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SPECIAL ISSUE: SENSORS, DATA ACQUISITION & ANALYSIS SOFTWARE

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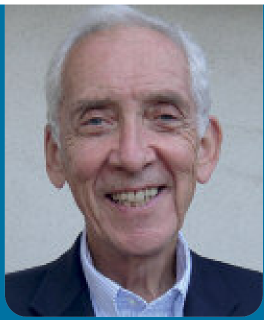
SENSORS AND DATA ACQUISITION AND ANALYSIS SOFTWARE

EDITORIAL BY ANGELOS N. FINDIKAKIS & RUI ALEIXO



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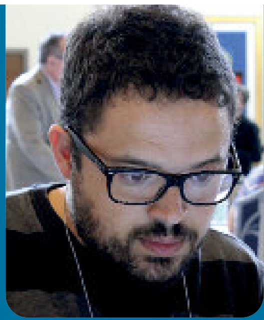
Hydrolink Editor



Rui Aleixo
Guest Editor

Sensors, instrumentation, and data acquisition and processing software are essential tools in basic research, as well as in searching for solutions to engineering and environmental problems. Hydraulics and hydro-environment research and engineering have benefitted greatly from advances in sensors and electronics. As an example, laser and acoustic based instrumentation, which make possible the rapid acquisition of accurate high-resolution data in the laboratory, have made it possible to study many flows over a broad range of time and spatial scales. In many cases, using multiple sensors sampling at high rates produces large amounts of data, which require efficient software tools to manage, filter, process, and reduce them to the point that they can be used to improve the understanding of the physical processes being monitored and validate numerical models for their simulation.

Recognizing the importance of sensors, instrumentation and software for processing and modelling in hydraulics and hydro-environment research and practice, IAHR through its Experimental Methods and Instrumentation (EMI) committee has organized over the years several technical events on these subjects. The latest of these events is the International Symposium and Exhibition on Hydro-Environment Sensors and Software, Hydrosensoft 2017, in Madrid, which aims at bringing together a diverse group of researchers, engineers and developers of instrumentation for data acquisition and supporting software. The publication of the current issue of Hydrolink coincides with the opening of Hydrosensoft 2017, and includes articles by some of the participants in this meeting, who provide examples of different new tools for use in field data collection, in the coordination of data from multiple sources and in hydraulic laboratory studies.

An example of the challenges encountered in using multiple sensors to obtain high-accuracy synchronized water level data in harsh environments is given in the article by Bousmar, Savary, Swartenbroekx and Zorzan that discusses data acquisition in navigation locks for use in optimizing performance.

The article by Sánchez-González, Gutiérrez-Serret, and Martín-Soldevilla describes use of digital imagery in laboratory studies of coastal hydrodynamics and morphodynamics at the Centre for Harbor and Coastal Studies of CEDEX in Madrid. The same article discusses also the measurements made in wave overtopping studies for breakwaters in harbors performed in the same laboratory.

Using large data sets efficiently is challenging, especially when real time decisions must be made as the data come in. Extracting timely and actionable information may require the use of artificial intelligence, machine learning and real-time predictive analytics. The article by Moya discusses the use of advances in these fields to develop a water network management system that helps water utilities making operational and maintenance decisions, and describes how this system is used by the utility that serves the city of Karlsruhe in Germany.

Another example of efficient use of large volumes of data is the Copernicus Emergency Management Service system described in the article by Natschke. This system, which was designed to support flood preparedness and forest fighting and prevention efforts, collects and validates meteorological observations across Europe, and uses them to produce maps of essential variables on a 6-hour basis, made available for downstream usage as input to flood and forest fire hazard forecast systems.

The development of new instruments helps not only provide new insights into the physics of different phenomena, but it also contributes to overcoming current limitations of existing instruments. It improves measurement reliability, but it also can create new challenges. For example, continuously recording data, including digital images, often requires very large storage capacity and long processing times. The article by Aleixo, Mendes, Antico and Ferreira presents an innovative way for bypassing this problem in hydraulic laboratory experiments for sediment transport studies by using pressure signals to count bedload particles instead of capturing and processing digital images. This reduces significantly the volume of data collected, stored and analyzed and offers the possibility of assessing test results in real time.

Collecting and processing data to extract essential information on different physical processes, and developing models to simulate and possibly control some of these processes are standard parts of the scientific method. However, as demonstrated in the articles of this issue, scientists and engineers do not work in a vacuum. In many instances their work serves specific communities whose trust is essential for the successful completion of their projects. Technical rigor is not enough by itself to establish such trust. In addition to transparency about the technical approach to the solution of specific problems, it is necessary to raise public awareness about their broader context and some of the major challenges in water resources planning and management such as climate change, pollution, sustainability and water security among others. Education and community outreach actions are essential in efforts to increase public participation in the decision-making process for water projects. Two of the articles in this issue discuss the use of serious gaming, as one of the tools used for this purpose.

Serious gaming has been used in education and community engagement and now is making its way into hydraulics and water project applications. A serious game is a game whose main objective is not entertainment, but training different players in how to operate in a set of diverse situations. A classic example of serious gaming is the use of flight simulators, where pilots train in a controlled and yet realistic environment and practice different strategies of flying a plane without being in any danger. Two articles in this issue describe the use of serious gaming in water resources planning and management. The article by Muste, Demir, Smith and Carson illustrates how serious gaming can be used to test different strategies for reducing drought and flood risks and for improving water quality by engaging different stakeholders and community actors in an effort to create strategies to address these problems. Similarly, the article by Chew and Lloyd describes a serious gaming initiative, called Aqua Republica, which includes the development of online games dealing with sustainability and water allocation issues, and their use in government strategy workshops, national competitions and stakeholder engagement workshops in different countries.

The articles published in this issue illustrate how quickly the hydraulics community can adopt and use advances in other fields ranging from sophisticated sensors, electronic instrumentation, and big data management and processing to artificial intelligence, machine learning and new approaches for stakeholder and community engagement such as serious gaming.

"Measure what is measurable, and make measurable what is not so."
Attributed to Galileo Galilei (1564-1642)

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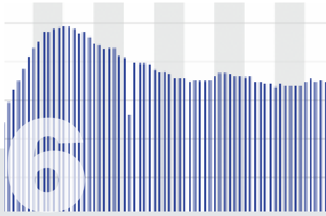
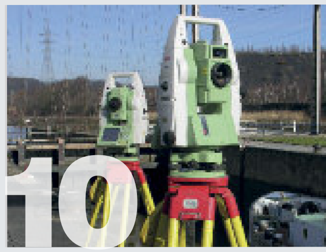
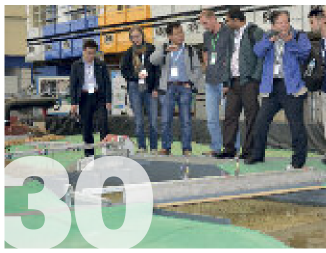






"Remember, when discoursing about water, to induce first experience, then reason."

Leonardo da Vinci (1452-1519)

Sensors, data acquisition & analysis software

COLLECTING IN SITU METEOROLOGICAL DATA AT EUROPEAN SCALE TO SUPPORT THE COPERNICUS EMERGENCY MANAGEMENT SERVICE

BY MICHAEL NATSCHKE

The early warning service of the Copernicus Emergency Management Service (EMS) is composed of the European Flood Awareness System (EFAS) and the European Forest Fire Information System (EFFIS). Both systems provide national and regional authorities as well as the European Commission services with harmonized and added value information to forecasts on floods and forest fire hazards at the European scale. A key component for the operation of of both systems is the Meteorological Data Collection Centre (EMS-MDCC). It has been designed to collect and to validate meteorological observations, to produce a European grid of 5 km by 5 km of essential variables on a 6-hourly basis and to make it available for downstream usage as input to the forecast systems.

Increasing the emergency prepardness on a European scale

Initially triggered by the severe Elbe and Danube floods in 2002, the European Commission successively invested into an inter-governmental emergency management infrastructure. Today – under the umbrella of the Copernicus Emergency Management Service (CEMS) [1] - continuous early warning, rapid mapping services as well as risk and recovery mapping services are delivered to the member states to increase the emergency preparedness and strengthen the emergency response including both forest fires and floods (Figure 1).

EFFIS supports public agencies in the European Union (EU) in charge of forest fire protection and provides updated and reliable information on wildland fires to the European Commission and the European Parliament (http://forest.jrc.ec.europa.eu/effis/). To increase the preparedness of stakeholders, EFFIS delivers a continuous fire danger and fire weather forecast on both a short-term and a long-term forecast horizon of up to 2 months. EFAS is the first operational pan-European system for the monitoring and forecasting of floods (https://www.efas.eu/). It provides complementary, flood early warning information up to 10 days in advance to its partners: the regional and national hydrological services as well as the European Response and Coordination Centre (ERCC). Floods such as triggered by Storm Desmond in December 2015 in the UK or the Balkan flood Mai 2014 have been forecasted with a lead time of 4 days. The EFFIS and EFAS early warning services are fully operational and require high quality meteorological data feeds in real-time. To harmonise the data base of both, the Copernicus Emergency Management Service established the joint Meteorological Data Collection Centre (EMS-MDCC) that is operated by the German Solution Provider KISTERS and the Global Precipitation Climatology Centre (GPCC) of the German Meteorological Office (DWD).

Operational data collection and validation

In 2014, the Joint Research Centre (JRC) of the European Commission published a tender for a 6-year service contract to setup and operate the EMS-MDCC to support the early warning systems of the CEMS. This service contract builds the foundation to establish a process for the sustainable collection and validation of meteorological data on a European scale.

In 2015, the solution provider KISTERS and the GPCC have been awarded with the contract to establish and operate the EMS-MDCC. KISTERS – as a technology provider – is hosting and operating the EMS-MDCC on a 24/7 basis. The meteorological data is collected and validated upon arrival in close cooperation with domain specialists of the GPCC/DWD. The EMS-MDCC receives meteorological data from 12 European Providers. In total more than 70,000 instances of essential parameters are collected, validated and processed on a daily basis, which include instances of cloud cover, dew point temperature, relative air humidity, solar radiation, precipitation, sunshine duration, air temperature, vapor pressure and wind speed and direction. The timeliness ranges from real-time over 15 minute to hourly and daily deliveries.

Figure 1. Copernicus Emergency Management Service - continuous early warning, rapid mapping, risk and recovery mapping services to support crisis preparedness, response and recovery operations [2]

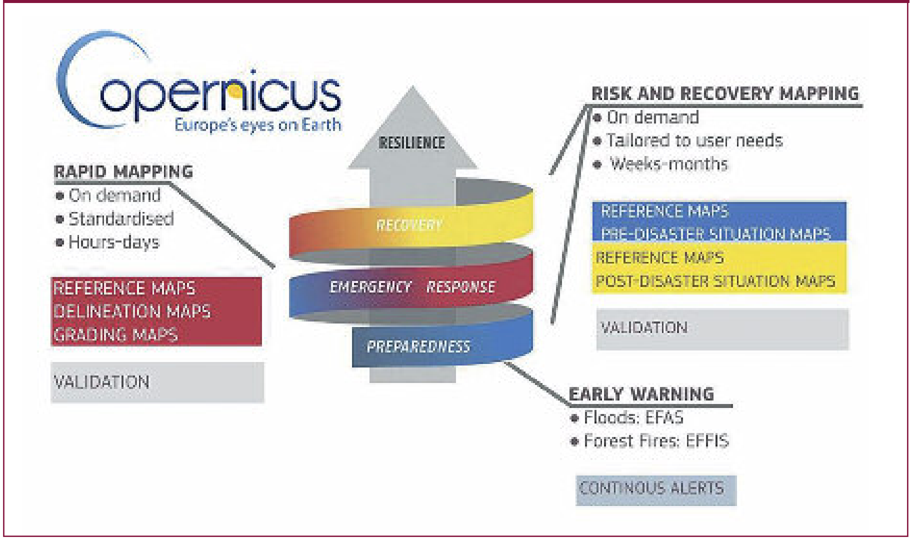
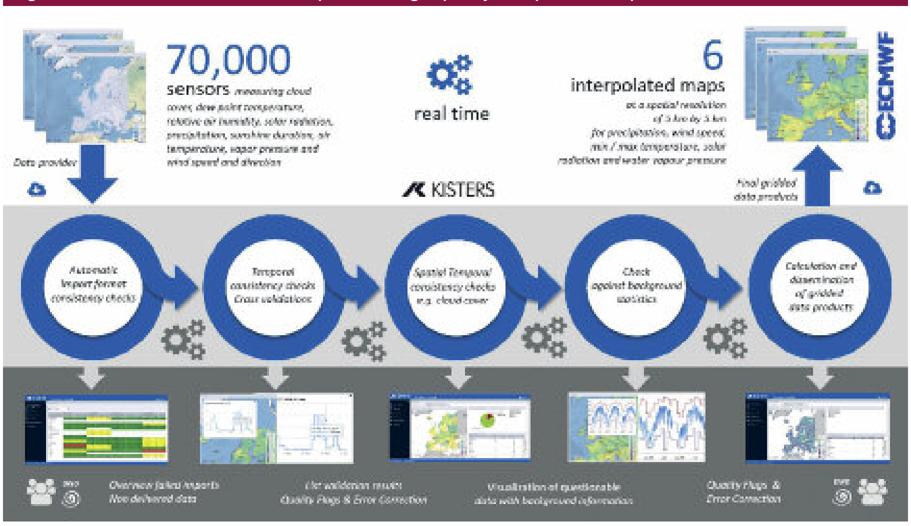


Figure 2: The KISTERS workflow to produce high quality interpolated maps inside the EMS-MDCC



Michael Natschke **is Head of Business Development of KISTERS' Global WATER Business Unit and has a solid track record in KISTERS Water Software Product Management and Key Account Management. He is a graduate in Water Resources Engineering from Aachen University / Germany.**

Michael has considerable experience in the design, architecture and implementation of data management systems at regional, national and global scale. He is a leading team member in making KISTERS' WISKI software a success in international markets and is responsible for steering software engineering into a future-oriented design implementing state-of-the-art technology and architectures fusing classical time series data management with big data analytics optimized for environmental data processing with emphasis on hydrology and meteorology.

In close collaboration with the JRC, a multi-layered quality assurance workflow has been setup to distinguish formal data delivery failures (including non-delivered data and format issues) from implausible data (Figure 2). Implausibility is detected automatically by a combination of the following rules set:

- **Interval consistency** rule ensures both availability of data (e.g. one value every hour, or every 6 hours) and the coherence of timestamps (e.g. timestamp at 12:00 and not at 12:02) within the expected time grid.
- **Outlier against monthly statistics:** Newly imported data is validated against computed monthly statistics. The monthly statistics include a set of long-term values which are updated monthly based on high quality data. Historical data is re-validated against newly calculated monthly statistics. Data outside of the range of monthly statistics gets flagged as "suspect".
- **Outlier or inconsistant rate-of-change against fixed thresholds**: Incoming data is validated against min/max thresholds. This includes their change to previous interval values. The thresholds are fixed but may depend on e.g. min or max dew point temperature, accumulation period (precipitation) or on geographical position and Julian calendar date (sunshine duration).
- **Cross variable validation rules** compare data with values of other variables at the same location. This rule is applied only on dew point temperature and on wind speed.

All incoming data is considered as high quality by default. Data that did not pass the automatic validation rules are downgraded and potentially excluded from further data processing (Table 1). The downgrade can lead to data periods being completely rejected from further processing. The GPCC team of specialists is supervising the overall quality assurance process and may interact manually where applicable.

Reliable data products for EFFIS and EFAS

EFFIS receives regular exports of the European meteorological conditions on a daily basis to forecast fire danger and fire weather. The deliverables consist of products of precipitation, air temperatures, wind speed and the relative air humidity.

LISFLOOD [3], the hydrological forecasting model of EFAS, runs at the EFAS Computational Centre hosted by the European Centre for Medium-Range Weather Forecasts (ECMWF). It requires a set of gridded data products as input. The EMS-MDCC computes these products continuously for precipitation, wind speed, min / max temperature, solar radiation and water vapour pressure at a spatial resolution of 5 km in the European domain. The grids are computed from ground observations by applying spatial interpolation methods as provided by the PCRASTER package[4]. The EMS-MDCC's spatial and temporal analytics provide a state-of-the-art technology stack for the automated data processing, starting at technical metrics regarding the download, import and processing of various data feeds, the data consistency of time series as well as primary and secondary data validation checks towards the generation of gridded products. The processing chain gets completed by modular monitoring and visualization GUIs which enable the domain experts of DWD to supervise the process, identify exceptions and interact, if required. ■

Table 1: The EMS-MDCC quality codes and their impact on the final data product

Quality Code	Key	Colour code	Meaning	Process relevance
Good	40	Green	Data passed all quantity and quality checks.	Data is included in grid processing and further aggregations.
Suspect	120	Yellow	Comparison checks against long term statistics failed, cross parameter validation failed.	Data is included in grid processing and further aggregations.
Rejected	160	Magenta	At least one of the Min/max or rate of change against fixed thresholds is violated.	Data is excluded from grid processing and further aggregations.
Missing	255	Red	Data is expected but not present	Data is excluded from grid processing and further aggregations.

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NEXT GENERATION INFORMATION AND COMMUNICATION TECHNOLOGY FOR SMART WATER UTILITIES

BY CAROLINA MOYA

The process of making operational and maintenance decisions in a water network management involves the analysis of a huge number of highly interrelated variables. Current management software systems are based on data gathering and modelling technologies. Nevertheless, an increased complexity in monitoring is rarely a synonym of a better efficiency. Having taken this into account, it can be certainly suggested that new approaches and technologies are required to leverage the already existing ones. A combined work of artificial intelligence, machine learning and real-time predictive analytics forms a decisive part of the next generation of Information and Communication Technology (ICT) systems for Water Utilities.

Water distribution systems face socio-economic, sustainability and resilience related challenges which include: overuse due to population growth, underestimation of the value of water, lack of coordination among actors, operational issues (ageing, leakages, quality, pressure, etc.), increasing energy prices and the need to respond to climate change issues. Large amounts of water-related environmental data are already being reported from local to supranational level. However, there is still a lack of a holistic approach to the assessment of resource efficiency and environmental performance of water utilities.

Hydraulic, economic, social, environmental and quality variables are highly interrelated. An optimization of energy consumption, supply risk, water storage levels or pressure might cause low performances in other variables or even not reliable scenarios. Therefore, to be able to take reliable operational decisions in water distributions systems, it seems unavoidable to turn to multi-criteria approaches.

Next Generation ICT support for Water Utilities

Nowadays, the definition of Smart Water Networks is associated with Supervisory Control and Data Acquisition (SCADA), hydraulic modelling, Geographic Information Systems (GIS), Big Data analysis, etc. At best, all those software and datasets work collaboratively to achieve a better understanding of what is happening in the water supply system. But, is this really smart or is it all about data ingestion? Does always having a large quantity of data lead to smarter decisions? Data collection is currently useful, but the key factor should be to be able to extract all the knowledge that is actually available in each piece of data.

A Smart Water Network involves evaluation of problems, elaboration of solving strategies and decision making and action taking. This article is introducing an application of innovative ICT developed for and applied to the water distribution sector. WatEner represents a non-structural solution for Water Utilities management having a great impact on several matters (e.g. climate change, carbon footprint, balance sheets, water losses, non-revenue water, long-term infrastructure planning, water sources) leveraging past investments in sensors, simulation models or GIS data.

WatEner is a next generation ICT solution that combines the key factors of energy consumption with further operational requirements of drinking water supply, to

Figure 1. WatEner. From information to knowledge

improve the management of water supply networks. In this regard, the results of the test case of the Karlsruhe Water Utility in Germany will be next outlined.

To achieve its objectives, WatEner makes use of innovative technologies in the generation of knowledge. Such knowledge is expressed as relations and foreseeable evolutions from existing information: sensor data, simulation models, GIS or infrastructure's technical characteristics. A set of Artificial Intelligence techniques is applied to provide short-term (real-time, operation) and long-term (infrastructure planning, maintenance) recommendations. Moreover, all the data, information and knowledge are shown in a very user-friendly web application, designed by and for water managers.

On the one hand, pattern recognition techniques are used to provide a ten-minute water demand forecasting for each district metering area of the network, based on the most similar day methodology. On the other hand, they are also applied for searching reliable operational strategies, taking into account customizable key performance indicator (KPI) which results related to key factors in water supply systems (e.g. energy efficiency, economic cost, water usage, quality of service, water quality).

Moreover, business rules inference engines are very powerful instruments in charge of the assessment of the operational strategy. The expert knowledge of the Water Utility team is captured and adopted in evaluating policies, best practices, supply risk assessment, feasibility and any other operational matter. Also, these techniques allow to gather and improve the expert knowledge and to maintain it within the organization.

Machine learning procedures provide the capability to continually improve the operational and planning recommendations. Through training modules designed for both expert water managers and operators, the ICT system and the expert staff learn how to operate better. Training modules will collect and assess operational strategies to face normal, abnormal or even theoretical situations.

Finally, the aim of the real-time predictive analysis is to check if during operation, the network situation evolution is proceeding as expected or if any anomaly can compromise the service. This module helps operators to track network events, detect service anomalies and compare them with the expected service KPI, not only in terms of quality of service, but also in energy, water and economic-cost efficiency. Furthermore, WatEner incorporates a rich set of dashboards designed for water managers, apt to enable easy access to events, operational recommendations and KPI. They are designed to incorporate the indispensable knowledge required by the distinct job profiles and the operational and business management in a Water Utility to perform their tasks in the best way possible. In addition, the platform is equipped with a special dashboard for the public/customers, intended to transparently provide information on the supply system, the quality of the service and the state of the water resources.

The case of Karlsruhe city

In 2009 the city of Karlsruhe (Germany) together with all its companies committed themselves to reduce their energy consumption and carbon footprint by 2% each year. Since then a lot of effort was made in drinking water supply already, e.g. investments in more energy efficient groundwater pumps feeding the water treatment facilities, power transformers, compressors and electric lighting. Stadtwerke Karlsruhe GmbH (SWKA) is the local energy (electricity, natural gas and long distant district heat) and drinking water supplier for the about 400,000 inhabitants of the region of Karlsruhe in Germany. Its shares are majority-owned by the city of Karlsruhe.

The SWKA network has four water works located around Karlsruhe that produce drinking water from the upper layer of an aquifer. The treatment of the raw water comprises the aeration and the removal of iron and manganese by biological sand filtration. Each of the water works has four network pumps with constant pump rates. The total drinking water consumption in the region of Karlsruhe is around 24 Hm^3 per year, or 65,000 m^3 per day.
The drinking water network has a length of more than 900 kilometers. Most of the city is located in one pressure zone, fed by all four water works. Attached to that pressure zone, there is a water storage tank of approximately 20,000 m^3 located about 50 m above street level, that stabilizes and controls the water pressure in this main pressure zone.
In this context, one of the present tasks for SWKA is the optimization of the daily pumping schedules of the treated drinking water fed into the distribution network and of the water storage tanks management. Furthermore, some important requirements have to be fulfilled: the water supply must always be assured, the highest possible water quality is not to be put at any risk and the energy costs should also be as low as possible.

In this case, the main objective of the implementation of WatEner sought to respond to the needs and requirements in terms of

Carolina Moya **is the technical director of WatEner. As Computer Science Engineer she has dealt with different technologies, always involving and focused on geographical information systems, geographical location systems, OGC services, sensoring and so on. Carolina specializes in Hydrological and Hydraulic modeling software for the management of resources and real time systems. She is constantly looking for the perfect match between high-performance/ high- availability systems and the main core of the hydraulic and hydrological know-how.**

Figure 2. Average daily consumption day

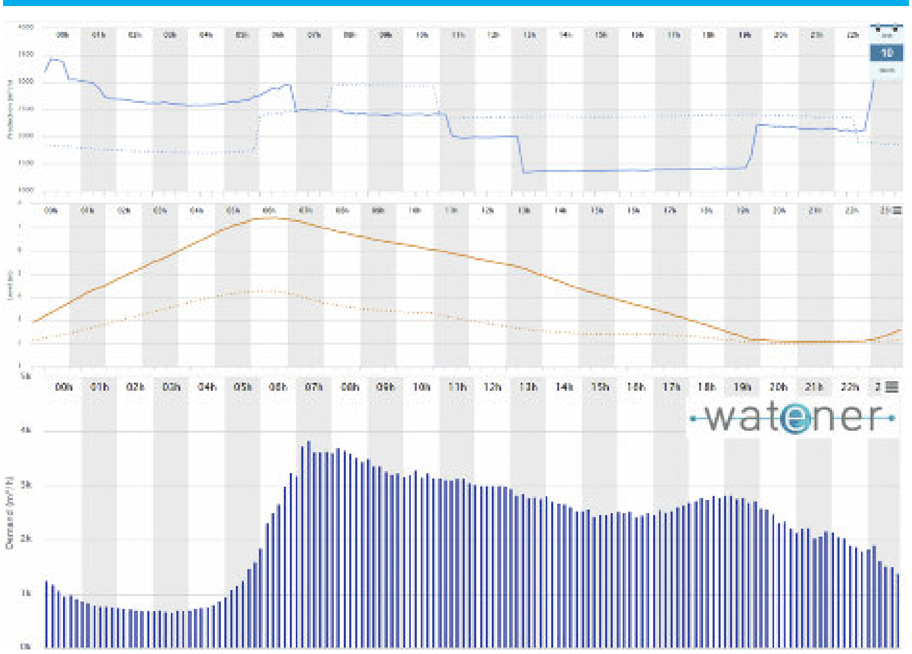
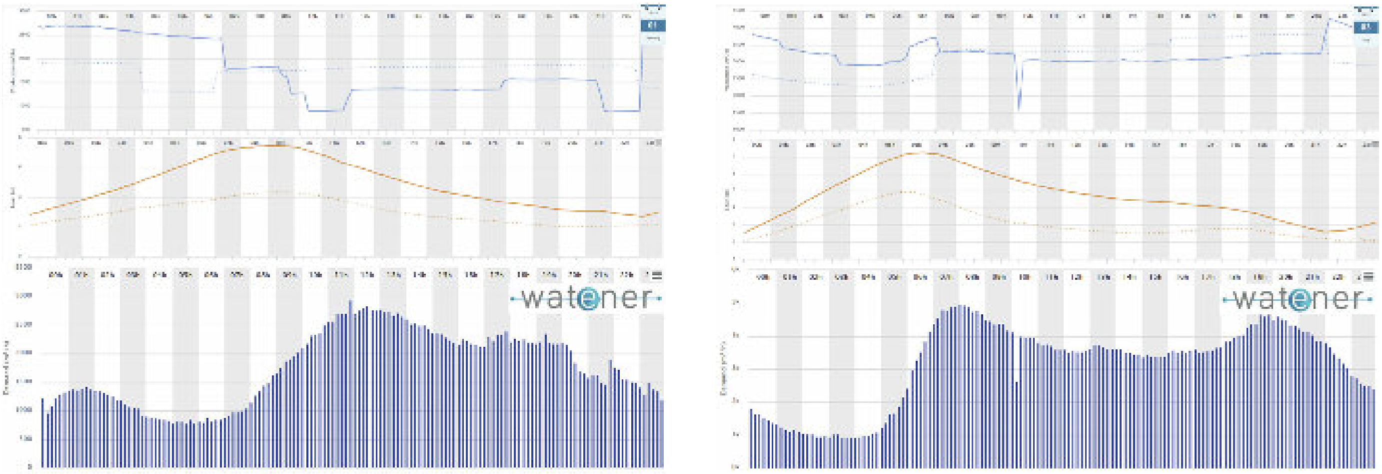


Figure 3. Minimum and maximum consuption days



energy saving and emission reduction, focusing on the following areas: (i) demand forecast of drinking water, (ii) management of the water storage tanks, (iii) pumping schedule of pumps feeding the network and, as a result, (iv) improvement of energy efficiency of the network pumps.

In this network, there are three main factors that can be used to adjust the energy efficiency. First of all, the water level in the main storage tank has a dominant effect on the entire network pressure. A lower water level reduces the pressure in the network and at the output of the water works' pumps, and it also increases the water output for a given energy use.
Secondly, it is possible to affect the energy losses by friction in pipes by maintaining the water velocity in the entire network close to the average velocity. This can be achieved by pumping homogeneous outflows in the water works, which causes less variable flow rates, lower pressure, lower friction and thereby lower energy consumption.

The third main factor is infrastructural; not all the pumps have the same energy efficiency. In most of the operational scenarios, using more efficient pumps increases the average energy efficiency.

Another important element not directly related to the supply network is the electricity tariff. The energy prices in Germany are most expensive from 8 am to 10 am and from 5 pm to 9 pm, and the cheapest ones are between midnight and 6 am. Regrettably, there is a coincidence between higher prices and higher water consumption periods.

In the daily operation before WatEner, the storage tank was filled during night time to benefit from the lower energy prices and fed the distribution network during the day to supply the water demand and avoid pumping during periods of higher energy prices. Also, the pump schedules were created in real time by the water works operators, reacting to the observed behavior of the system. The multi-criteria approach of WatEner was adopted to combine the effects described above to design new pump schedules which optimize energy and do not compromise the quality and level of service. Hereafter, the real effects of the new pump schedules are shown using three significant days of the year 2015: the 1st of January as the lowest water consumption day, the 3rd of July as a very hot summer day and consequently with the highest water demand and the 3rd of March as an average working day.
The Figure 2 depicts the average consumption day management, showing the scenario before optimization (solid lines) and WatEner optimized one (dashed lines). The optimized scenario recommends a pumping schedule where the evolution of total outflow is close to the average during all day and the main tank fills less during the night, avoiding losses by friction and overpressure. Against what would have seemed to be an adequate option, this enhanced scenario through a minor pumping during valley tariff provides an energy saving of 7.5% and cost savings of 7.2% and ensures that water and service quality remain constant and unaltered.

The minimum and maximum consumption days present a similar situation. The WatEner recommendation is to apply a pumping schedule which fills less the main tank during the night and feeds the network with a total outflow close to the average, providing a more efficient

Table 1

	Low demand (January, 1st)		Average demand (March, 10th)		High demand (July, 3rd)	
Consumption	42,200 m^3		54,500 m^3		75,000 m^3	
	Original	**Optimized**	**Original**	**Optimized**	**Original**	**Optimized**
Network pressure	Tank filled to 7.7m	Tank filled to 4.1m	Tank filled to 7.5m	Tank filled to 5m.	Tank filled to 7.4m	Tank filled to 4m
Losses by friction	14 switching operations.	6 switching operations. Outflow close to the average.	20 switching operations.	8 switching operations. Outflow close to the average.	12 switching operations.	5 switching operations. Outflow close to the average.
Energy efficiency	0.2263 kWh/m^3	7.6% lower	0.2237 kWh/m^3	7.5% lower	0.2300 kWh/m^3	6.2% lower
Cost efficiency	0.0379 €/m^3	7.7% lower	0.0374 €/m^3	7.2% lower	0.0385 €/m^3	6.0% lower

operation in terms of energy and cost. Also, water quality and service quality are ensured.

Table 1 summarizes the three scenarios; all the numerical data is extracted from WatEner KPI set. The energy cost reduction for the average consumption day is 147€ (7.2%). With this day as reference the platform saves, only taking into account water production pumping costs, 54,000€ and 334.34 MWh (7.5%) per year.

Conclusion

The size of the population served by a Water Utility, the energy costs and other factors related to particular situation/region, have a major influence on the return on investment (ROI) and water/energy savings that can be achieved with the next generation of ICT solutions.
This article described the implementation of WatEner in a medium-sized Water Utility (400,000 inhabitants) in Germany. In larger and megacities in developed countries, as well as in cities in developing countries too, the savings are expected to be quite similar as in the Northwestern Europe pilot.

Next generation of ICT tools foster a change in the operational paradigm of water utilities by dealing wit relevant matters from a different perspective, specifically by:

- Leveraging of previous investments in monitoring, modelling, GIS and other tools.
- Adopting a multi-criteria and holistic vision of operations. These tools facilitate the assessment of different management strategies in the supply network, improving the savings and preventing inefficiencies in the entire network.
- Dynamically adapting in real-time to the continuous operational issues that can happen in a water supply network, such as temporary halts or services restrictions in some parts of the network for maintenance or failure.
- Adding flexibility to provide useful recommendations, regardless of the technical monitoring level of the water utility.

In conclusion, through the analysis of the above illustrated obtained results, it is reasonable to affirm that non-structural solutions inr the operation water utilities can have a beneficial impact on several significant matters of our age, such as climate change and carbon footprint, as well as affect positively business balance sheets and the control of water losses, all within the range of a reasonable investment.

Acknowledgments

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FEEDBACK FROM 10 YEARS OF FIELD MEASUREMENT ON NAVIGATION LOCKS

BY DIDIER BOUSMAR, CELINE SAVARY, CATHERINE SWARTENBROEKX & GIL ZORZAN

Navigation locks are the keystones of any waterway network. Design of modern locks and upgrade of existing ones rely on detailed hydraulic investigations. Besides numerical and physical modeling, field measurement is a must for existing lock diagnosis; new lock commissioning; and data collection for models validation. Such investigations necessitate specific methods considering the required accuracy of the measurements collected with non-permanent equipment in a harsh environment, while attempting to minimize traffic disturbance.

Locks and inland waterways

Navigation is an environment-friendly way of transporting goods. Its fuel consumption and related carbon emission per ton-kilometer are up to five times lower than for road transport. Navigation generates less noise than rail and road transport and has a much lower impact on natural sites and fauna. Moreover, in developed countries, waterways are usually less congested than railways and roads. As a result, inland waterways transport has an averaged share of 7% of freight in Europe and much higher share in countries with good waterways infrastructure. During the last 20 years, its growth rate rose to 25%.

Improved competitiveness of navigation is notably the result of the growth of inland vessels. Whereas 300 t and 600 t vessels were dominant fifty years ago, the European standard is nowadays a 2000 t vessel, sized 110 m x 11.40 m, for self-propelled units, and tows reaching 9000 t, sized 195 m x 22.80 m, or even more on the downstream part of the Rhine river. Larger vessels require larger locks, and the hydraulic design of these locks calls for more detailed analysis to optimize their performance. Their design has to address two concurrent objectives: (1) minimizing the transit duration, to increase the lock efficiency; and (2) reducing the perturbation generated in the lock chamber by the leveling waves, to limit the mooring forces and the risk of accidents during leveling (PIANC, 2015). Existing locks can also be re-engineered to improve their performance accordingly.

Figure 1. Measuring vessel position at Roselies lock

The constant progress of numerical and physical modeling methods supports such improved designs. Nevertheless, in many cases the field collection of hydraulic data on locks remains very valuable. Data collection may be required for improved understanding of the physical processes involved during lock leveling and/or as validation data for the improvement of the numerical modeling tools supporting lock design and operations. Data collection can confirm performances during a new lock commissioning. Lastly, data collection is also a convenient support tool for existing lock inspection, to possibly solve a reported problem or to improve its performance.

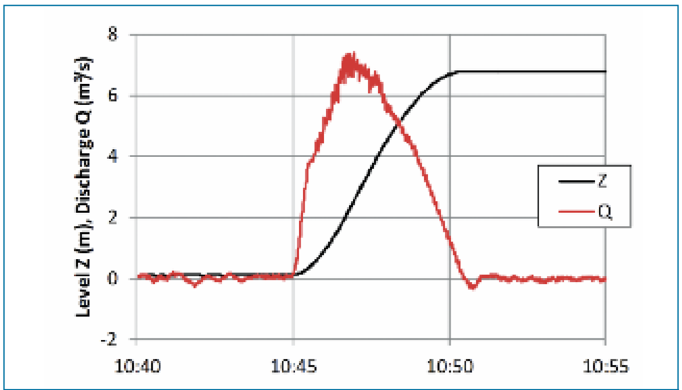


Figure 2. Filling curve for Thieu lock

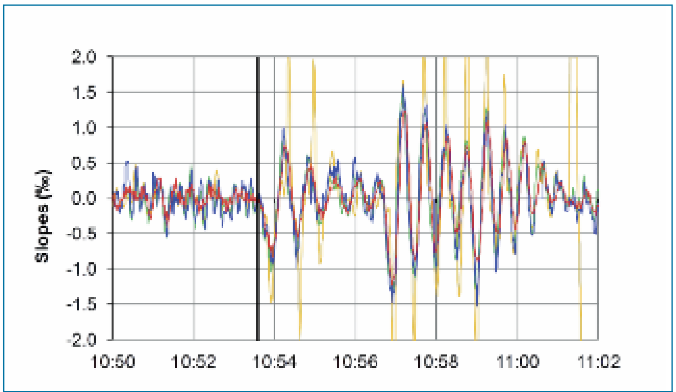


Figure 3. Filling at Roselies lock: water slope (red), vessel slope from total station (green), GPS (blue) and clinometer (yellow)

Lock instrumentation

Standard lock instrumentation is focused on the operation of the electro-mechanical system. It encompasses usually a single water level measurement in the lock chamber, one level in upstream and downstream reaches, gate and valves position, signaling, various electro-mechanic controls (oleo-hydraulic pressure, etc.) and safety equipments (CCTV, etc.). Data logging of these data is only available with recently installed controllers and, in most cases, data extraction for other purposes than electro-mechanical supervision is not easy. Specific data collection is therefore required for hydraulic investigation purposes. The necessary setup has to fulfill several requirements: (1) non-permanent use; (2) possibly harsh environment, with humidity and possible adverse meteorological conditions; (3) limited time available for measurement campaign, to limit impact on traffic; and (4) adequate accuracy regarding the investigated phenomena (Bousmar et al., 2017).

Various parameters should be collected on the lock. Water level is definitively the most important: (1) Direct measurement of the water level in the lock chamber provides the leveling curve and the locking duration; (2) Derivation of the leveling curve gives the total instantaneous filling/emptying discharge; (3) Measuring water level at several places in the lock chamber enables water slope computation; and (4) Level measurement with all gates and valves closed enables accurate estimation of gate leakage. Depending on the study objectives, single or multi-point measurements may be required. Sensors accuracy, time-resolution and synchronization are of particular importance, notably when water surface slope is investigated. Other relevant parameters that can be collected, depending on the measurement campaign purpose, are: pressure in the lock culverts; valves and/or gates position; vibration and/or noise level, notably for cavitation detection; vessel position and trim angle.

Several examples will be illustrated in this article, based on studies performed by the Hydraulic Research Laboratory of the Service Public de Wallonie, Belgium.

Data collection for model validation

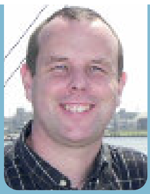
Ten years ago, Wallonia initiated a large investment program on its waterway network, involving the building of several new locks. As support to this program and to the development and the validation of the numerical models used for the new locks design, the Hydraulic Research Laboratory conducted a data acquisition campaign on two locks: Thieu (Canal du Centre historique, 41 m x 5.20 m x drop 6.80 m) and Roselies (Sambre river, 112 m x 12.50 m x drop 3.60 m).

The Thieu lock is mainly devoted to recreational navigation, in such a way that almost no vessel uses this lock between November and March. Test measurements were thus done at this lock to validate the methodology for water surface slope measurement. First level measurements were collected using autonomous pressure probes with integrated data loggers. The leveling discharge $Q = A\,dZ/dt$ could easily be deduced by derivation of the so-recorded leveling curve $Z(t)$, where A is the lock chamber horizontal area (Figure 2). Due to inaccuracies in the time synchronization of the probes, the water surface slope computed from the level difference between two sensors was significantly biased: the difference due to the vertical filling velocity dZ/dt was found to be significantly higher than the actual water slope dZ/dx. Further measurements with other probes, cable-connected to a centralized data acquisition system, solved the synchronization problem and enabled adequate water surface slope estimation.

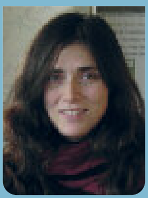
Further improvements of the measurements techniques were tested at the Roselies Lock with notably the objective to track vessel position and trim angle during leveling. The vessel position measurement equipment had to be versatile and easy to install as no specific vessel was hired for the measurement campaign: only the vessels constituting the normal traffic were instrumented. First tests were conducted with video tracking of two targets located at the bow and the stern of the vessels. As no stereoscopic system was used at the time, the lateral movements of the vessels jeopardized the analysis of the video. Further tests were conducted with clinometers and with topographic equipment (Figures 1 and 3). The clinometers did not deliver satisfactory results as a significant overshoot was observed at each peak, with also some slight phase shift at the beginning of the filling sequence. The topographic equipment provided very good results with the use of a pair of automated total stations that tracked in x, y and z two target prisms located at bow and stern, in parallel with a pair of GPS receivers. Although one total station suffered a temporary loss of its target prism due to a black cloud of smoke released by an old vessel engine, both measurements delivered consistent results. The collected observations confirmed that the vessel follows almost exactly the water slope. The analysis also highlighted the influence of the vessel obstruction on the Eigen frequencies of the waves oscillating in the lock chamber.

New lock commissioning

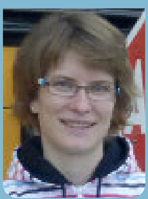
The new locks of Ivoz-Ramet (Meuse river, 225 m x 25 m x drop 4.45 m) and Lanaye (Canal Albert, 225 m x 25 m x drop 14 m) were commissioned in 2016. The measurement



Didier Bousmar **holds a PhD in hydraulics from the Université catholique de Louvain (2002). He has been working in the Hydraulic Research Laboratory of the Service Public de Wallonie, Belgium since 2004 where he has been in charge of various studies on navigation locks, river weirs and fish passes, involving not only numerical and physical modeling, but also field investigations. Didier Bousmar has more than 20 years of experience in fluvial and structure hydraulics.**



Céline Savary **obtained her PhD in hydraulics from the Université catholique de Louvain in 2007. She joined the Hydraulic Research Laboratory of the Service Public de Wallonie, Belgium in 2009. As a research engineer she has been conducting studies in different subjects such as: navigation locks, river weirs and hydraulic structures using physical and numerical models, and field studies.**



Catherine Swartenbroekx **holds a PhD in hydraulics from the Université catholique de Louvain (2012). She has 8 years of experience in fluvial and structure hydraulics. As from 2013 she works in the Hydraulic Research Laboratory of the Service Public de Wallonie, Belgium, as a research engineer. Since then, she has been in charge of several studies on navigation locks, river weirs and hydraulic structures, using both numerical and physical models, and field measurements.**

Gil Zorzan **holds a master in civil engineering. He joined the Hydraulic Research Laboratory of the Service Public de Wallonie, Belgium in 1991. As a research engineer, with over 25 years of experience, he has been responsible for the field investigations management and for numerous studies on hydraulic structures.**

techniques developed previously were used to verify that the lock performances were in agreement with prescriptions and studies predictions. The following aspects were notably checked: filling time and discharge, water slope in chamber, and leveling waves (Savary et al. 2016).

In both cases, up to 25 temporary sensors were installed for a few days measurement campaign (Figure 4). In order to insure proper synchronization, most of the probes were cable-connected to data acquisition devices connected to laptops and dispatched at 3 or 4 locations. A cable loop was then installed between all acquisition devices. At the beginning of each measurement sequence, a step signal was sent on the loop and recorded by all laptops, enabling to post-synchronize all recording with an accuracy of 0.05 s. This solution was tedious to install, with large lengths of cables (e.g. at Lanaye lock, 3,300 m of temporary cables were installed) and the need of appropriate shelters, but it enabled proper measurements of all required parameters.

At Ivoz-Ramet, several filling and emptying operations were recorded, in normal and in asymmetric mode. Asymmetric mode means that one valve remains closed, which may happen during a maintenance period. All results were found conform to hydraulic design studies. Additionally, an emergency stop of the lock was tested. Filling valves were quickly closed at the peak discharge time. Large additional waves were generated by the abrupt discharge gradient, but maximum slope remained acceptable.

At Lanaye, some concerns were raised during lock building about possible cavitation risk at the valves. Accordingly, modified valve opening schedules were investigated to reduce the cavitation duration. Cavitation risk was estimated from pressure measurements in culverts and computation of the cavitation number, which expresses the ratio between the absolute pressure downstream the valve and the headloss through the valve. Noise and vibration measurements were also used in an attempt to quantify the actual cavitation level. Large high frequency vibrations were observed during the first stages of valve opening, when cavitation number is the smallest. In-situ valves inspection conducted after 12 months of service however confirmed that no cavitation damage had occurred yet.

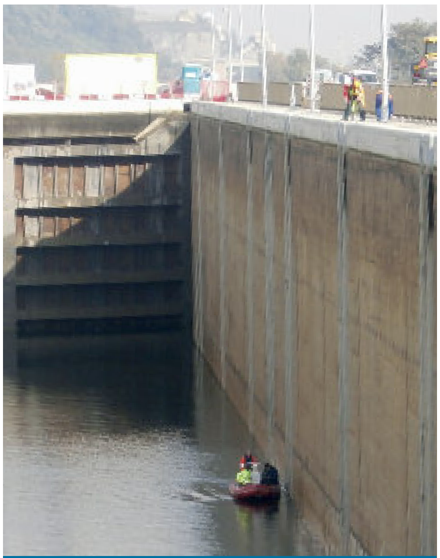


Figure 4. Installing a pressure probe in Lanaye lock chamber

Existing lock diagnosis

The measurement techniques depicted above were also applied to existing locks with the purpose of maintenance planning or performance optimization. A first example of a simple application of water level measurement in lock chamber is the estimation of leakage discharge at gate seals. Such information is relevant for maintenance work planning, for work acceptance, but also in water resource planning studies. Bousmar & Zorzan (2015) give a detailed presentation of the method. The water level is recorded in the lock chamber during periods with no navigation, e.g. during nights. All gates and valves being closed, water losses or gains are only due to leakage at the downstream or upstream gates and valves. The leakage discharge is then estimated from the time derivate of the level. A modeled leakage equation can then be fitted to the field data.

Another application of water level measurement is the evaluation of leveling surge waves propagation on the Canal Charleroi-Bruxelles (Swartenbroekx et al., 2014). Each lock emptying or filling generates waves in the adjacent reach. A too large amplitude of those waves may hinder navigation. In particular, the reach between Viesville and Gosselies locks (both 86 m x 11.50 m x drop 7.20 m and 7.50 m) is only 2.5 km long so that many wave reflections and superpositions can be observed. Measurements were conducted during night after two days of navigation interruption (during a week-end) so that only limited residual waves were present on the canal. It should be noted that a first measurement campaign did not produced accurate results due to adverse

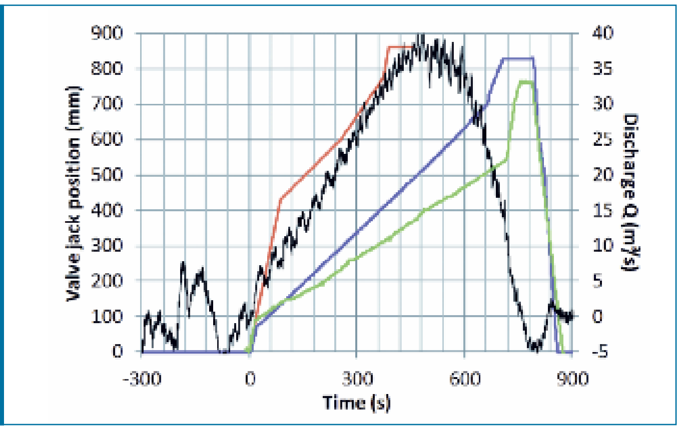


Figure 5. Valve schedule at Havré lock (red = theory, green and blue = actual left and right valve, black = discharge)

weather conditions: storms and strong wind generated too much waves at the canal surface. Several autonomous pressure sensors were installed along the canal and the locks to record the wave propagation, reflection, and damping. These results were then used to validate a numerical model to be used during the design of a second lock to be built in parallel with the existing one.

Leveling curve measurement is also useful when reworking a valve opening schedule. On the Havré lock (Canal du Centre, 124 m x 12.50 m x drop 10 m), valve schedule and filling curves were recorded when planning replacement of the whole electro-mechanical equipment of the lock. The actual valve opening schedule was found to be very different from the theoretical schedule found in original study reports (Figure 5). As a consequence, the whole filling process had to be re-studied. Recorded filling curves were then used as validation data for the numerical model. The re-engineered opening schedule enabled a gain of more than 2 minutes on the lock filling duration.

Summary

Field measurements on navigation locks are useful to support the hydraulic diagnosis of these works and to improve their performance in support of waterways transport development. As any field measurement, equipment and methodology has to be adapted to guarantee proper accuracy, with a non-permanent installation in a harsh environment. Moreover, disturbances to navigation have to be minimized. Nevertheless, properly conducted measurements proved to be valuable for data collection in support of model development and validation. Such measurements were also helpful during lock commissioning to control and optimize lock performance. When applied on existing locks, these measurement methodologies provided relevant information for maintenance planning and/or for re-engineering studies. ■

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NEW INSTRUMENTATION AT THE CENTRE FOR HARBOUR AND COASTAL STUDIES OF CEDEX: EXAMPLES AND APPLICATIONS

BY JOSE F. SANCHEZ-GONZALEZ, RAMON M. GUTIERREZ-SERRET & MARIA J. MARTIN-SOLDEVILLA

The Centre for Harbour and Coastal Studies of CEDEX (Spain) is continuously carrying out physical model experimental studies in its Experimental Maritime Laboratory, both for applied research and consultancy in the maritime hydraulics field. These activities, especially the applied research, allow introducing and developing of new types of instrumentation. The obtained results are used to gain not only a better knowledge of different types of flows and their interaction with maritime structures, but constitute a valuable data base for numerical model calibration and validation.

A variety of advanced instrumentation equipment, currently employed in breakwater overtopping research and in beach nourishment physical model studies, is presented. A brief introduction to CFD modelling of breakwater overtopping is also presented.

Advances in overtopping research

Wave overtopping is a key parameter in the design of breakwaters in harbours. Depending on the facilities installed on the lee side such as container yards, cranes or docks it must be minimized, but then the forces acting on the crown wall are severely increased, leading to oversized and consequently overpriced structures. On the other hand, these facilities can be severely affected and damaged if overtopping happens. Therefore, guidelines for a balanced design are needed.

Currently, overtopping is estimated by means of empirical formulae derived and calibrated from physical model data. The mean overtopping rate, defined as the average discharge per linear meter of width, q, for example in m^3/s per m, is the most widely used parameter to characterize the overtopping phenomenon. Although the mean rate is a robust and practical indicator it does not constitute a direct measurement of the overtopping effect on the structures and facilities. Regarding the physical models testing, scale effects must be taken into consideration to gain a better knowledge of overtopping effects.

This has led Puertos del Estado (the Spanish State Ports Body) to commission CEDEX a new research study based on physical model experimentation. The new research will test both vertical and rubble mound breakwaters at three scales: 1:15, 1:35 and 1:60. The test program for each model consists of 3 depths, 3 crown wall heights, 3 wave peak period and several wave heights, starting from the initiation of overtopping. The testing conditions will also include reproduction of wind for the large-scale tests, since they will be performed in the Large Wind and Wave Flume of CEDEX (90 m long, 3.6 m wide and 6 m deep near the wave board) for scale 1:15 and two smaller wave flumes 46 m and 30 m long for scales 1:35 and 1:60 respectively.

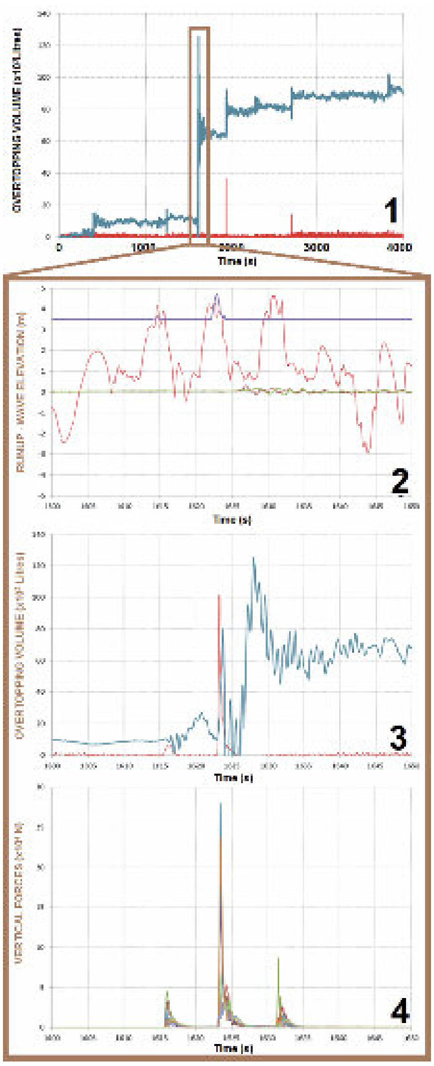
Besides the mean overtopping, several other variables are measured, namely: overtopping volume per wave, vertical and horizontal forces in the breakwater backside platform (to help to measure the overtopping extent) and wave disturbance in basin near the breakwater.

Figure 1. Instrumentation and overtopping in the vertical breakwater tested in the Large Scale Wind & Wave Flume of CEDEX

The instrumentation used in the test includes (Figure 1, items 1 to 4):

- Vertical forces at the leeside platform: 15 load cells distributed in 3 rows and 5 columns (item 1);
- Overtopping volume evolution: 0.8 m3 tank supported in a load cell to register the volume of each overtopped wave. Another load cell was deployed at the rear of the crown wall in order to detect the instant when waves overtop the breakwater (item 2);
- Wave disturbance at the leeside: Wave gauges (see zoomed area in Figure 1-a) located at different distances from the wall (item 3);
- Horizontal forces at the leeside platform: 3 load cells (equivalent to a 1.80 m tall person) at three distances from the rear side of the breakwater crown wall (item 4);

Figure 2. Examples of test results. Top graph: overtopping volume time series; Graph 2: Wave elevation and runup at the wall; Graph 3: Overtopping “switch” and volume; Graph 4: Vertical forces measured in the breakwater backside platform



Runup on the breakwater was also measured with two ad hoc gauges located in front of the wall. Finally, wind generated in the Large Flume was measured by means of a Pitot tube located immediately upstream of the breakwater model. The overtopping effects are characterized using the aforementioned instrumentation. Figure 2 shows an example of some results obtained in the Large Flume during the experiments. Since the mean overtopping rate is also measured it becomes possible to correlate these recent results with the previous measurements of the mean overtopping rate, being necessary an intense analysing effort in order to understand the physics of the overtopping process.

Advances in the measurements of mobile-bed physical models

During the last decade CEDEX has carried out more than 10 projects comprising mobile bed physical model experimentation. During this time, significant advances in beach evolution measurements have been introduced in the Laboratory for Maritime Experimentation.

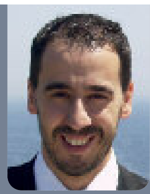
The KOSTA System is a system used to monitor beach and nearshore morphodynamics. This system has been developed by AZTI-Tecnalia based on the technology developed by the Coastal Imaging Lab (CIL) at Oregon State University in the early 1990s (Lippmann and Holman, 1989). The system makes use of video-cameras focusing into different parts of a beach in order to cover a wide area. By means of photogrammetry techniques, the images captured by several cameras can be rectified and stitched together, thus producing an ortho-image of the beach.

Although these systems were designed to monitor real beaches, they have been proven to perform well in the experiments, when scaled to the laboratory dimensions as follows:

- The height of the cameras related to the physical model is of the order of 10 m, i.e. more than 100 m at the prototype scale;
- The point of view is almost vertical, thus reducing lens distortion;
- Up to 4 different focal lengths (6 mm ≤ f ≤ 35 mm) allow wide views or detailed views of the model where necessary;
- Finally, the acquisition rate is very flexible (from 1 image/minute to 1 image/hour), thus allowing it to fit well to the model time-scale.

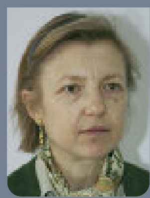
The main limitations of the KOSTA System are its accuracy and the spatial resolution of the images, which are a function of the camera parameters (focal length, sensor dimensions (3.6 mm x 4.8 mm) - and sensor resolution (1.3 Mpx)) and the cameras location in relation to the model. Considering standard conditions (f = 12 mm, 1.3 MPx CCD and a distance of 20 m) the pixel size results is of the order of 1 cm. The measurement uncertainty is of the order of 5 cm, but is also a function of the skills and experience of the operator, since the analysis is made visually.

Images captured with this system have been used to monitor shoreline variation,



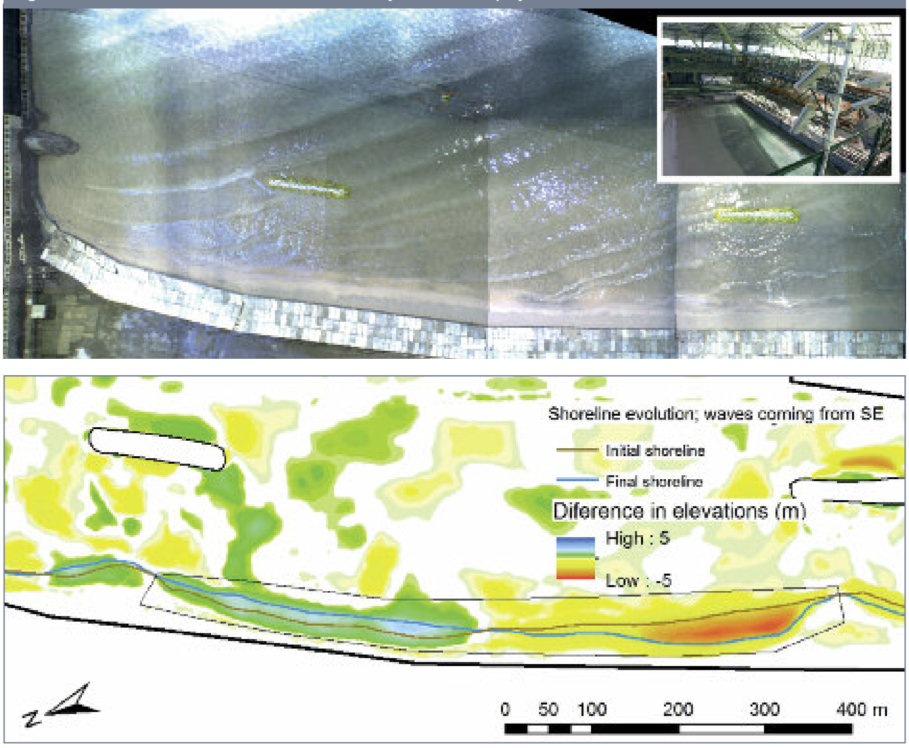
José F. Sánchez-González **is the Director for Coastal Engineering. He has been working at CEDEX for 16 years involved in several fields, formerly harbour structure design and marine environment studies (desalination discharges, dredging material management and oil spill contingency planning). In the Coastal Engineering Department he has been dedicated to applied research in beach erosion and hydrodynamics. Much of his research has been based on physical model experimentation.**

Ramón Gutiérrez-Serret**, IAHR Secretary General, is the Director of the Maritime Hydraulics Laboratory of CEDEX. He is currently involved in studies of physical models in the maritime domain and ship manoeuvring simulation. He has over 20 years of experience in hydraulics works.**



María Jesús Martín-Soldevilla **is the Head of the Port Studies and Maritime Climate Sector. Her activity is centred on the characterization of maritime loads, on the numerical simulation of problems related with maritime installations, maritime traffic and investigations of new procedures to deal with the extreme events characterization. She is also working on the development of advanced Computational Fluid Dynamics codes to study the aforementioned problems.**

Figure 3. Results obtained with the KOSTA System in the physical model of S'Abanell beach



hydrodynamics (wave refraction and breaking process) and morphodynamics (bed evolution and sediment transport), the latter by means of a digital terrain model obtained from the images. Figure 3 presents an example of the use of the KOSTA System in the study of the nourishment and protection of S'Abanell beach. The system for this test was configured with 5 cameras, two with f= 6 mm and f = 12 mm and the fifth with f=25 mm, capturing an image every 5 minutes. The previously mentioned limitations of the KOSTA System have been recently addressed with the acquisition in 2016 of a 3D laser scanner, allowing faster, denser and more accurate data acquisition. Moreover, the scanner has also a built-in RGB camera that acquires coloured point clouds, making easier the visual analysis of the results. In standard conditions the resolution of the scanner is of the order of 1 mm and the RMS error is 2 mm (measured at 10 m). The main limitation of the scanner is its low time resolution in comparison with the cameras systems, since the tank must be emptied prior to a scan. However, in many circumstances there is no need for such high time resolution, being more important the quality of its results.

Figure 4. Results obtained with the laser scanner in the physical model of Salinas beach and Port of Avilés breakwater

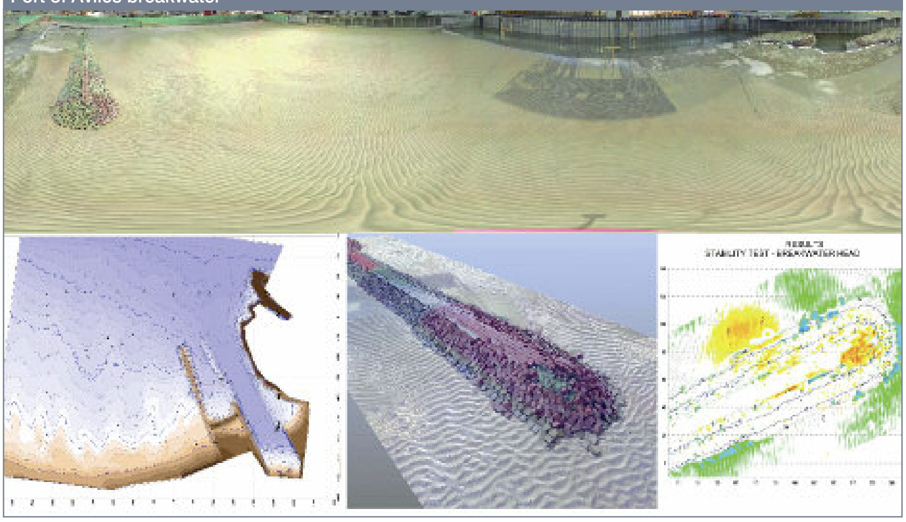


Figure 4 presents some examples of the scanner results; these include a panoramic view of a mobile bed model of a beach (a) and its Digital Elevation Model - DEM - (b); a very dense coloured point cloud of the head of a breakwater (c); and the stability results of the same breakwater (d), given by the difference between its DEM before and after the stability tests.

CFD modelling of breakwater overtopping

Numerical modelling of rubble-mound breakwaters and vertical breakwaters supported on rubble-mound berms requires dealing with flow in a porous medium (the armor layer). RANS/VOF numerical models deal with this issue by considering the rock mound as a porous body and taking into account the influence of its porosity.

Among the numerical codes currently available, FLUENT (Fang et al. 2010) and OpenFOAM have been successfully used to solve the problem of porous media flows. Currently, Fluent simulations are being made at CEDEX using appropriate meshes to reproduce the overtopping in a rubble-mound breakwater. In a future research phase a vertical breakwater will be simulated. The numerical results will be then be compared with those from the physical model, including the assessment of the mean overtopping rate, the individual overtopped waves, and the overtopping evolution in time.

Conclusion

The instrumentation presented in this article provides a large amount of data that can contribute to improve the understanding of the complex processes studied in a series of physical model tests. This is possible not only because of the volume of data collected, but also because the described instrumentation can capture many more features of the flow processes of interest, which cannot be studied when only average quantities are measured. The experimental measurements are also expected to play an important role in calibrating and validating the results of CFD simulations of the flow problems under consideration. ■

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MiCas: FROM PRESSURE SIGNALS TO COUNTING BEDLOAD PARTICLES

BY RUI ALEIXO, LUÍS MENDES, FEDERICA ANTICO & RUI M.L. FERREIRA

A new device to measure bedload transport, MiCas, is presented. It analyzes pressure time series by recognizing the imprints of impacts of individual particles as they hit pressurized membranes. A pattern analysis algorithm is used to identify the impact events. The implementation of this principle in a dedicated microprocessor allows for real-time measurements of particle hits and cumulative particle count. MiCas particle counts correlate well with the results of image analysis. MiCas provides hardware-based measurements, hence its key advantages of minimal needs of data storage and low processing times to retrieve bedload discharge rates.

To characterize the morphological evolution of loose bed channels it is necessary to develop a deep understanding of bedload transport processes at several scales. Despite the advancements made in the last 60 years, driven by the improvements in measurement techniques, research efforts on grain-scale mechanics of bedload are still required, especially to clarify the intermittent nature of bedload, its stochastic structure and its scale dependence.

Several types of instrumentation have been employed to pursue this research. Existing instrumentation can be grouped into:

i) **weighing methods**, that measure the cumulative weight of the sediments,
ii) **impact methods**, that count the impacts of particles on a sensitive plate and
iii) **digital image processing methods**, that rely on image acquisition and processing to identify and count the particles.

For bedload discharge purposes, most of the existing devices, independently of the method group that belong to, are not designed to work in recirculating flumes (in the application of weighing methods), and/or do not have the capability to resolve individual particles and particle flow rates in a time resolved manner (in the application of weighing methods and some impact methods), or are too expensive in terms of data storage requirements and processing times (for the use of image processing methods).

The MiCas device, used in a new pressure-based impact method, is intended to overcome those limitations. It has been initially developed by researchers of the Fluid Mechanics for the Built and Natural Environment (FMBNE) Group of the Civil Engineering Research and Innovation for Sustainability (CERIS) Center and is currently installed in the Hydraulics Laboratory of Instituto Superior Técnico of the University of Lisbon. It was designed to meet the following key requirements: simple data output composed of time instant and location of impacts; no need for post-processing – impacts determined through hardware and firmware; capable of computing simple statistics in real time such as cumulative particle counting and discrete lateral distribution of cumulative particle counts; able to run for very large periods (days, weeks); ability to detect particle impacts of large size fractions that are separated by a few milliseconds; composed of robust and relatively cheap components.

These characteristics allow the collection of very long time series of particle impacts since the output data are provided in a file with positions and instants of particle hits, which is relatively small (order of kb or a few Mb), compared to the size of the high-speed video footage needed to extract similar information (order of hundreds of Mb or Gb). Data can be collected with very high temporal resolution since successive impacts distanced about 12 ms in time can be identified. Characterization of intermittency (Ancey et al. 2008) and discussion of scale effects in the definition of bedload rates (Ballio et al. 2014) can be based on the data

Figure 1. Schematic of the key mechanical features of the MiCas system

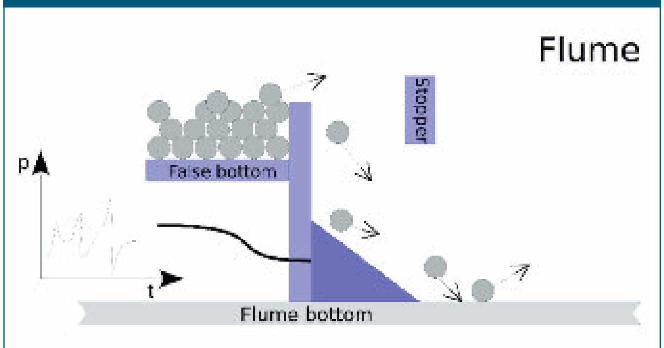


Figure 2. Overall view of MiCas system from downstream with membrane boxes installed in the flume visible in blue. Each membrane box constitutes a bin

provided by this system. Further details about the design process and applications can be consulted in the website of FMBNE (http://www.fluidmechenv.tk/). Preliminary results and detailed description of the key features of the system have been published in Mendes et al. (2016).

MiCas – THE PRESSURE-BASED IMPACT PARTICLE COUNTER

MiCas stands for **M**edidor **i**ntegrado de **Ca**udais **s**ólidos, in Portuguese, or integrated system for solid discharge measurement in English. This device counts impacts on a sensitive surface and was conceived to be installed at the downstream end of a mobile bed reach of a laboratory recirculation flume, as sketched in Figure 1. It is divided in two subsystems: mechanical and electronic. The mechanical system includes the sensitive element (blue surface in Figure 2), composed of a hollow box filled with air at a certain pressure, P, connected to a pressure transducer through silicon tubes (the tubes passing near the flume lateral glass walls, as depicted in Figure 2). The upward face of this prism is made of a rubber membrane. Each pair of boxes is separated by a plastic surface that extends upward and downstream in relation to the actual box dimensions. It is placed in such a way as to avoid propagation of pressure waves to adjacent boxes, thus reducing sources of possible false impact detections (white vertical surfaces in Figure 2). For the experimental installation at FMBNE 10 membrane boxes were made and identified from 1 to 10. Each membrane box is considered a bin. This allows characterizing the lateral distribution of bedload with a spatial resolution equal to the membrane box width.

Sediment particles hitting the rubber surface cause a pressure variation that is measured by the pressure transducers. A sequence of particles impacting the membrane boxes is shown in Figure 3.

The pressure transducers are part of the electronic subsystem that convert the pressure signal into an electrical signal, which is then sampled and analysed with Digital Signal Processing and Patten Recognition (DSP) techniques to be validated as a particle impact. A simplified block diagram of the MiCas system is depicted in Figure 4. The Pressure Sensors (PS1,PS2,PS3) convert the corresponding pressure signal variations into a voltage signal, which is then filtered by the respective 1st order Low Pass Filters units (LPF-1) for noise removal.

Figure 3. Sequence of 5 mm glass beads hitting the membrane boxes. Hydraulic test with Fr = 0.756, θ = 0.014 and Φ = 0.001 (where Fr, θ and Φ stand for Froude number, Shields parameter and non-dimensional bedload rate). All frames are 0.25 seconds apart except frames 2 and 3 that are 0.10 seconds apart

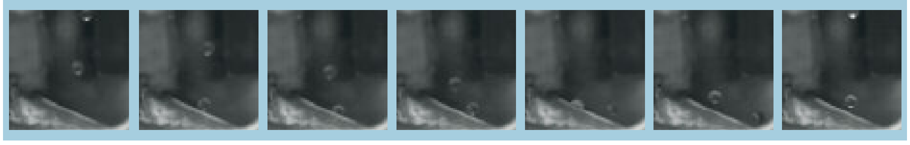
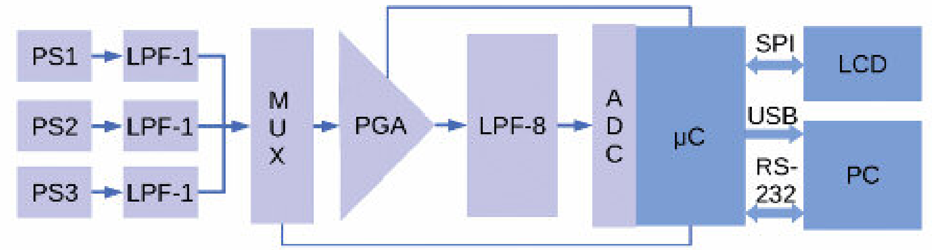


Figure 4. Simplified block diagram of the MICAS system. PS1 to PS3 are the pressure transducers. LPF represents the low pass filter unit. MUX is the MiCas Multiplexer and PGA is the programmable gain amplifier. LPF 8 is an 8th order anti-aliasing Butterworth filter block. The ADC is the analog-to-digital converter that converts the analog signal into a digital form to be then processed by a microcontroller. This microcontroller has outputs for an LCD screen and a PC

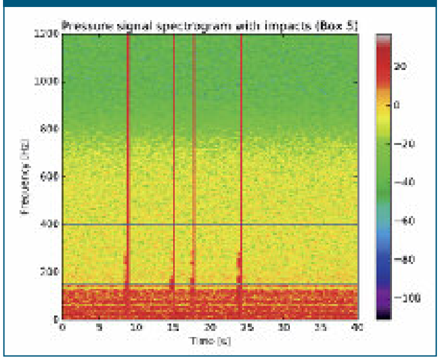


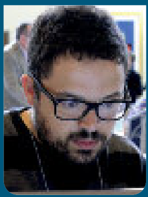
The analog Multiplexer unit (MUX) follows, connecting in round-robin fashion, one of the PS1,PS2 or PS3 sensors output signal to the input of the Programmable Gain Amplifier (PGA) unit. The PGA output is then connected to the 8th order Butterworth Low Pass Filter (LPF-8) input, unit, which contributes for the aliasing effect reduction. Following the LPF-8 unit output the signal enters the Analog to Digital Converter (ADC) to be sampled by the microcontroller (μC). The digital sampled signal is then processed with Digital Signal Processing techniques to extract the relevant signal characteristics that define a bead impact on the membrane box surface. Those characteristics are then fed to a pattern recognition algorithm to identify the presence of the impact pattern. If an impact is identified, then the instant of the impact detection is recorded and sent to the client terminal connected through the RS-232 and USB interfaces. A Liquid Crystal Display (LCD) monitor is also updated with the number of impacts detected and displays a graphic that shows the lateral bedload discharge distribution in real-time.

SIGNAL PROCESSING AND PARTICLE IDENTIFICATION

When a particle impacts the membrane, it generates a pressure signal. This pressure signal is converted into an electrical signal by means of a pressure transducer. This signal is then filtered and analysed to be confirmed as a particle impact. It is important to identify the signature of a particle impact on the membrane, being able to distinguish it from other signals' signatures like for instance, the turbulence signal. To do so, the k-Nearest Neighbour (k-NN) algorithm is used in the signal processing and analysis. The k-NN is a pattern recognition algorithm that can be fitted within the machine learning sub-area of artificial intelligence. By fitting an unknown measurement data as belonging to the class of its nearest already known classified measurement that is in the agent knowledge base, where for this case, the agent is MiCas. For this case three classes of events are considered: 1) particle impact, 2) silence (i.e. background noise) and 3) turbulence. For each class the system is trained using the MiCas only subjected to each event. For example, the training for particle impact class was made with impacts produced by dropping individual particles at random locations of the membrane in still water. After the training process, the system can identify the different events.

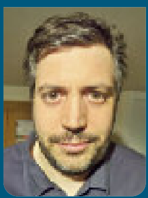
Figure 5. Spectrogram obtained from pressure sensor sampled signal of an operating flume with occasional bead impacts on the membrane box. The red colour in the spectrogram correspond to higher intensity signals. Vertical red lines denote a possible impact while the horizontal blue lines denote the 150Hz-400Hz range. Scale is in dB



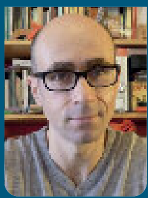


Rui Aleixo **has a PhD in Engineering Sciences from Université catholique de Louvain, Belgium. After a post-doc in the National Center for Computational Hydroscience and Engineering (USA) he joined the Fluid Mechanics for the Built and Natural Environment Group of CERIS, Instituto Superior Técnico. He is currently working in the University of Bologna. He is the IAHR Experimental Methods and Instrumentation committee (EMI) chair for the period 2015-2017. As EMI chair, he co-organized the W.A.T.E.R. Summer School and HydroSenSoft 2017 conference.**

Federica Antico **is a Civil Engineer graduated from University of Padova, Italy, in 2013, with specialization in Hydraulic Engineering. In March 2014, she was enrolled in the project "Sediment transport in fluvial, estuarine and coastal environment" (SEDITRANS), as PhD Candidate at Instituto Superior Técnico (IST), Lisbon, Portugal. Her PhD research focuses on the experimental study of bedload mechanics at grain-scale in a granular bed subjected to a steady-uniform turbulent open-channel flow.**



Luís Mendes **started working as a software engineer back in 2007 following his masters in informatics and computer engineering at Instituto Superior Técnico. He worked for several companies including Nokia Siemens Networks. In early 2015 he completed a B.Sc. for the electronics and computer engineering field at Instituto Superior de Engenharia de Lisboa, complementing the previous expertise on software. Since February 2014 he joined the CERIS multidisciplinary research team at Instituto Superior Técnico.**



Rui M.L. Ferreira **is Associate Professor of Instituto Superior Técnico, Universidade de Lisboa and a CERIS senior researcher. For the past 20 years, he has been involved in experimental research in fluvial, estuarine and coastal processes, development of laboratory instrumentation and mathematical modelling of free-surface flows. He is a member of the leadership teams of the Fluvial Hydraulics Committee and of the Experimental Methods and Instrumentation Committee of IAHR.**

A key feature of this system is the possibility of doing real-time measurements. In fact, the computations are made at the hardware level thus allowing fast time processing. The implemented MiCas system consisted of 10 independent membranes. The micro-controller available analog to digital converter (ADC) units were multiplexed to scan every membrane box, thus saving costs, by reducing the number of ADC units to the ones available on-chip.

Figure 5 depicts the spectrogram obtained from one of the pressure transducers of the MiCas system. The darker spots aligned along the vertical indicate possible impacts. Each of these events is analysed through the k-NN algorithm to check if it corresponds to a particle impact or not.

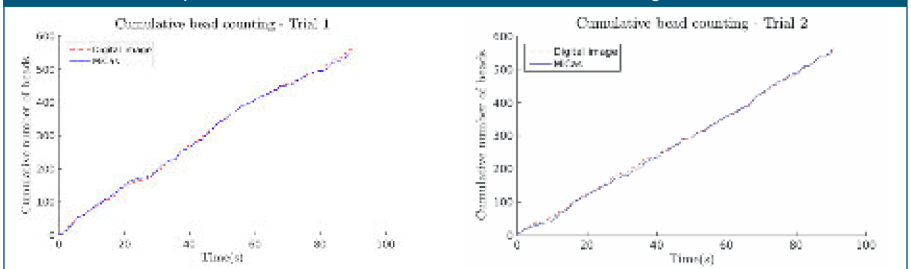
VALIDATION OF THE MiCas SYSTEM

To validate the results obtained by the MiCas system, its particle cumulative count was compared with the count obtained from the analysis of a high-speed video footage. Each particle impact was tagged with membrane box identification (from bin 1 to bin 10) and the respective instant.

Experiments were carried out in the 12.5 m long and 40.5 cm wide glass-sided flume of the Laboratory of Hydraulics and Environment of Instituto Superior Técnico, University of Lisbon. This flume has two independent circuits for water and sediment recirculation. A cohesionless granular bed, composed of 4 layers of 5 mm glass beads, subjected to a steady-uniform turbulent open-channel flow, was analysed. All tests featured a period of 90 s data collection. For a detailed description of the laboratory facilities and test conditions see Mendes et al, 2016.

The cumulative particle count results are depicted in Figure 6.

Figure 6. Cumulative bead counting for two tests performed under conditions of weak bedload transport. The main flow characteristics are: flow rate, $Q=0.0167m^3/s$; steady-state flow depth, $h=0.067m$; slope of the flume, $i=0.0022$; Froude number, $Fr=0.756$; Reynolds number, $Re=46057$; particle Reynolds number, $Re^*=182.9$, Shields parameter, $\theta=0.014$; non-dimensional bedload discharge, $\Phi= 0.001$



The results obtained with the two techniques are in good agreement. The measurements carried out allowed to demonstrate that the MiCas system is able to track particle impacts in real-time within an error margin of 2.0%. Different tests performed under the same conditions proved the repeatability of the MiCas system measurements.

The main advantages of MiCas relatively to digital image processing methods are:

a) independence from optical access, thus avoiding problems with light intensity variations and oscillating free surfaces;
b) small volume of data associated to particle counting, which allows the acquisition of very long data series (hours, days) of particle impacts. In the cases that were tested, it would take more than two hours to generate 1 MB of data with MiCAS. For the current validation tests, 90 s acquisition time generated 25 Gb of data using the digital method, but only 11 kB of MiCas data to monitor the same experiment. On the other hand, the time necessary to process the digital images may be days, effectively limiting its usage to small time series.
c) MiCas offers the possibility of real-time measurements, allowing for detection of problems during the experiments and minimizing some post-processing steps.

On the downside, the MiCas system does not achieve sub-particle resolution nor highly resolved lateral particle distribution. However, the MiCas bins can provide a coarse but reliable lateral bedload distribution. ■

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SERIOUS GAMING FOR COMMUNITY ENGAGEMENT IN MULTI-HAZARD MITIGATION

BY MARIAN MUSTE, IBRAHIM DEMIR, JASON SMITH & ANDREA CARSON

With the threat of floods, droughts, and water quality issues reoccurring in the Cedar River Basin of Iowa (U.S.A.), the U.S. Army Corps of Engineers and the City of Cedar Rapids (in Iowa, U.S.A) sought to enhance the community's problem-solving and decision-making skills towards selecting a watershed adaptation strategy through a multi-hazard tournament (MHT). The MHT was designed to be delivered in a game-like environment that promotes social learning through teams playing out potential adaptation strategies to reduce drought and flood risk while addressing water quality issues. A decision support system (DSS), dubbed the Iowa Watershed DSS (IoWaDSS) was designed by IIHR-Hydroscience & Engineering (IIHR), The University of Iowa to support each team's selection of adaptation strategies and inform decisions. Described next are the context of the gameplay and the critical role played by the web-based DSS to make it successful.

Figure 1. The Multi-Hazard Tournament participants are discussing watershed management strategies with their team members during the game in Cedar Rapids, Iowa (U.S.A.) on September 1, 2016. Photo credit: M. Muste, IIHR-Hydroscience & Engineering

Prototyping the Multi-Hazard Tournament

The MHT is considered a competitive tabletop exercise that provides hazard scenarios that teams aim to address (IWR, 2016). Unlike a conventional tabletop exercise where everyone works on the solution together, the MHT adds a competitive element where teams independently decide between tradeoffs and create the best solution, composed of 'adaptation options' (also commonly referred to as management measures), for a particular climatic scenario affecting the basin. Teams are challenged to decide how to deal with each hazard-based scenario within the budgetary, temporal, technical, and regulatory constraints set before them. Teams' decisions are then presented and assigned "scores" by the other teams and a group of technical specialists (the referees) based on the appropriateness of their proposed solution. On September 1, 2016, in Cedar Rapids, Iowa, the U.S. Army Corps of Engineers and the City of Cedar Rapids organized and delivered the prototype MHT with the participation of water resources management stakeholders from federal, state, and local agencies as players within teams (see Figure 1). The gameplay and tools used to enable the MHT are briefly described next.

Tournament Actors

There are four main actors involved in the MHT game – players, referees, team facilitators, and the announcers. The players are part of a team and they use their knowledge and expertise to help their team select adaptation options, communicate the reasoning behind their decisions through press release responses, and assign scores to the other teams. The referees act as content experts by providing consultation, insight, and feedback to competing teams. They evaluate the feasibility of innovative adaptation options and participate in the scoring process. Along with participating as a team player, the team facilitators also track their team's budget, facilitate team discussions, and submit their team's decisions, press release responses, and scores. The announcers present the constraints of each turn, monitor time, and calculate the scores.

Gameplay Phasing

Each MHT turn consists of four steps as illustrated in Figure 2. The Iowa Watershed Decision Support System (IoWaDSS) web-based portal enabled the teams to simultaneously and in real-time choose potential adaptation options as part of their watershed management strategy based on the climatic scenario associated with a particular turn.

Turn Scenario Set-Up and Presentation. For each of the four tournament turns, there was a different climate scenario that the teams confronted and accounted for within their adaptation option planning. The first turn represented the historical climate record. Teams used this turn to establish the foundation for

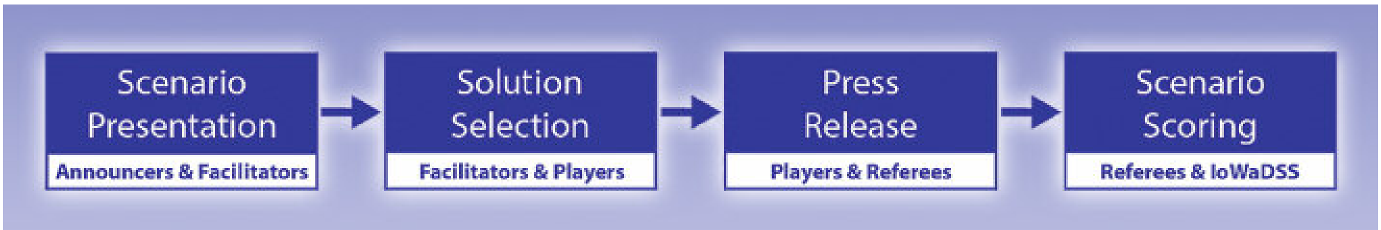

Figure 2. The MHT activities leading to the selection of the winning team

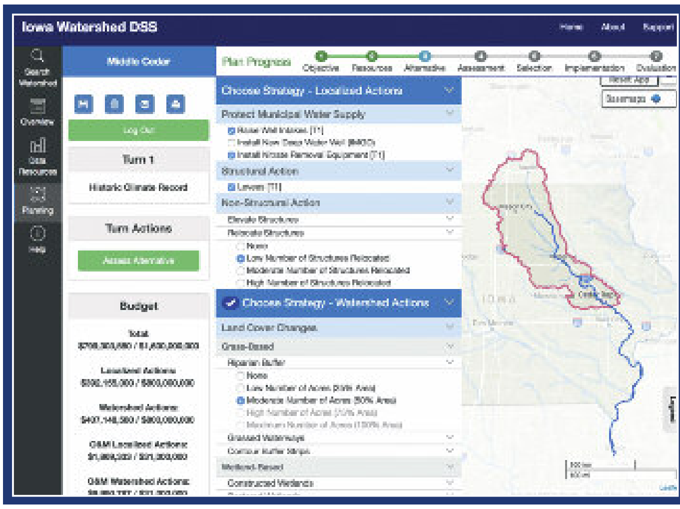

Figure 3. Teams used the IoWaDSS interface to select their adaptation options, analyze their budget, review the operation and maintenance costs from the selected actions, and submit their watershed strategy through the decision support tool. The web-portal allows players to evaluate for each turn how well their adaptation options performed against a pre-established evaluation matrix

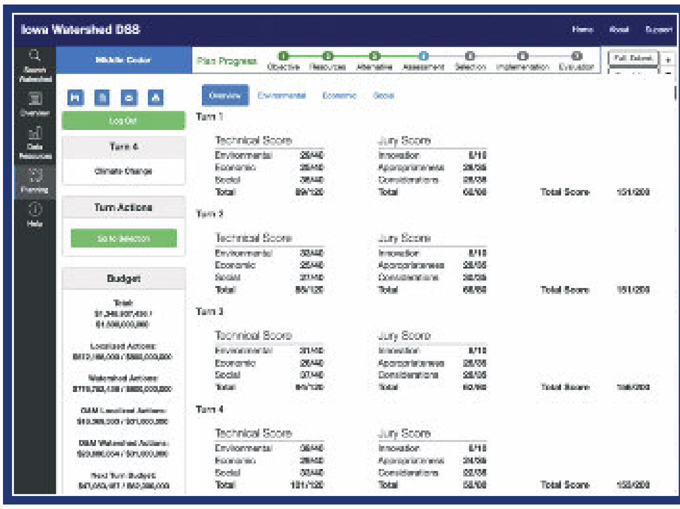

Figure 4. Screenshot of the interface visualizing the score of a team participating to the tournament

their watershed management strategy, using the money to allotted them to invest in capital and watershed improvements over a 20-year planning horizon. Teams had the option of choosing structural, and/or non-structural adaptation options that in turn influenced their strategies and budgets for turn 2 (flood scenario) and turn 3 (drought scenario). Turns 2 & 3 represented a 1-year planning horizon which had to account for the operation and maintenance costs associated with decisions made in turn 1 in addition to the costs related to new adaptation options. Turn 4 presented a climate change scenario that included more frequent and extreme hazards. For turn 4, the team's watershed management strategy was reset to a 20-year planning horizon so that teams could reinvest their full budget based on the lessons learned in the three previous turns. The budget values used in the tournament were based on realistic estimates of the anticipated funding to be invested in the Cedar River near and upstream of the City of Cedar Rapids within the next 20 years.

Adaptation Option (Solution) Selection. With a limited budget, each team carefully considered budget constraints, tradeoffs, and the cost-effectiveness of their plan. The pre-defined adaptation alternatives used in the simulations were selected based on the options currently being used or considered in the Cedar River Basin. The adaptation options included localized alternatives (i.e. protect the municipal water supply, structural actions, non-structural actions) and watershed actions (i.e. land cover change that is either grassland-based, wetland-based, grassland and wetland-based, or land cover and land management change). The information needed to inform each team's selection of pre-defined adaptation options was obtained through an extensive number of computational simulation results that were embedded in the IoWaDSS.

The computational simulation results embedded in the IoWaDSS were obtained from running simulations with 8 different multi-domain models (physical and socio-economic). The watershed based simulations used 40 different alternative practice combinations. Each combination was applied for each of the 4 climate scenarios (historic, flood, drought, composite) to build a landuse change database. Watershed based actions were combined with localized practices based on their flow, stage and/or temperature relationships to generate a numeric database of localized and watershed-actions. These numeric results are then tied to a suite of economic, social and environmental metrics by normalizing the numbers. The input and output data associated with the pre-run simulations were stored in the IoWaDSS relational database along with information on how each of these pre-run simulations, if selected in different combinations by the teams, would interact with each other and ultimately impact the environmental, economic, and social scores. A snapshot of the IoWaDSS interface used by players to select the adaptation options is provided in Figure 3. Teams also had the option of presenting an idea for a strategy that was not on the pre-defined list for the referees to decide if the "innovation" could be included. If the referees deemed the innovation well thought out, if it enhanced the team's watershed strategy, and was considerate of the economic, social, and environmental impacts on the basin, the team was scored by the referees and fellow teams accordingly.

Press Release Presentation. During the press release, the teams presented their proposed solutions and described the rationale for the adaptation options they invested in to prepare for the forecasted climate conditions, why they felt this approach was the most appropriate, and what were the implications in terms of tradeoffs between impacts to the physical landscape as well as tradeoffs between impact on different economic, social, and environmental sectors.

Scoring. The scoring of each team's watershed management strategy was based on several different factors. The scoring of the economic, social, and environmental outcomes associated with a team's selected adaptation options were scored using the library of simulations embedded in the IoWaDSS database, with each category accounting for 20% of a team's total score. The participant score category, acquired from other teams' and referees scores, was based on three components: (i) appropriateness of the adaptation options (17.5%), (ii) consideration of impacts and tradeoffs (17.5%), and (iii) innovation (5%).

The IoWaDSS interfaces that automated the score-keeping and budget tracking during the tournament is illustrated in Figure 4.

Lessons learned

A growing number of researchers have recognized that technical solutions do not always perform well in mitigating sustainability and adaptability strategies for practical situations, and thus have proposed that role-playing games where the stakeholders play an active role in the decision making. The co-production of the decision making with the involvement of local stakeholders in addition to the management agencies with missions in various hazard mitigation areas has potential to improve the quality and efficiency of the decision-making process. By sharing the roles in the formulating the decisions, the game-like approach to management of hazards can increase considerably the viability of the implementation plans as the local stakeholders are co-owners of the plan. The MHT serious-gaming prototype presented in this paper is one of the possible paths to engage the community in the planning process by hiding the complexity of the technical aspects and providing a problem-solving environment that is understandable and adapted to the technical skills of the local watershed stakeholders. The IoWaDSS user-friendly interfaces allowed the teams to consider holistic and systematic approaches to deal with water-related hazards by enabling players to share their knowledge and the local perspectives on the issues in a manner that they have not experienced before. According to a post-tournament survey, 71% of the participants were favorable to the idea of using the tournament results to inform future decisions. For this purpose, participants have been given permanent access to the decision support tool (http://iowawatersheds.org/dss/tournament) so they can go back and examine each team's choices, plans and outcomes to continue informing decisions going forward. The large team of federal and local agencies involved in developing and delivering the tournament will be checking back with participants in the upcoming months to see exactly how the tournament changed their approach to reducing risks from flood, drought and water quality.

Acknowledgement

The IoWaDSS has been built atop of a large dataset produced by a large interagency team coordinated by the USACE Flood Risk Management Program, Collaboration and Public Participation Center of Expertise, Asset Management Program, and ICIWaRM. Partners involved: the U.S. Army Corps of Engineers Rock Island District, Portland District, and the Institute for Water Resources; Sandia National Laboratories; the University of Iowa IIHR; the City of Cedar Rapids; the National Drought Mitigation Center at University of Nebraska-Lincoln; the Natural Resources Conservation Service; the U.S. Geological Survey; the National Integrated Drought Information System; and Iowa State University. The authors are thankful for this large amount of collective work that made IoWaDSS development possible. ■

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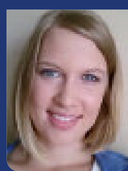

From left to right: _H. Xu, H. Hameed,_ and _M. Windsor_ – University of Iowa graduate students involved in the IoWaDSS design & development

Prince Sultan Bin Abdulaziz International Prize for Water

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Winners for the 7th Award (2016)

Creativity Prize

Creativity Prize

The Prize was shared by two teams of researchers:


Dr. Rita Colwell


Dr. Shafiqul Islam

1) Dr. Rita Colwell (University of Maryland at College Park) and Dr. Shafiqul Islam (Tufts University, USA)
for using chlorophyll information from satellite data to predict cholera outbreaks at least three to six months in advance.


Dr. Peter J. Webster

2) Dr. Peter J. Webster (Georgia Institute of Technology, USA)
for applying knowledge of the effects of ocean-atmosphere interactions on monsoon strength to provide one to two-week lead time forecasts of monsoonal floods for highly populated coastal regions.

Surface Water Prize

Surface Water Prize


Dr. Gary Parker

Dr. Gary Parker (University of Illinois Urbana-Champaign, USA)
for contributing to our understanding of meandering rivers, the shapes they take, and how they change themselves and their floodplains as they migrate.

Groundwater Prize

Groundwater Prize


Dr. Tissa H. Illangasekare

Dr. Tissa H. Illangasekare (Colorado School of Mines, USA)
for improving the fundamental understanding of fluid flow and chemical transport in porous media, leading to the reliable prediction of the long-term fate of pollutants in groundwater systems.

Alternative Water Resources Prize

Alternative Water Resources Prize


Dr. R. Wang Dr. A. G. Fane

Dr. Rong Wang & Dr. Anthony G. Fane (Nanyang Technological University, Singapore)
for developing hollow fibre membranes that combine forward osmosis with a reverse osmosis (RO)-like inner selective layer and a previously undiscovered positively charged nanofiltration (NF)-like outer selective layer, which effectively reduces the effects of scaling and flux losses.

Water Management and Protection Prize

Water Management & Protection Prize


Dr. Daniel P. Loucks

Dr. Daniel P. Loucks (Cornell University, USA)
for the development and implementation of systems tools that provide an effective, dynamic, and successful framework for addressing practical water resources management problems worldwide.

Nominations are open for the 8th Award. Nominations can be made online until 31 December 2017.

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AQUA REPUBLICA – HUMANISING WATER AND ENVIRONMENT EDUCATION AS WELL AS STAKEHOLDER ENGAGEMENT WITH SERIOUS GAMING

BY CHENGZI CHEW & GARETH JAMES LLOYD

DHI, UN Environment and UNEP-DHI Partnership have been developing and using online games since 2013, working to engage and educate stakeholders through a serious gaming initiative called Aqua Republica. During this time we have worked with many types of organisations using different versions of the Aqua Republica in a range of settings including government strategy workshops, national competitions and stakeholder engagement workshops.

Serious Games?

There is a big difference between what motivates people and what does not. While all have their own personal preferences, some activities can generally be considered much more exciting or interesting than others. A specific example of this is found in schools, where students are typically more stimulated by activities that they consider to be informal and fun, and often less so with more formal activities and materials (after Stapleton, A J, 2003; Shute, V. J., Ventura, M., Bauer, M. I., & Zapata-Rivera, D., 2009). Unfortunately, it is the more formal stuff that is usually considered to be of greater academic importance.

Figure 1: Testing out gameplay with a board game version of Aqua Republica

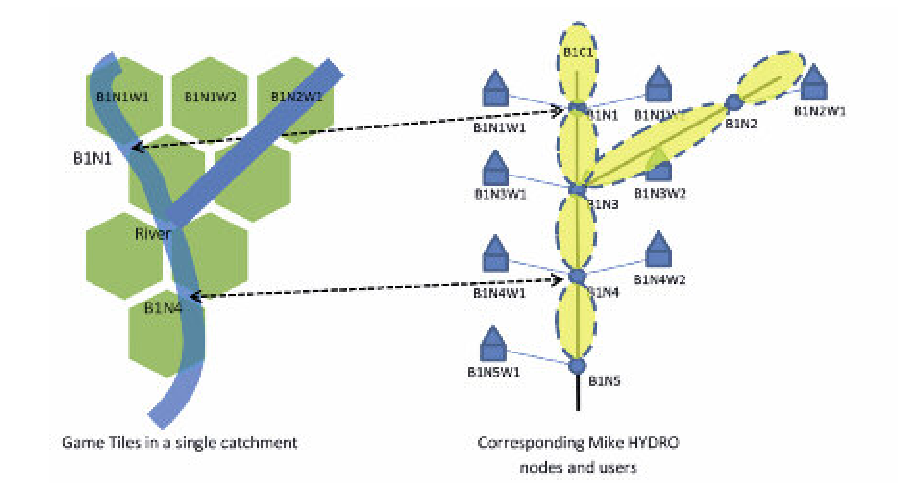


Figure 2. Schematic representation of how the Aqua Republica game connects to the MIKE HYDRO BASIN model

A serious gaming approach combines a learning objective in a fun activity, in order to increase the potential for learning uptake. Such an approach is of course not new and has a long history of application in everything from the songs children learn, to various work-related teambuilding events that they may have been subjected to over the years when they were growing up. Perhaps one of the best-known applications of an electronic-based serious "game" is that of flight simulators used in pilot training. One of the main reasons for the success of this kind of application is the recognised fact that pilots need a very realistic learning environment, but also one that is low risk and allows them to make non-catastrophic mistakes that they can learn from.

This learning by playing approach is commonly termed as "meaningful play" and a well-designed serious game environment provides a feedback mechanism that allows the player to reflect on his or her actions and adopt different approaches or strategies. The internalisation of actions and reactions stimulates learning, often resulting in an increase in self-learning and knowledge retention.

Our professional passion lies in the field of water and environment, and one of our shared non-work passions is in playing a wide variety of online games, as well as traditional board games. When we first started out on the pathway that led to Aqua Republica our ambition was to try to combine these interests in a way that would help people better appreciate the critical connections between water, social and economic development, and environmental

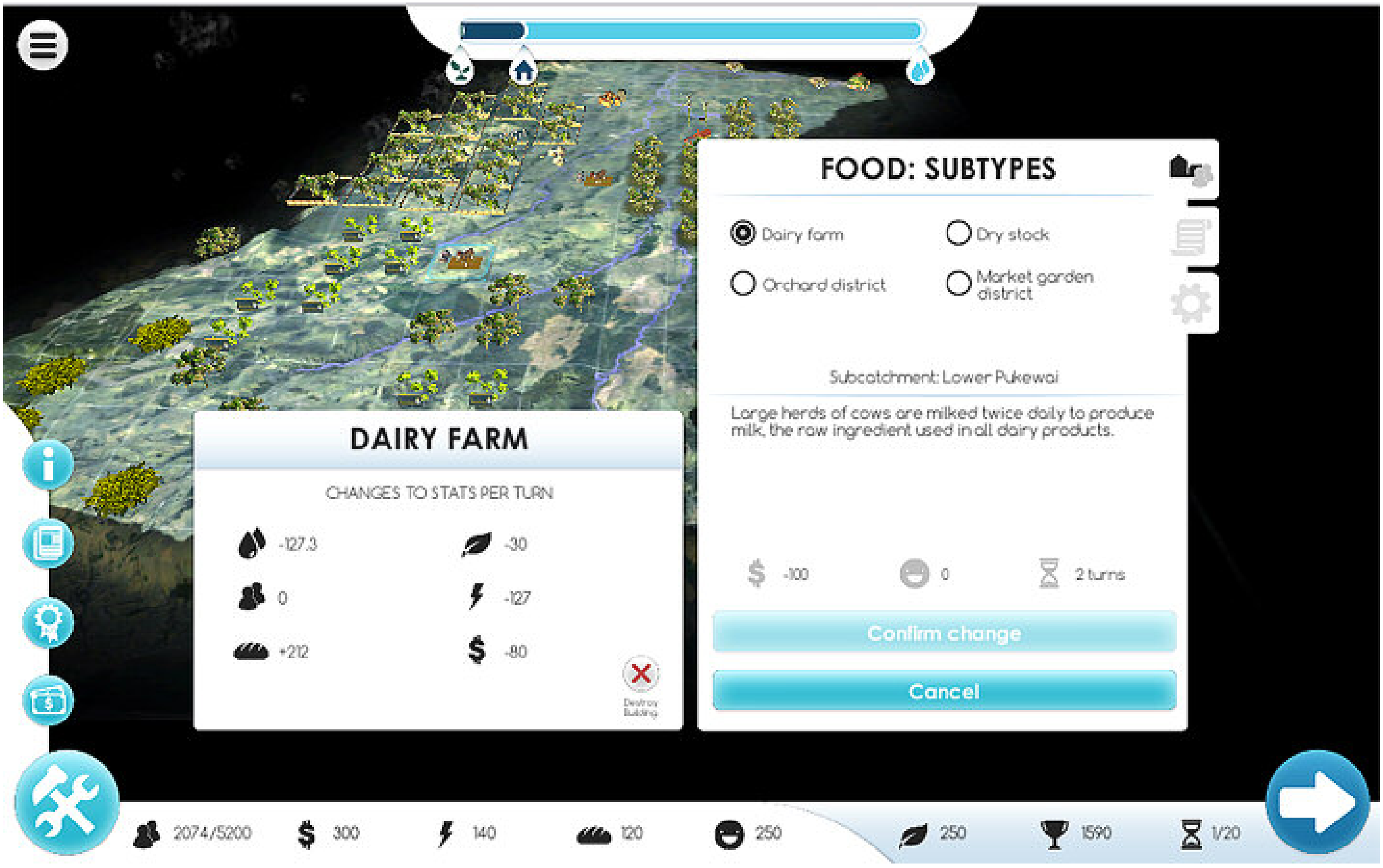


Figure 3. Screenshot of an example of different farm types in the game

sustainability – something we could see was a serious issue requiring greater attention. Another constantly reoccurring issue we were seeing, and still see, are situations where there is a lack of good decision-making, or even a complete lack of decisions, on how water should be allocated between various municipal, agricultural, industrial and energy users and uses, while also taking into account climate change impacts. What we wanted to do was to use a serious game to further the cause of sustainable development, with water as the connecting element that would promote policy-based actions that integrate climate change responses with holistic planning approaches. The big question though was, could it be done?

From humble beginnings, a lot of healthy scepticism from good colleagues, and numerous user pilot tests, Aqua Republica began to quickly evolve from half a page of A4 paper, to a board game and finally to a digital prototype that combined numerical models, a game engine, and an attractive but deceptively simple user-interface. The end result is a sophisticated game that reflects the challenges of real life. In the real world trade-offs between shorter and longer term development goals are often essential, but what is even more important is the awareness of the broader consequences. This philosophy is reflected in Aqua Republica.

One platform, many unique versions

The foundation of Aqua Republica is the game platform. This consists of components that can be combined and/or modified to produce many different unique versions. In Aqua Republica a water allocation model (MIKE HYDRO BASIN) communicates and interacts with the game engine simultaneously, while the player is playing the game.

The water allocation model is widely used by different governmental agencies around the world to help in calculating and forecasting water balances in river basins, so that different scenarios can be analysed, as part of management decision processes. There is no better way to understand the physical environment and interactions in a river basin than to the use the laws of physics and hydrology as part of the rules in the game. The game engine uses the results from the model that are linked to other parameters, such as population, economy and other social issues related to water. In line with the fact that nothing remains constant in real life, the interaction between the game layer and the scientific

Chengzi Chew **works as the Head of Serious Games at DHI. He started the Aqua Republica initiative together with colleagues in DHI and has been working extensively with Gareth to promote the use of serious gaming in water and environmental education and communication. Chengzi has a background in hydro-informatics and water management.**

Gareth James Lloyd **works as senior advisor at UNEP-DHI Partnership, a United Nations Environment Programme collaboration center on water and the environment. Based in Denmark, but with an international focus, his portfolio includes U.N. work linked to the Sustainable Development Goals, technology transfer to developing countries and serious gaming. He has degrees in environmental science and environmental policy.**

model produces evolving scenarios to which players must react and adapt.
Experience has shown that this interaction between game, the scientific model and the player provides a really interesting and relevant learning experience for users. It can also function as a way of sharing and discussing scenarios based on data and model results with non-expert stakeholders. For example, a model using climate change data, using local water data and then linking up with local water issues in a game can help those who play the game learn many details of local water issues. Through playing the game, people become more interested in these issues and start to investigate and learn more about them, and come up with ideas that can help solve various challenges.

A typical version of the game starts by introducing players to Aqua Republica, before informing them that they have the responsibility of developing what is a small but ambitious nation in the most sustainable way possible. As the game progresses and time moves on, drivers such climate change, population growth and associated demands for homes and jobs, force players to adapt to survive and thrive. For example, should the strategy be to grow crops for food or biofuel, and if both, what should be the balance - given various alternatives and risks? Players quickly learn that developments are costly, take time to implement, and often impact the resource base on which they are reliant, as well as neighboring countries.

Uses and impacts

To date, there are many different unique versions of Aqua Republica developed to teach different aspects of water and environment management to different groups of stakeholders, ranging from food-energy-water nexus issues for water users in New Zealand, to water security issues for the Government of Singapore. Aqua Republica has also been successfully used in many other educational activities, such as the annual UNEP-DHI Eco Challenge competition, where more than 7000 students have participated since 2013, the World University Challenge, as well as part of Master and Bachelor programmes around the world. In addition, Aqua Republica has also been used in research projects where the objective is to continuously seek improvements on how to better use this technology to reach out to even more people.


Figures 4 and 5. Participants trying their hands on the Aqua Republica game at Stockholm World Water Week and Students in Kenya playing the Aqua Republica game as part of a workshop

"Wow! This is a lot of fun and we are learning so much about water, its uses and how important it is. Why can't more of our lessons be like this?"

Timothy Yip, 14, United Christian College, Hong Kong

"These competitions are extremely important. As we activate the youth to take an active role and interest in water issues, we help to educate the next generation of water professionals."

Rüdiger Heidebrecht, DWA (German Water and Wastewater Association), Germany

"Aqua Republica is an excellent learning resource linking the Food – Energy – Water nexus ..."

Todd Jarvis, Oregon State University, USA

Figure 6. MSc students in McGill University, Canada using the Aqua Republica as part of an IWRM course

What's next?

While we are very pleased with the uptake and positive feedback we have received so far, we are always looking for additional opportunities to collaborate and further develop the game. One of the most exciting projects we are currently working on is SIM4NEXUS. It is a Horizon 2020 European research project led by Wageningen Economic Research (the Netherlands), which brings together a multidisciplinary team of 25 partners including DHI. The aim of SIM4NEXUS is to address knowledge and technology gaps and thereby facilitate the design of holistic development policies. The delivery mode is through a serious game in the form of a cloud-based, integrated tool for testing and evaluating policy decisions. This is done by combining a number of thematic models on water, land, food, energy and climate to quantify the impacts of different policy decisions. The aim of this game is still to help people better understand and evaluate the decisions that they are taking, based on the complexities of real life. In doing so, they will better appreciate the consequences of both action and inaction. ■

6TH INTERNATIONAL SYMPOSIUM ON HYDRAULIC STRUCTURES: A RETROSPECT

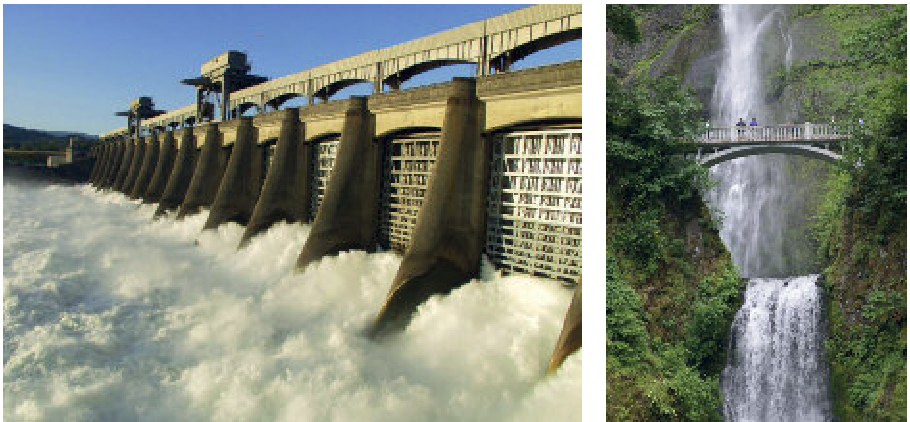
JUNE 27-30, 2016, PORTLAND OREGON, USA

BY BRIAN M. CROOKSTON, BLAKE P. TULLIS, MICHELE PALERMO & DANIEL B. BUNG

The gathering of engineers, practitioners, and scientists at the 6th International Symposium on Hydraulic Structures (ISHS2016), held in Portland, Oregon June 27-30, 2016, represented a valuable opportunity for knowledge exchange, perspectives, and networking regarding critical issues and design perspectives related to hydraulic structures. Co-sponsored by IAHR and the U.S. Society on Dams, a total of 136 participants attended the event, representing 18 countries and 5 continents. The largest delegation came from the host country (USA) with 94 participants. Experts from practice, research, and implementation were well represented and included delegates from key U.S. Federal entities U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Federal Energy Regulatory Commission, U.S. Department of Agriculture, and the Tennessee Valley Authority.

The symposium began with a full-day workshop focused on stepped spillway hydraulics, team-taught by two leading experts: Prof. Dr. Hubert Chanson (University of Queensland) and Dr. Sherry Hunt (USDA-ARS). About 40 individuals attended this specialty workshop, which emphasized hydrodynamics of stepped spillways, applied research, design, operational records, and group discussions.

The symposium also included four notable keynote speakers. Dr. Anton Schleiss, professor and Director of LCH at EPFL (Switzerland) and current ICOLD president, discussed Interaction of Hydraulic Structures with Air, Water, and Rock – the Challenges of Researchers and Designers. Dr. Vijay Singh, professor at Texas A&M, discussed Hydraulic Structures and Entropy-Based Modeling. Philip Burgi (U.S. Bureau of Reclamation-Retired) provided insights on Challenges in Design and Use of Hydraulic Structures in Response to New Realities. Thomas North (U.S. Army Corps of Engineers) discussed Hydraulic Structures, the Future of Design.



Field Tour: Gated Spillway at Bonneville Dam and Multnomah Falls

Field Tour: Fish Ladder at Bonneville Dam

The symposium included 13 technical sessions featured 75 presenters, and covered a wide range of topics including:

- spillway hydraulics, stepped spillways, 3D weirs
- scour, erosion, and sedimentation
- energy dissipation
- canals and waterways
- coastal structures
- operation, maintenance, and dam safety risk assessments
- ship locks and spillway gates
- dam rehabilitation
- fish passage
- pressurized flows

A highlight of the technical program also included the specialty session on large river basin management and the role of hydraulic structures. Three of the most significant river systems in the US were discussed: the Tennessee River System (Keil Neff, Tennessee Valley Authority), the Colorado River Basin (Daniel Bunk, U.S. Bureau of Reclamation), and the Columbia River Basin (Peter Dickerson, U.S. Army Corps of Engineers).

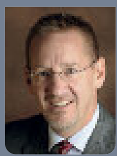
The Columbia River Basin represents one of the key waterways in the US. Dams have been built along the river course to improve navigation and generate hydropower while preserving natural resources such as fisheries. Bonneville Lock and Dam is one of the most significant structures on the river and is operated by the U.S. Army Corps of Engineers. A field tour took place on the last day of the symposium. Participants had the chance to visit the Bonneville Lock and Dam, including a close-up inspection of the power house, lock, and fish passage facilities. En route, the field tour stopped at Multnoma Falls, followed by the Bonneville Fish Hatchery operated by the Oregon Department of Fish and Wildlife. Special thanks to the U.S. Army Corps of Engineers for working closely with event organizers to arrange this memorable field tour!

A total of 77 manuscripts comprise the ISHS2016 Proceedings-Hydraulic Structures and Water Systems Management

(ISBN 978-1-884575-75-4). Each paper was thoroughly peer-reviewed for technical quality and presented at the Symposium. 65 individuals formed the International Peer Review Panel. The Proceedings was published by Utah State University and is available open access at http://digitalcommons.usu.edu/ishs/2016/. Each manuscript includes the ISBN of the Proceedings as well individual direct object identifiers (DOI). Each manuscript is indexed by Scopus and Compendex. [During the first 2 months following publication, there have been over 2,200 downloads from six continents.] ■

ISHS2016 would not have been a success were it not for the support and involvement of the following organizations: American Academy of Water Resources Engineer of ASCE, Association of State Dam Safety Officials, Bechtel Corporation, École Polytechnique Fédéral de Lausanne , FH Aachen University of Applied Sciences, FH Lübeck University of Applied Sciences, Instituto Superior Técnico, International Association of Hydro-environment Engineering and Research, International Congress on Large Dams, Schnabel Engineering, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Federal Energy Regulatory Commission, Université de Liège, United States Society of Dams, University of Queensland, University of Pisa, University of Coimbra, USDA Agricultural Research Service, Utah State University, Utah Water Research Laboratory and West Consultant. Special thanks to our financial sponsors: Schnabel Engineering, West Consultants, ACF Environmental, Gannett Flemming, and HDR.

***Brian M. Crookston*, PhD, PE, M.ASCE, (ISHS2016 Scientific Chair) is a Senior Engineer with Schnabel Engineering. His consulting and research interests are focused on water conveyance, including the design of hydraulic structures, nonlinear spillways, flow acoustics, energy dissipators, scour, fish passage, dam breaches and flooding, and physical and numerical modeling of hydraulic structures. Prior to joining Schnabel, Brian obtained a PhD from Utah State University and was a researcher at the Utah Water Research Laboratory.**



***Blake P. Tullis*, PhD, F.ASCE, (ISHS2016 Scientific Vice-Chair) is an associate director at the Utah Water Research Laboratory and professor at Utah State University. He conducts research in the areas of labyrinth and piano key weirs, weir submergence, culvert hydraulics, and fish passage. Blake teaches courses on hydraulic structure design, pipeline hydraulics, and fluid mechanics.**

***Michele Palermo*, PhD, is a Researcher at the University of Pisa, Italy. His main scientific interests are localized scour phenomena downstream of hydraulic structures, design of eco-friendly structures for river restoration, scour control at bridge piers, plunge pool scour process, physical modeling of hydraulic structures, and hydraulic jump on rough beds.**

***Daniel B. Bung* is a Professor for Hydraulic Engineering at FH Aachen University of Applied Sciences, Germany, since 2012. He finished his studies in Civil Engineering at Bergische University of Wuppertal, Germany, where he was also awarded his doctoral degree in 2009. In his PhD project, he studied flow properties of self-aerated stepped spillway flows by means of experimental work. His main research interests are air-water flows, gas transfer, and experimental and numerical modeling with a focus on hydraulic structures.**

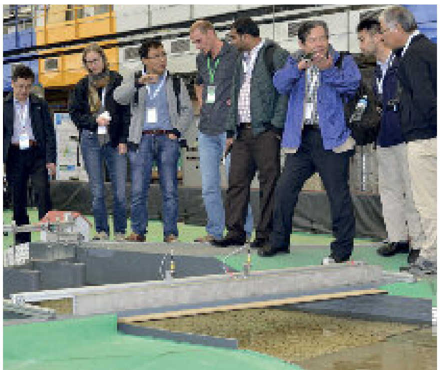
SEDIMENT MATTER(S)

A REPORT FROM THE ISRS SYMPOSIUM 2016 - STUTTGART, SEPTEMBER 19 - 22

BY STEFAN HAUN, KAROLIN WEBER, MARIA COSTA & SILKE WIEPRECHT

The International Symposium on River Sedimentation (ISRS) was established in 1980 by the Chinese Hydraulic Engineering Society (CHES) with institutional support from the United Nations Educational, Scientific and Cultural Organization (UNESCO) and is held every three years. The main idea of the founders of the symposium series was to attract scientists and engineers interested in understanding fundamental physics of sediment transport the symposium topics include applied science and case studies. Under the auspices of the International Research and Training Center on Erosion and Sedimentation (IRTCES) the symposium has been held so far twelve times. In 2004 the World Association for Sedimentation and Erosion Research (WASER) was founded and since that time the symposium serves as the official symposium series of WASER.

The 13th International Symposium on River Sedimentation (ISRS) 2016 was organized by the University of Stuttgart and was held at the university campus from September 19 to September 22 with almost 300 registered participants. The goal of the conference was to bring together a broad range of scientists, professionals and decision makers with the goal toward a true understanding of sediment dynamics as well as sediment management through strong inter- and transdisciplinary interaction. Beside natural scientists and engineers, also ecologists, sociologists, economists as well as politicians were in attendance.



Dr.Ing. Markus Noack explains the participants the measurement equipment of a physical model for flood retention studies.

Conference Program

The majority of rivers, reservoirs and lakes are no longer in a natural morphodynamic status. Understanding sediment transport and dynamics is therefore of great importance for re-vitalizing these water bodies and for avoiding further negative impacts. An important issue with regard to sustainable development is taking into account the spatial scale (from catchment scale to micro scale), the temporal scale (from short term like the movement of a single grain to long term effects like morphological changes) as well as the multiple disciplines that must be considered. The conference topics were therefore organized to address a multitude of disciplines and scales:

A - Integrated Sediment Management at the River Basin Scale
B - Sediment Transport
C - River Morphodynamics
D - Hydromorphology meets Ecology
E - Reservoir Sustainability
F - Social, Economic and Political Aspects of Sediment Management

Five additional special sessions were scheduled, focusing on topics which are currently a part of many research projects world-wide, with a special focus on human intervention on water bodies and the way to avoid them.

1 - Hydropower and Sediment Management
2 - Navigation and River Morphology
3 - Innovative Measurement Techniques
4 - SEDITRANS – Sediment Transport in Fluvial, Estuarine and Coastal Environment
5 - Sustainable Land Management

The International Scientific Committee reviewed together with the local organizing committee a total number of 303 submitted abstracts, which were submitted from 51 countries. After the review process of the extended abstracts and full paper submissions, 185 papers were selected for publication in the conference proceedings. Within 30 sessions, 183 papers were orally presented during the symposium as well as 39 posters were displayed during the poster exhibition.

Maria Costa Jornet **studied translation and interpreting at the Universitat Pompeu Fabra (Spain). She has worked as an administrative assistant at the Institute for Modelling Hydraulic and Environmental Systems of the University of Stuttgart since 2007.**

Karolin Weber **studied chemistry at the University of Braunschweig, Germany and received a PhD from the Institute of Applied Geology at the Karlsruhe Institute of Technology in 2001.**

Silke Wieprecht **is a full-time professor and the head of the Department of Hydraulic Engineering and Water Resources Management of the University of Stuttgart. She is advisor of the Baden-Württemberg Young Professional Network of the IAHR ,and member of the World Council of the IAHR.**

Stefan Haun **studied Civil Engineering at Graz University of Technology and obtained his doctoral degree from the Norwegian University of Science and Technology in 2012. He is the head of the working group Hydromorphology at the Institute for Modelling Hydraulic and Environmental Systems of the University of Stuttgart.**

Highlights

Highlights of the congress included the keynote lectures presented by Weiming Wu, Clarkson University, Potsdam, N.Y. (USA), David M. Paterson, University of St Andrews, St Andrews (UK), and Bruce W. Melville, The University of Auckland, Auckland (New Zealand). In addition, a special "Workshop on International Sediment Advancements" including a plenary discussion by Rollin Hotchkiss (ISI-UNESCO), Zhaoyin

Wang (IAHR), Desmond Walling (IAHS), Giampaolo Di Silvio (WASER), Ildefonso Pla Sentis (CONSOWA) and Silke Wieprecht (Chair of the local organizing committee of ISRS 2016) took place during the conference.

Awards

During the closing ceremony several awards were presented. Due to his outstanding contribution to sediment transport research, Prof. Chi Ted Yang was announced as a new honorary member of WASER.

Prof. Chi Ted Yang was announced as new honorary member of WASER. Prof. Giampaolo Di Silvio handed over the certificate to Prof. Mathias JM Römkens in the absence of Prof. Yang

The last task of Prof. Silke Wieprecht, Chairperson of the LOC of the ISRS 2016 in Stuttgart, was to hand over the ISRS banner during the closing ceremony to Prof. Liu Guangquan, the representative of the permanent ISRS Secretariat

Three papers published in the "International Journal of Sediment Research" were granted an award for their distinguished publications:

- Xi-Xi Lu et al. 2013: "Sediment loads response to climate change: A preliminary study of eight large Chinese rivers",
- Qianqian Shang et al. 2014:" Biofilm effects on size gradation, drag coefficient and settling velocity of sediment particles" and
- Moritz Thom et al. 2015: "Seasonal biostabilization and erosion behavior of fluvial biofilms under different hydrodynamic and light conditions"

Proceedings

The hardback conference proceedings were published by CRC Press / Balkema (Taylor and Francis group) and contained extended abstracts as well as an electronic copy of the full papers. The official title: River Sedimentation: Proceedings of the 13th International Symposium on River Sedimentation (Stuttgart, Germany, 19-22 September, 2016) can now be ordered directly from Taylor and Francis, ISBN: 978-1-13802-945-3.

High quality papers were selected for additional publication in one of four special issues in peer reviewed international journals, namely: Journal of Applied Water Engineering and Research (JAWER), International Journal of Sediment Research (IJSR), International Journal of River Basin Management (JRBM) and Journal of Soils and Sediments (JSS).

Two technical excursions (hydropower plant Iffezheim and sediment supply in the Rhine River as well as the pump storage plant Schluchsee) and two local tours (visit of the hydraulic laboratory of IWS combined with either a city tour to Stuttgart or "Stocherkahnfahrt" in Tübingen) were offered during the symposium.

The symposium was closed on Thursday and the official ISRS symposium banner was handed over to Prof. Liu Guangquan, the representative of the permanent ISRS Secretariat. He thanked the 13th ISRS LOC in Stuttgart and announced the venue of the next ISRS at Sichuan University in Chengdu, China. Finally, Prof. Lin Pengzhi, the representative of the 14th ISRS LOC received the symposium banner.

37th IAHR World Congress

13-18 August 2017, Kuala Lumpur, Malaysia

The National Hydraulics Research Institute of Malaysia, Department of Irrigation and Drainage Malaysia and the River Engineering and Urban Drainage Research Centre, Universiti Sains Malaysia are collaborating with International Association for Hydro-Environment Engineering and Research (IAHR) to organize the IAHR World Congress 2017. The congress received more than 1300 abstracts from 60 different countries. Full paper submission was closed on 15th February 2017. Online registration of the congress will be opened in April 2017.

The theme of the congress is "Managing Water for Sustainable Development - Learning from the Past for the Future". 11 keynote speakers will be giving keynote speeches for seven different themes of the congress. The opening keynote speech will be delivered by Dr. Tyler A. Erickson, senior developer advocate at Google on how to democratize access to global water information with Cloud Technologies.

More information of the congress can be found in Congress website at **www.iahrworldcongress.org**

Six pre-congress workshops will be organized:

- Hands-On Introduction To Google Earth Engine
- 2-Day Workshop On Stormwater Management
- Master Class On River And Sediment Management
- Master Class On Flood And Estuary-Coastal Management
- 2-Day Workshop On Coastal Management
- 1-Day Workshop On River Management

There will be six special sessions available during the congress:

1. Transients in Pipes
2. Sustainable Water Resources Planning & Management under Climate Change
3. Function of Governance to River Restoration under the Climate Change
4. Green Infra as Disaster Risk Reduction Measures in the Asian-Pacific Region
5. The path to resiliency in low gradient coastal regions for present and future conditions
6. Coastal Reservoir -- A Technology that Can Develop Freshwater from the Sea Without Desalination

IAHR 2017
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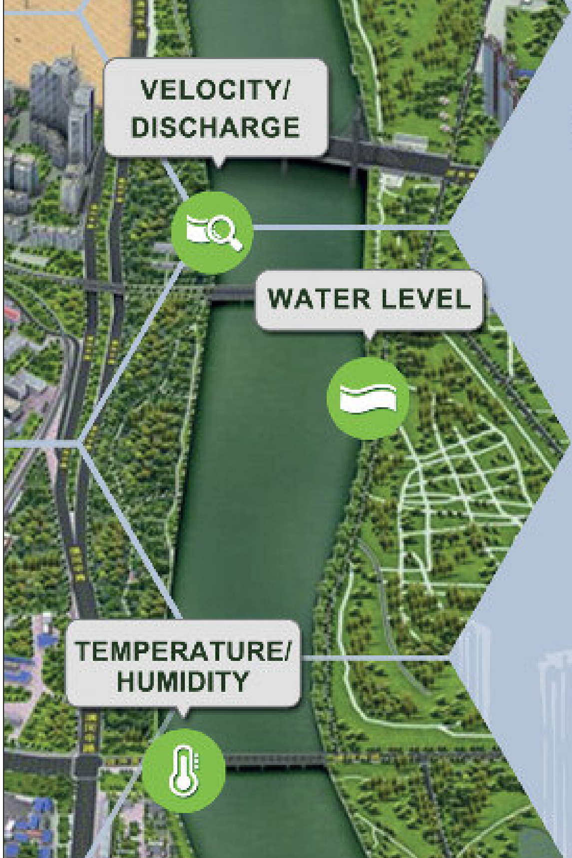

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