2015 - 2016

3rd Hydro-Environment World Heritage Award



Terusan Wan Mat Saman (Wan Mat Saman Canal)
Muda Agricultural Development Authority (MADA)

For more information on the awards & winners visit: www.iahr.org

尚水股份
SINFOTEK

WM The Intelligent Management System of Sponge City

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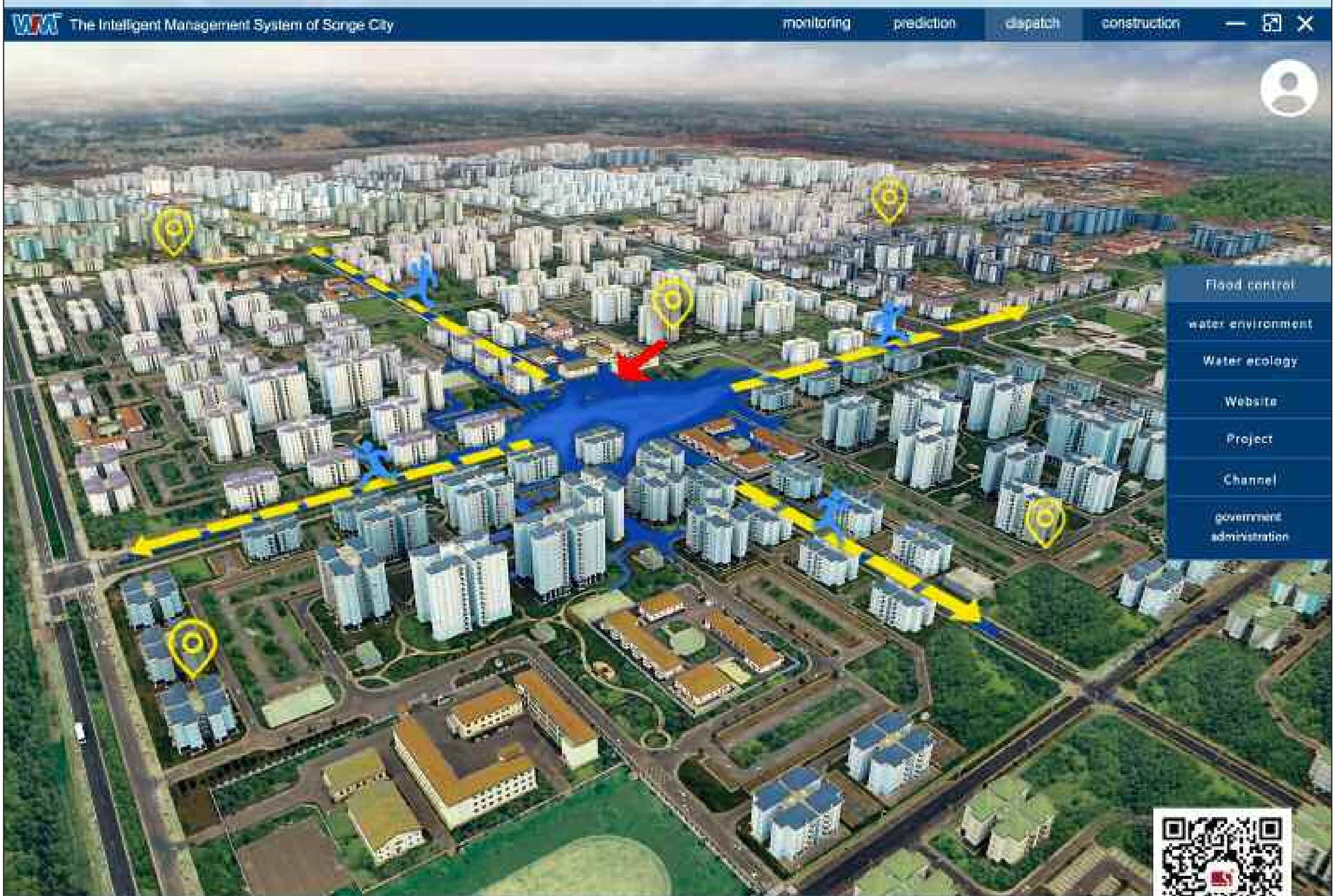
COMPREHENSIVE CONTROL

Intelligent application management system for integrated water ecology, water environment, water resources and water security

SOLVING MULTI-LEVEL PROBLEMS

Alleviating urban flooding, reducing urban runoff pollution load, saving water resources, protecting and improving the urban ecological environment



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