hydrolink

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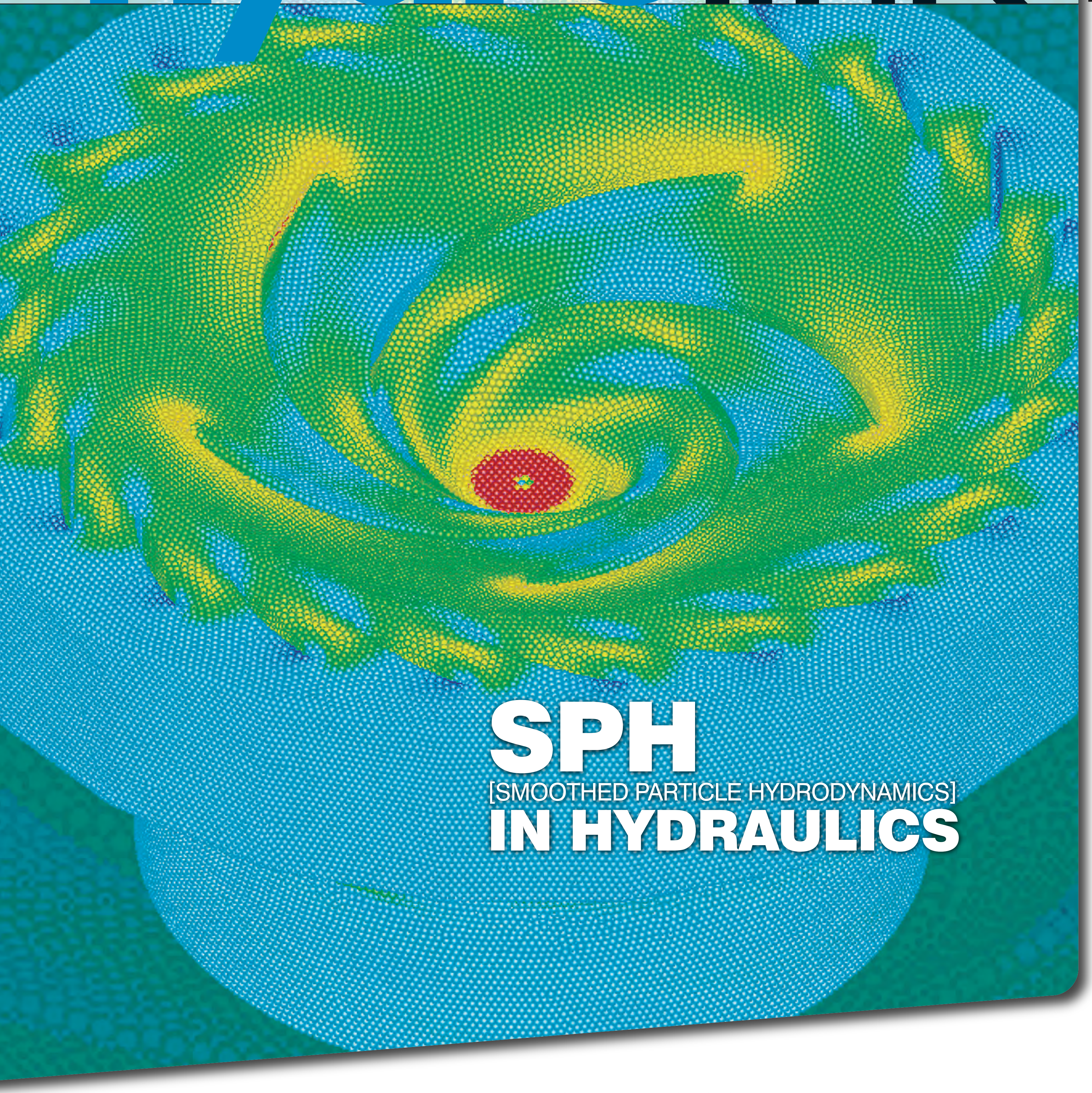

SPH
[SMOOTHED PARTICLE HYDRODYNAMICS]
IN HYDRAULICS

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IAHR
AIRH
International Association
for Hydro-Environment
Engineering and Research

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EDITORIAL

BY ANGELOS N. FINDIKAKIS

Angelos N. Findikakis
Hydrolink Editor

In the 80 years since it was founded IAHR has evolved from a small group of hydraulics laboratories into an organization that brings together researchers and practitioners working on the many challenges posed by the need to develop and better manage freshwater resources, avoid water-related disasters, and protect the environment. In addition, it has grown from a Eurocentric group in the 1930's to a truly global organization today with its Secretariat being based in both Madrid and Beijing, and its membership spread across all continents.
Hydraulic research is by its nature applied research, as it is driven by the need to solve a broad range of specific problems from the design of hydraulic structures to the mitigation of flooding hazards, and from the management of water resources and the efficient water use to the processes affecting water quality and the habitat of aquatic organisms.
The two factors that have been directing the attention of public opinion increasingly more towards water-related problems over the last few years are the realization that limited freshwater resources must support continuing population and economic growth, and the need to adapt to the consequences of climate change, such as managing more hydrologic extremes, floods and droughts, and sea-level rise.
In view of these challenges, IAHR former President, Professor Roger Falconer, laid out his vision for the future of the Association in the last issue of Hydrolink stressing the need for IAHR, working together with other water associations, to engage in supporting international agencies funding water projects, water industry stakeholders, farming associations or other water user groups, and play a greater role in advising national and regional governments on grand challenge initiatives and on the direction of research on water issues.
Hydrolink can help make this vision a reality. Since its launching in 2008 as a replacement of the IAHR Newsletter, it has been publishing articles and stories that illustrate how hydraulic research and engineering practice come together to solve some of today's pressing water issues. Designing each issue of the magazine around a single theme helps draw attention to the subject. Examples are issues on themes such as global water security, major water infrastructure developments, e.g. the Three Gorges Project and the New Panama Canal, the environmental challenges of the Sacramento-San Joaquin River Delta in California, and the experience of the Dutch in managing their Delta. Other themed issues have focused on new developments in research in experimental hydraulics, such as the issue on Hydralab, or emerging numerical methods and tools such as the current issue on smoothed particle hydrodynamics.
Future issues of Hydrolink, already in the planning stage, will focus on various water issues and projects in Africa, wastewater treatment and water reuse, and the role of hydraulic laboratories in supporting the design and construction of water infrastructure projects and in mitigating their environmental impacts. We are also planning a special issue on water projects in Latin America, which will circulate at the time of the Latin America Division in Lima, Peru next September. I would like to invite our readers to contact us with suggestions on other themes and specific articles that they would like see published. Information on how to contact the Hydrolink editorial team and guidelines for the preparation of articles for the magazine can be found on the Hydrolink page of the IAHR website.
In closing, I would like to congratulate my predecessor Professor Michele Mossa for his great work and his many accomplishments as Editor of Hydrolink the last five years. During his tenure Hydrolink doubled in size and its content was significantly enriched.

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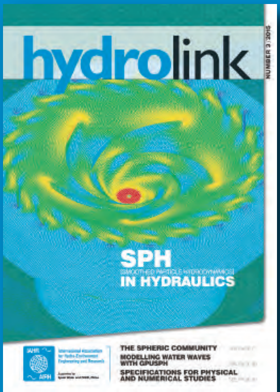

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Cover picture: Detail of a SPH generated flow velocity of a turbine. *From the article "Study of flow patterns in hydraulic turbines with SPH-ALE"*

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Careers at HKUST

Faculty Position in Hydraulics/Environmental Fluid Mechanics
Department of Civil and Environmental Engineering

Job Posting Details

The Department of Civil and Environmental Engineering invites applications for a substantiation-track faculty position at Assistant/Associate Professor level in experimental hydraulics/ environmental fluid mechanics.

Applicants must have a PhD degree in hydraulics/environmental fluid mechanics or a related field. The appointee is expected to demonstrate strong potential for effective teaching and promising research in the respective fields, as well as play a key role in the development and operation of the Hydraulics/Water Resources Laboratory.

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Interested candidates are invited to send (i) an updated Curriculum Vitae, (ii) a statement of research and teaching interests, and (iii) names and contact information of at least three referees by email to cejob@ust.hk or by fax to (852) 2335 5493. Review of applications begins immediately and will continue until the position is filled. Enquiries can also be sent to cejob@ust.hk.

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Human Resources Office

THE SPHERIC COMMUNITY

BY DAMIEN VIOLEAU AND BEN D. ROGERS

The Smoothed Particle Hydrodynamics (SPH) numerical method is nowadays becoming a classical tool in academic research and in recent years has produced numerous successful industrial applications in fluid dynamics and fluid-structure interactions. As a purely Lagrangian technique, SPH enables the simulation of highly distorting fluids and solids. Fields including free-surface flows, solid mechanics, multi-phase, fluid-structure interaction and its original field of development, astrophysics, where Eulerian methods can be difficult to apply represent ideal applications of this meshless method.

Publications in peer-reviewed journals show that an increasing number of academic institutes or industrial companies contribute to this development all around the world, particularly in Europe. Collaborations between labs of various countries are also becoming increasingly numerous, meaning that SPH is approaching maturity in applied and industrial sciences.

SPHERIC, or “SPH European Research Interest Community”, is an international community which aims to promote the SPH method in both academic and industrial fields and enhance collaborations between countries and institutes. It was recognized as a Special Interest Group (SIG) within Ercoftac (European Research Community on Flow, Turbulence and Combustion) in January 2006. Today, SPHERIC has more than 60 member institutes, including several industrial partners. Currently, 28 countries are represented. A Steering Committee of 13 individuals from academia and industry meets twice a year for a 1-day meeting to take decisions regarding the group activities.


The Paris SPHERIC workshop (June 2014)

SPHERIC’s website (https://wiki.manchester.ac.uk/spheric) depicts the activities of the group. The main event is the annual workshop, a 3-day small conference where about 100 delegates meet to share their recent improvements. High quality proceedings are provided for the participants, and a training day allows newcomers to get more familiar with SPH. The best student presentation is awarded the Libersky prize.

Benchmark test cases are also available on the website, as well as job proposals, a large list of reference papers in Bibtex format, useful links, etc. A biannual newsletter is published and sent all around the world with each issue containing 8 to 10 pages submitted by SPHERIC members detailing significant innovations and applications of SPH in various fields. The past issues can be downloaded from the website.

***Damien Violeau* has been working since 1997 at the Laboratoire National d’Hydraulique et Environnement of EDF R&D, where he was appointed Senior Scientist in 2013. He was introduced to IAHR in 2003. He was co-opted member of the Council in 2013 and was appointed Associate Editor if the JHR in January 2015.**

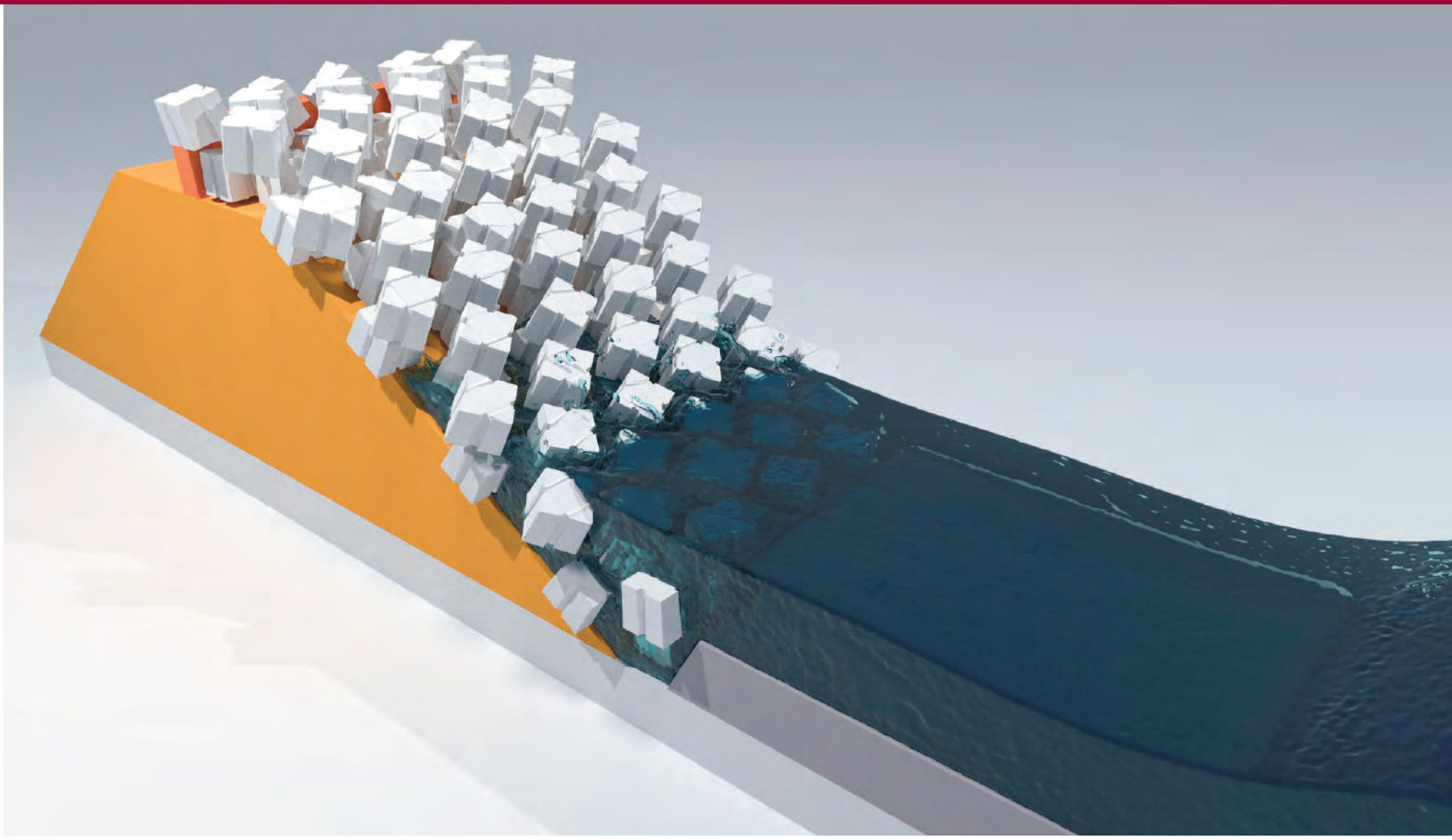
***Benedict Rogers* is a Reader at the School of Mechanical, Aerospace and Civil Engineering (MACE) in the University of Manchester. With his doctoral studies in numerical simulation of free-surface flow for shallow water, he has more than 13 years of experience of SPH research having published over 30 journal papers on SPH.**

Though being a mature approach, SPH still suffers from a lack of broad recognition from the scientific community as a serious candidate to become one of tomorrow's numerical tools. One of the main reason of this is that SPH still has unknown characteristics, and many questions remain unanswered on purely theoretical grounds. In order to progress in the knowledge of these problems, SPHERIC has identified four Grand Challenges: Convergence, Numerical stability, Boundary conditions and Adaptivity. Named after one the original developers of SPH, the Joe Monaghan Prize has been established to recognise SPH researchers who make outstanding advances in one or more SPHERIC Grand Challenges.

Newcomers in SPH are encouraged to visit our website and attend our workshops. We hope this special issue of Hydrolink will enhance the interest in this challenging and fascinating numerical method.

A BRIEF HISTORY OF SPH IN HYDRAULICS

BY JOSEPH J. MONAGHAN



DualSPHsics team

The first description of Smoothed Particle Hydrodynamics (SPH) was published in 1977 by Joe Monaghan and Bob Gingold, and independently by Leon Lucy. The method originated in the desire to simulate the formation of binary star systems. These systems are characterised by flows with complicated geometry and very large variations in density. None of these characteristics could be handled with the finite difference methods that were then available. The basis of SPH was the assignment of the properties of the system to particles with fixed mass. By using interpolation modelled on the kernel method that statisticians used to estimate probability densities, it was possible to estimate derivative of quantities, such as the pressure and temperature that were known at the particles. Gravitational forces could be calculated by summing over the particles, though a straightforward summation was soon replaced by more sophisticated tree-code algorithms. In this way the forces acting on the particles were calculated and the motion of the particles followed. These particles represented elements of fluid and their stream lines and acceleration were estimates of the same quantities for the fluid. The methods were extended to deal with thermodynamic effects in gas dynamics, and to deal with the shock waves that are very common in astrophysical simulations. An attractive feature of SPH was that the resolution could be allowed to vary in space and time, although the correct way to include this in the algorithms was not known for 25 years. Another attractive feature was that the algorithms were simple, but very complicated problems could be simulated easily.

The application of SPH to liquid problems began in 1993. I had an interest in Archaeology and attended a seminar on the demise of the Minoans. The speaker pointed out that there was considerable evidence that the Minoan civilisation on Crete had been badly disrupted at the time of the eruption of a massive volcano on Thera (Santorini), and some investigators thought the volcanic eruption had produced tsunamis that destroyed the coastal towns of Crete. I was intrigued by this and asked an archaeologist, Peter Bicknell (an old friend, who worked with us on this problem), if the archaeologists would be interested in a fluid dynamicist calculating whether tsunamis would have been produced, and then what damage they might cause. He said they would be, and he referred to the fluid dynamics simulations as "the hard evidence" that was all too rare in Archaeology. At this time I had never simulated any problem in liquid dynamics but I was convinced that waves breaking on the Cretan coast could be simulated using SPH. It seemed to me too difficult to treat a liquid as incompressible and I decided to explore the possibility that slightly compressible fluids could give a good approximation to liquids like water. Incidentally, water is slightly compressible, but with a speed of sound of around 1500 m/s and this was too high for the simulation of a fluid on a macroscopic scale of 10 or 20 km. I therefore gave the fluid an artificial equation of state that was large enough to guarantee, in most cases, that the fluctuations in the density were small. For me small was ~ 1%, and this could be achieved by ensuring the speed of sound was a factor 10 greater than the impact speeds in the fluid dynamics problems we might consider. Apart from that, I used the same algorithm that I used for gas dynamics, with the exception that the astrophysicists calculated the density by a summation over the SPH particles while I found that, for liquids, it was better to integrate the continuity equation. The resulting algorithm was applied to a dam breaking over a triangular obstacle, a bore, and the generation of waves surging up a beach (Monaghan 1994). The resolution was poor but the main features of the flow were correct to within 10%. To end this story we set up a laboratory and studied waves produced by moving bodies and we received a grant for a team to core likely areas on the coast of Crete for evidence of marine inundation. The work was exciting but the results were meagre. Following this we began extending SPH to a wider class of problems including waves breaking on beaches, and waves produced by rigid bodies sliding down ramps (Monaghan and Kos 1999, 2000). This was taken up and applied successfully by Colagrossi and Landrini (2003) and later by Landrini et al. (2007)). Good examples of the application of SPH to problems involving liquids is the work on oil spill over and under booms (Violeau et al. 2007) and sloshing (Souto-Inglesias et al. 2006). It was also immediately clear that SPH could be easily used to simulate problems involving two or more fluids (Monaghan et. al. 1999) as in the simulation of flow into a stratified fluid. During the same period we got interested in the fracture mechanics of materials largely because we wanted to consider geological fractures like those produced by magma beneath volcanoes (Gray and Monaghan 2004). Now we are simulating fracture produced by boat hulls hitting water. Fracture was the focus of the work of Willy Benz who used SPH very successfully to model the impact of asteroids (Benz and Asphaug 1994). When we started we had no knowledge of fracture mechanics, but I was also sure that few (if any) people could simulate the fractures seen in practice. I can still remember being in the Monash library and looking at the several shelves of books on fracture and convincing myself that most of them were either wrong or described methods that could not be used for complicated fracture problems. I still think I was right.

Progress has been made in a number of areas (for a review see Monaghan 2012). The first of these is in modelling surface tension and multiphase problems (Adami et al. 2010), the most important of which is the combination of air and water as in a breaking wave (Grenier et al. 2009, Monaghan and Raffiee 2013). The mass of the air is negligible but its pressure isn't and that makes air important. The second is the study of the accuracy of SPH algorithms near boundaries (see for example Macia et al. 2011) which shows that improvements can be made using an appropriate mapping of the velocity field of the fluid onto ghost particles in the boundary. The third is improvements in the modelling of boundaries (for example Adami et al. 2012 and Leroy et al. 2014). Adami et al. (2012) use ghost particles with a pressure and velocity interpolated from the fluid particles. The density of these particles is then calculated from the pressure using the equation of state. Leroy et al. (2014) use analytical methods. The fourth improvement is the extension of SPH algorithms to three dimensions. It is ironic that the application of SPH to astrophysics always used algorithms for three dimensions whereas all the early SPH applications to fluids were for 2D. It is one of the pleasures of using SPH that the code for three dimensions is as easy to write as one for two dimensions. However, in the case of nearly incompressible flow, the time steps are small, and the computations in 3D were too time consuming. The situation has now changed with progress being driven by new hardware. Looking back 10 years, we can see that the astrophysicists were using between 105 to 109 SPH particles for their simulations. These simulations required parallel processing units, and there is publicly available software for astrophysical gas dynamics (Gadget) pioneered by Volker Springel. In the last 2 years there have been increasing applications of GPUs (Graphics Processing Units) to SPH problems relevant to Engineering problems (Hérault et al. 2010), and public software (SPHysics) due to Ben Rogers and Tony Dalrymple and their colleagues is now available. This hardware allows ~ 106 SPH particles to be used in hydraulic computations. Finally, it is worth remembering, that SPH is widely used for special effects in movies where its ability to model violent impact with water is appreciated.

Joe Monaghan **is Emeritus Professor of Applied Mathematics in the School of Mathematical Sciences, at Monash University, Australia. He is the author of numerous papers concerned with the development of SPH and its application to astrophysical problems, the motion of liquids and gases, elasticity and fracture, and the dynamics of dusty liquids and gases.**

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SPH APPLICATION IN THE DESIGN OF HYDRAULIC STRUCTURES

BY DAVID LOPEZ, RUBEN DIAZ, JUAN. J. REBOLLO AND VICENTE CUELLAR

The hydrodynamic study of hydraulic structures is challenging for hydraulic engineering. Traditionally this study has been addressed through physical modeling since there was no commercial software to study with this type of design guarantees. Hydraulics structures usually have complex geometries on a violent flow flowing at high speeds where the free surface is very deformable, which greatly hinders proper modeling. Physical modeling has very high costs so it is justified in works of a certain size. In addition, both artisanal construction procedures as laborious instrumentation techniques require sometimes excessive times. For this reason, a numerical tool is essential to complement these studies using hybrid modeling, numerical and physical.

Figure 1 - Physical and SPH dam break simulation

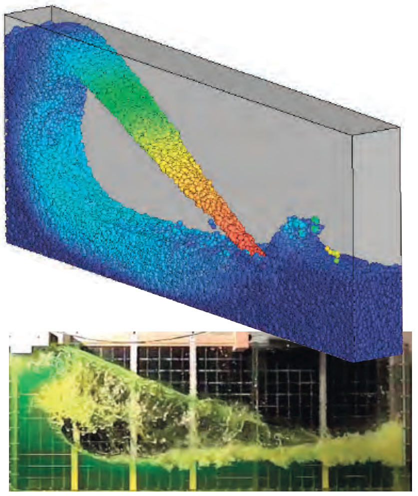
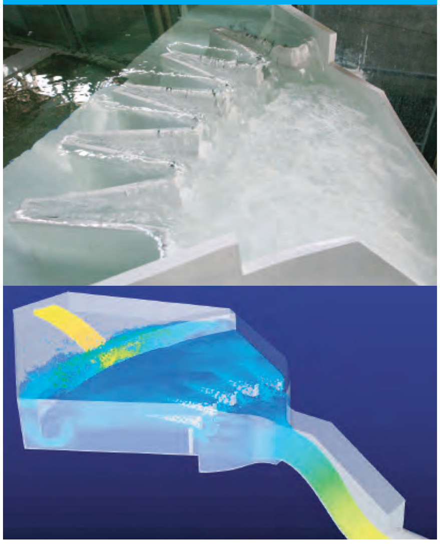


Figure 2 - Physical and SPH simulation of the new Calanda spillway



CEDEX (Research and Experimentation Center of Public Works, an autonomous organisation of the central Spanish State Administration) has developed a model based on the SPH method. There is evidence that Lagrangian models and SPH method especially allow to simulate the hydrodynamic flow of this type of infrastructures. The main drawback has been the high computational cost. The computer code MDST is a FORTRAN code (Grassa, 2004) that has evolved since 2004, from a sequential version to a parallel version with MPI (Message Passing Interface) paradigm for supercomputing in cluster. MPI version allows simulating millions of particles and solving real problems. The impressive improvement of the computing capabilities of graphics cards has allowed the development of a version CUDA FORTRAN called SPHERIMENTAL (López, 2013).

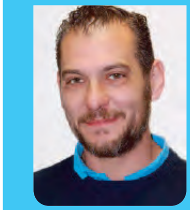
At the same time that the capacity of calculation has been improved too, the calibration of SPH method has progressed in in this application field. On the one hand, a turbulence model based on vorticity of particles has been developed to reproduce viscous dissipation due to turbulence, using as test case the hydraulic jump. (López, 2010). In addition to this, a friction boundary condition has also been implemented as essential premise to reproduce the flow in open channels. On the other side, boundary conditions input and output have been introduced in SPHERIMENTAL (López 2012).

A numerical diffusion problem has been detected in studies of wave propagation with SPH which attenuates the energy of the system. Using the test case dam break (Figure 1), a thermodynamic correction method has been implemented in the code (López, 2015).

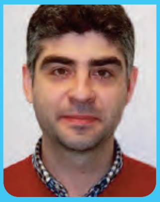
The SPH model has been used in a complementary manner in multiple studies of technical assistance developed in CEDEX, improving the method calibration. The first one was the new spillway of Calanda dam. Currently, this dam has a surface spillway. To increase drainage capacity, a new spillway tunnel was projected on the right side. In this sense, a physical model was used for the spillway analysis. After a laborious tests process, this design showed several failures of flow behavior. Then, to save time, the original design modifications were only carried out with SPH simulations. Moreover, other different types of spillway were analyzed with this numerical method. This numerical study allowed a general vision of the different alternatives in a short lapse of time. A labyrinth spillway was selected as best solution that finally was built in physical model (Figure 2). Since then, in cases where deemed necessary, a preliminary analysis is performed on numerical model to improve the design prior to the study of the physical model.

ALIVESCA project helped to study the influence of side walls in stepped spillways. A study was performed on physical model at the Polytechnic University of Catalonia and CEDEX with SPH to simulate numerically the stepped spillway upper zone where the aeration has less influence. The study looked into the lateral expansion of the flow and also in the analysis of the mechanism of exchange of momentum between the nappe flow and eddies into the steps (Figure 3).

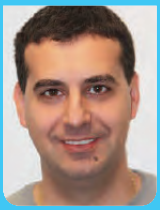
Recently the spillway of Nagore dam has been studied with SPH. It is a rock fill dam with an overflow spillway tunnel. By numerical modeling, the spillway rating curve has been obtained. Moreover, transient phenomena have been analyzed during the initial working phase, when there is a mobile hydraulic jump which moves along the gallery depending of the flow rate (Figure 4). For this study, a correctly reproduction of friction boundary condition is very important, requiring a laborious calibration process.



David López **is Ph.D. in Civil Engineering and member of the State Corps of Civil Engineers. He started working in the Hydraulics Laboratory of the CEDEX in 1993, developing different projects and researches in areas related to hydrodynamic studies of hydraulic structures by using physical and mathematical modelling (SPH), river hydraulics, sediment transport and fluid mechanics.**



Juan José Rebollo **is M.Sc. in Civil Engineering and member of the Technical Scale of the Ministry of Public Works and Transport. His professional career began in the CEDEX in 2009 as engineer of the Hydraulics Laboratory. His interest areas are related to the physical and numerical modelling of hydraulic structures, fluid mechanics and hydro-environmental researches.**



Rubén Díaz **is M.Sc. in Civil Engineering and member of the State Corps of Technical Civil Engineers since 2006. He began his professional career in the Hydraulics Laboratory of the CEDEX in 2009. His current interest fields are the physical and numerical modelling of hydraulic structures, hydro-environmental researches and river dynamics.**

Vicente Cuellar **is a Civil Engineer with more than 15 years of experience working in software development and high performance computing. Has ample experience in such fields as Machine Learning, Big Data and Numerical Modelization. Has been working for many years in parallelization (CUDA and MPI) and has passion for data visualization (OpenGL, HTML5, Canvas, etc.)**

Also, the remodeling of the intermediate spillway of the Bárcena dam has been recently studied. In 1996 a study was conducted at the Hydraulic Laboratory of CEDEX with a physical model test. Construction is running at present. The customer has raised a number of amendments to simplify construction, such as the size reduction of the center pile (Figure 5), providing a short period for this study. This work was performed within two months using numerical simulation with SPHERIMENTAL model, allowing to analyze the flow of the influence area at the drainage intake and check the velocity and vorticity field. The calibration of the friction boundary condition was performed with data of the former physical model.

Another researching line in CEDEX is the EMULSIONA project. This project analyzes the influence on the efficiency of dissipation of energy in a hydraulic jump, aeration inflow in an energy dissipation basin. A physical model has been built for this purpose. The basin is 9 .5 m long, 2 m high and 0.5 m wide, fed by a pressurized flow which introduces a flow velocity of 10 to 20 m / s. the physical model has also a forced aeration system. The experimental data are being used for the calibration of aeration in the SPH model (Figure 6).

Conclusions

The physical and numerical hybrid modeling allows to deepen in the physical basis of the problems analyzed. It also provides more information and help to reduce time and costs of implementing the physical models. Finally facilitates very useful information for calibration of numerical models.

Acknowledges

Ministry of Economy and Competitively of Spain for supporting EMULSIONA and ALIVESCA projects presented to the National Applied Research Projects under the National framework of I+D+I. As well as different administrations of the Spanish Government which have funded the studies included in this paper.

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Figure 3 - Physical and SPH simulation of a stepped spillway

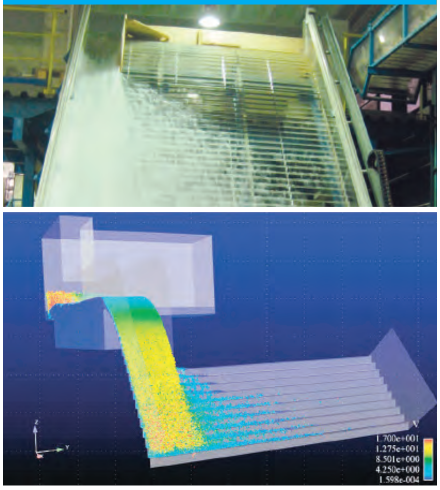


Figure 4 - SPH simulation of Nagore overflow spillway tunnel

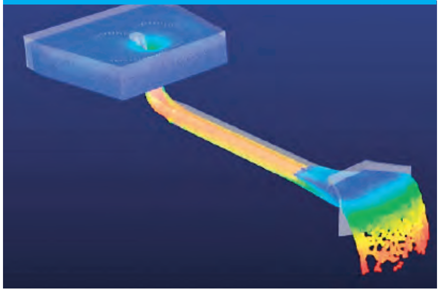


Figure 5 - Physical and SPH simulation of the intermediate spillway of Bárcena dam

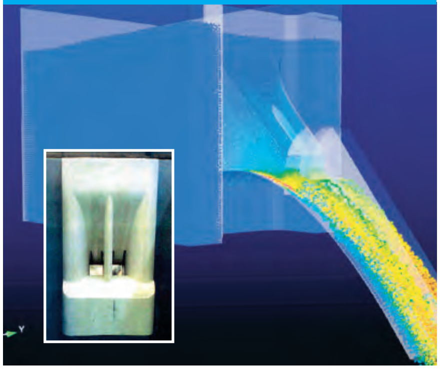


Figure 6 - EMULSIONA Project. Physical and SPH simulation of hydraulic jump

STUDY OF FLOW PATTERNS IN HYDRAULIC TURBINES WITH SPH-ALE

BY JEAN-CHRISTOPHE MARONGIU, MARTIN RENTSCHLER AND ETIENNE PARKINSON

Hydropower is the most developed and stable source of renewable energy. It relies on efficient and reliable mechanical equipment, and primarily on hydraulic turbines whose size can vary from micro power plants (several kilowatts) to large projects (several hundred megawatts). Performance of hydraulic turbines is primarily defined in term of efficiency, which is the ability to convert the mechanical energy of water into mechanical energy for the electro generator.

Global performance also includes stability and safety of operation, cavitation margin, sensitivity to hydro-abrasive erosion, vibration and noise levels and design robustness. Head and flow discharge at site define the amount of energy that can be produced; they also define the type of turbine that can be used and the contours of hydraulic components must be perfectly adapted to these local conditions. Each new project consequently requires an important phase of hydraulic engineering in order to optimize global performance. Computational Fluid Dynamics has naturally acquired an important role in the design process, enabling much faster developments and supporting the continuous improvement of hydraulic performance.

Traditional CFD (Computational Fluid Dynamics) approaches are however limited when treating the free surface flows in Pelton turbines. Mesh-based methods make use of a rotating mesh domain around the runner and steady mesh domain(s) in the casing. The flow coming from the water jet enters the rotating domain, interacts with the rotating buckets, and leaves the rotating domain to enter the casing (1). It crosses the so-called rotor-stator mesh interface twice, which leads to an unacceptable diffusion of the free surface and the impossibility to predict the flow characteristics in the casing, far from the runner.

A mesh-less method like SPH presents obviously some interesting properties for this type of application, thanks to its lagrangian nature. Starting in 2004, ANDRITZ Hydro has developed an internal tool named ASPHODEL which is based on a variant of the SPH method called SPH-ALE (Arbitrary Lagrangian-Eulerian) (2). Compared to the traditional SPH method, this approach allows the use of an arbitrary particle motion which can be Lagrangian (computational particles follow the fluid motion), Eulerian (computational particles are steady) or resulting from more complex models.
ASPHODEL has been tightly integrated into the design process of Pelton hydraulic components. Engineers are relieved from the burden of mesh generation and can concentrate on flow analysis and on hydraulic design. SPH also offers great savings regarding the time to result for Pelton applications. On top of the simplified pre-processing, ASPHODEL simulations outperform the computational time required by mesh-based approaches by a factor of 5, thanks to the possibility of having computational particles only in the liquid phase. For Pelton applications this allows for much reduced case sizes.

ASPHODEL is routinely used in ANDRITZ Hydro for the shape optimization of Pelton buckets and the evaluation of mechanical stresses in Pelton runners. This task is critical for Pelton

Figure 1 - Left: global view of a Pelton unit. Right: flow simulation in a 6-jets Pelton runner with ASPHODEL. Computational particles colored by their velocity in the absolute frame of reference. Blue means low and red means high velocity magnitude values

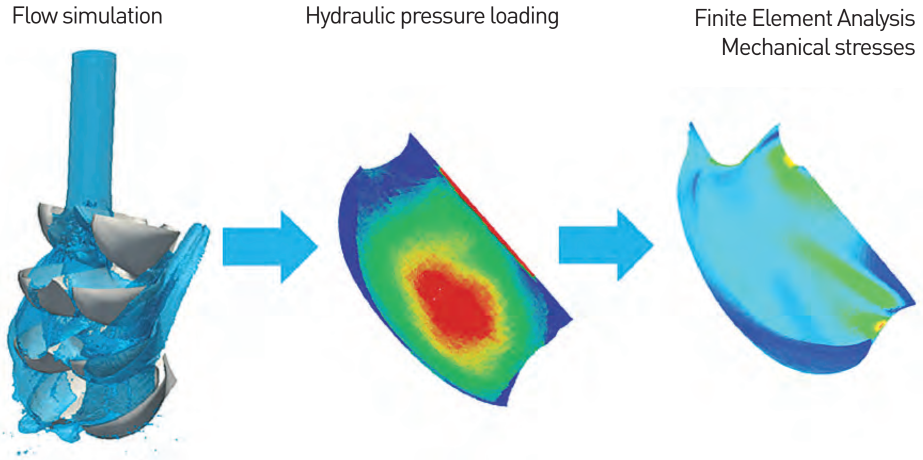


Figure 2 - Coupled Fluid-Structure studies for the mechanical assessment of Pelton buckets. SPH-ALE flow simulation produces an unsteady pressure field transferred to a FE tool for computation of mechanical stresses. Center: blue means low and red means high pressure values. Right: blue means low and red means high Von Mises stress values

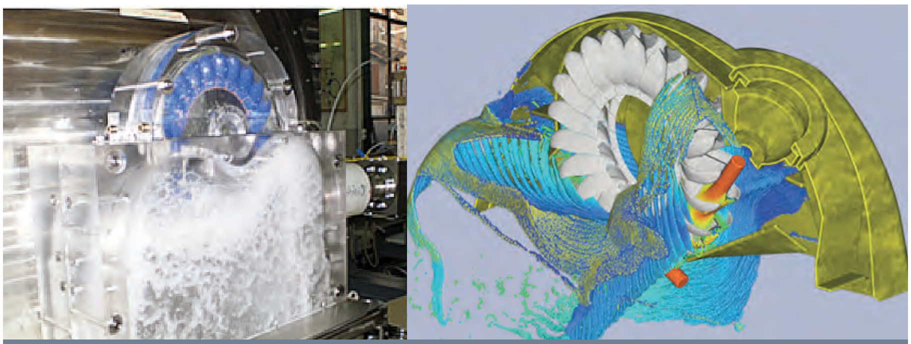
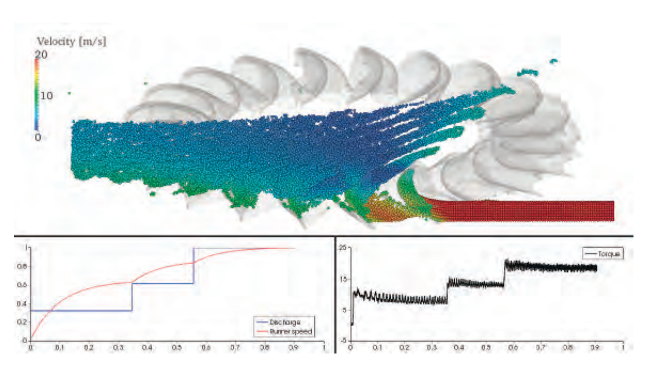


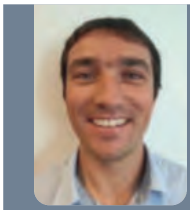
Figure 3 - Study of free surface flows in Pelton casing. Left: model testing of a 2-jets horizontal shaft turbine in hydraulic laboratory. Right: corresponding SPH-ALE flow simulation. Computational particles colored by their velocity in the absolute frame of reference. Blue means low and red means high velocity magnitude values

Figure 4 - Start-up of a Pelton turbine. Top: view of the flow. Bottom-left: time evolution of the flow discharge (blue) and the runner rotation speed (red). Bottom-right: hydraulic torque on the runner. The start-up sequence is composed of three levels of discharge obtained with three different jet diameters. The runner rotation speed results from the hydraulic torque and an externally applied resistive torque



turbines owing to the high amplitudes in the hydraulic loading of rotating buckets, being periodically impacted by water jets. In these studies, ASPHODEL provides an unsteady pressure field on the bucket surface that is then transferred as an external load in a Finite Element Analysis for the evaluation of the mechanical stresses. Thanks to the cost reduction permitted by SPH, these assessments have become systematic, resulting in more optimized designs.

The particle method offers the possibility to precisely capture the water sheets evacuated from rotating buckets until their impact on casing walls. This opens a new era where simulation can help improving the whole hydraulic setting. This is of importance in rehabilitation and modernization projects that combine existing components (casing) and new furniture (runner). Thanks to the numerical prediction of water sheets trajectories, it is possible to detect and correct unfavorable flow phenomena occurring in the casing that could



***Jean-Christophe Marongiu* graduated in Fluid Mechanics and Turbomachinery at Ecole Centrale de Lyon, France. After a PhD on free surface flow simulations with the SPH-ALE method in Ecole Centrale de Lyon, he joined Andritz Hydro in Switzerland in 2007, where he led numerical activities for Pelton turbines. Since 2012, he leads the R&D team located in Lyon, France, responsible for the development of the in-house SPH-ALE software and its application to business areas of the Andritz group.**

Etienne Parkinson graduated in Fluid Engineering at the Hydraulic and Mechanical Engineering school of Grenoble, France. Following a PhD on fluid modelling at Ecole Centrale de Lyon, France, he worked as a research assistant in hydraulic machinery at the Swiss Federal Institute of Technology in Lausanne, Switzerland, until 1995. Moving to ANDRITZ Hydro, he worked actively on numerous R&D issues, especially numerical simulation and model tests for Pelton turbines and Pump-turbines. He is now responsible of Technology Management for Pelton Turbines.

***Martin Rentschler* graduated in Mathematics at the University of Bonn, Germany. After a PhD in mechanics at the Swiss Federal Institute of Technology in Lausanne, Switzerland, he worked as consultant for several projects before joining ANDRITZ Hydro in 2011 as Simulation Engineer. Currently team leader, he is mostly involved in numerical simulations applied to Pelton turbines.**

otherwise lead to a drop in hydraulic efficiency or to vibrations, and which are hardly observable on model tests.

The dynamic nature of SPH-ALE offers unique possibilities to study highly transient operations like the start-up of a Pelton unit. It becomes possible to predict the global acceleration of the runner and the mechanical stresses in the buckets during this very demanding phase. The topic of dynamic operation is of growing importance because of recent evolutions in the electricity market that require more frequent starts and stops of peak-energy hydropower plants, and SPH-ALE is the right tool to answer these issues.

The flexibility of SPH-ALE opens new perspectives in the study of transient internal flows in other types of turbines. Indeed the mesh-less approach presents valuable benefits for moving components and deformable computational domains. ASPHODEL has been used to simulate the start-up of a Francis turbine. The initial configuration involves a ring of guide vanes in fully closed position, isolating the high pressure (spiral casing) and low pressure (runner) parts. Guide vanes are progressively opened, allowing the flow to establish through the runner in the direction of the draft tube. Similarly to the case of the start-up of a Pelton unit, it is then possible to predict numerically the runner acceleration and the mechanical stresses acting on the runner blades.

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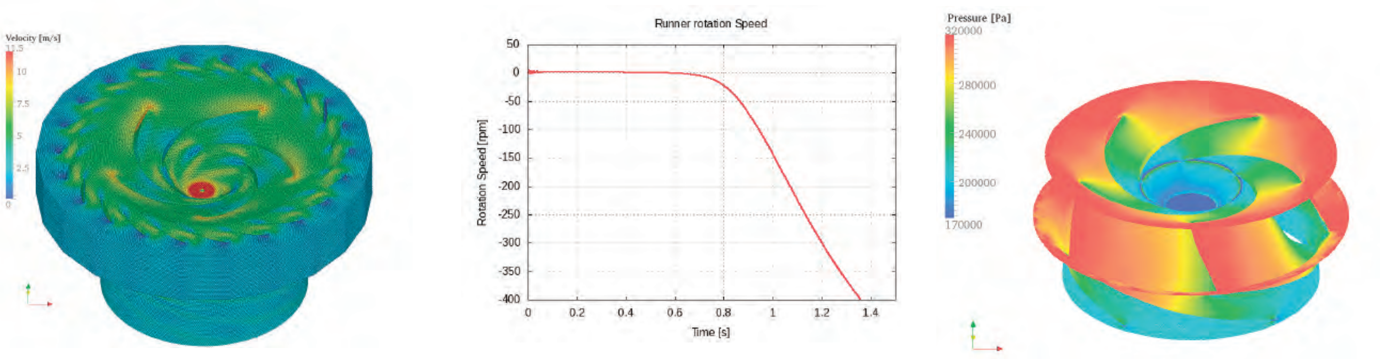


Figure 5 - Start-up of a Francis turbine. Left: flow velocity. Center: runner acceleration. Right: pressure field on runner blades. The start-up scenario is fictitious and consists in gradually opening the circle of guide vanes

DEVELOPING SPH SIMULATIONS FOR COASTAL APPLICATIONS ACCELERATED ON GPUS USING DUALSPHYSICS

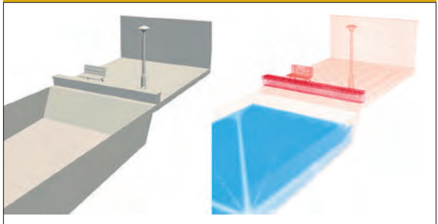
BY BENEDICT D. ROGERS, ATHANASIOS MOKOS, GEORGIOS FOURTAKAS , ALEJANDRO J.C. CRESPO, J.M. DOMÍNGUEZ, CORRADO ALTOMARE, AND R. CANELAS

Coastal defences in the next 20-100 years will be subject to increased stress as sea level rise becomes significant and climate change modifies the magnitude and frequency of storms to an uncertain degree. At the same time, coastal populations are expected to grow and the exploitation of marine resources will increase requiring development of existing and new coastal infrastructure. Furthermore, there is a risk of disasters involving multiple factors; such as severe storms or tsunamis affecting defences designed with outdated guidelines and already subject to sea-level rise. Coastal structures need to be adapted to these new scenarios of coastal vulnerability.

Analysing structures effectively requires new tools building on the highly empirical approaches presently used with conservative safety factors. Sophisticated tools are now at a formative stage and here we are actively developing the novel, flexible numerical technique Smoothed Particle Hydrodynamics (SPH). As a meshless and Lagrangian technique SPH is ideally suited to fluid and solid mechanics with highly nonlinear deformation and is opening new avenues of research in several areas, notably fluid-structure interaction, multi-phase flows and importantly, engineering application.

Traditionally an expensive computational technique, in the past few years significant advances have been made in the acceleration of SPH simulations. This has largely been due to the emergence of graphics processing units (GPUs) whose streaming multi-processor technology has enabled the acceleration of SPH for desktop applications without the need for massive high-performance computing (Crespo et al., 2011). Several GPU-based codes for SPH have now been developed. At the Universities of Vigo, Manchester, Parma, Lisbon and Flanders Hydraulics we have been developing SPH codes accelerated by GPUs for applications including wave impact, fluid-structure interaction and multi-phase flows in industrial processes. This has led to the development of the open-source DualSPHysics code (www.dual.sphysics.org).

Figure 1 – Pre-processing: CAD to SPH geometry (Barreiro et al., 2013)



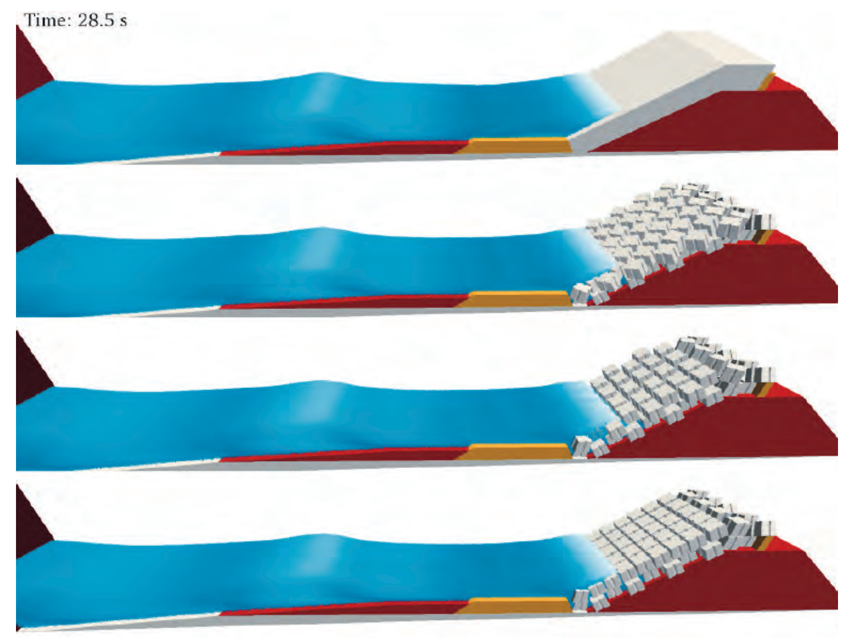
(a) CAD file (b) Initial particle arrangement

The DualSPHysics project

DualSPHysics started from the weakly compressible SPH formulation implemented in the computer code SPHysics. Using CUDA (Compute Unified Device Architecture), a parallel architecture language for Graphics Processing Units (GPUs) provided by Nvidia (an American worldwide technology company manufacturing GPUs), DualSPHysics has been developed to be open source and freely available putting the power of mini-supercomputers in the hands of engineers in industry (Crespo et al., 2015). The code is now being used by industry for a range of applications from coastal protection schemes to energy converters.

The DualSPHysics code comes with dedicated pre-processing software which can use a whole range of different input files for the geometries including CAD, STL, PLY files, etc., making setting up simulations straightforward. Figure 1 below shows a CAD file for a coastal walkway being converted into particles.

Figure 2 - Using DualSPHysics to investigate the runup for different armour units for a rubble-mound breakwater (Altomare et al., 2014)

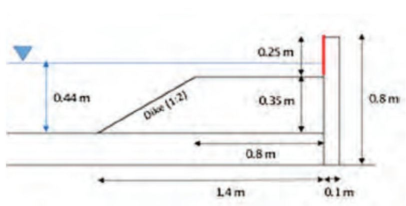


Application to Coastal Defences

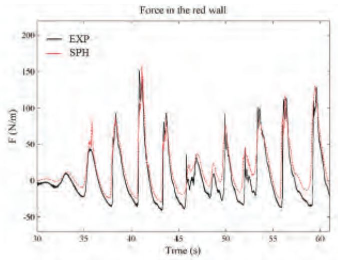
The DualSPHysics model has already been applied to coastal defence applications involving wave interaction with complex geometries such as rubble mound breakwaters. We used DualSPHysics to investigate the effect of waves with different armour units in different arrangements as shown in Figure 2. DualSPHysics was able to reproduce the wave run up over a range of Iribarren numbers, Ir, in close agreement with the well documented experimental data ($\mathrm{Ir} = (L_0/H)^{1/2} \tan \alpha$, where L_0, H and tan α are offshore wavelength, wave amplitude and dyke slope, respectively). However, in comparison with experiments, the DualSPHysics code with its powerful pre-processing allowed us to run many simulations very quickly changing the geometry without needing the expensive laboratory resources of physical experiments.

DualSPHysics has also demonstrated that it can be used to assess accurately the forces exerted by sea waves on coastal defences. For example, we have applied DualSPHysics to wave–structure interaction computing forces exerted by large waves on the urban furniture of a realistic promenade. That study presented a very preliminary analysis of the accuracy of the model when simulating hydraulics loadings. Moreover, DualSPHysics has been further validated against experimental data from physical model tests in Altomare et al. (2015) with a close agreement between numerical solutions and the experimental results both for water surface elevation and wave forces exerted on a vertical and parapet storm return walls (Figure 3).

Figure 3 – Estimation of sea wave impact on coastal structures (Altomare et al., 2015)



(a) Numerical model setup



(b) Comparison between numerical and experimental wave

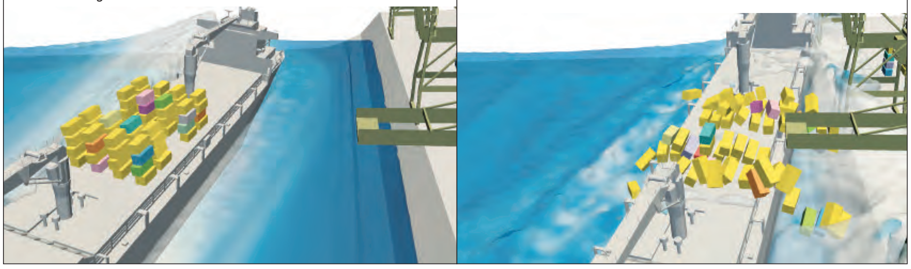
Fluid-Structure Interaction

Many problems in the coastal zone involve a combination of the incoming wave and fluid motion interacting with structures that are often moving. Canelas et al. (2014) have coupled the SPH method with the discrete element method (DEM) to provide a robust and versatile description of fluid-structure interaction. This model has been applied to the arrival of an extreme wave arriving at a port where the containers are modelled using the DEM while the SPH model predicts the fluid motion as shown in Figure 4.

Multi-Phase Flows with SPH

Many SPH codes, such as DualSPHysics, have been released mainly for single-phase simulations. However, there is a great need within the engineering industry to simulate multi-phase problems where conventional grid-based solvers struggle. Developing multi-phase SPH to run on GPUs with CUDA raises other issues that need to be considered, for example, the efficiency of the code for different phases which may have very different physical properties and hence numerical properties (Mokos et al., 2015).

Figure 4 – SPH-DEM simulation for fluid-structure interaction of a container ship (Canelas et al. 2014)



(a) Incoming wave

(b) Containers in motion

Figure 5 – 3.5 million particle air-water multi-phase simulation for a dam break impacting an obstacle (Mokos et al., 2013)

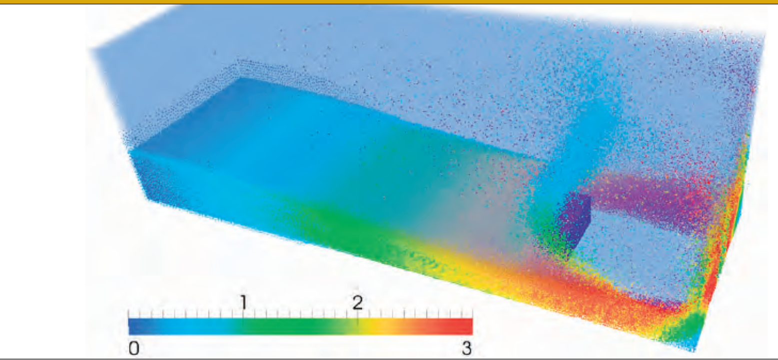
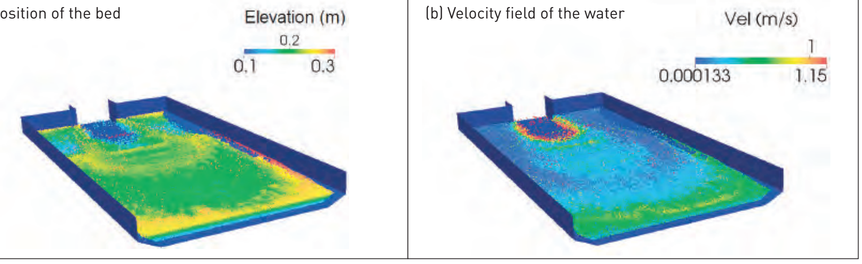


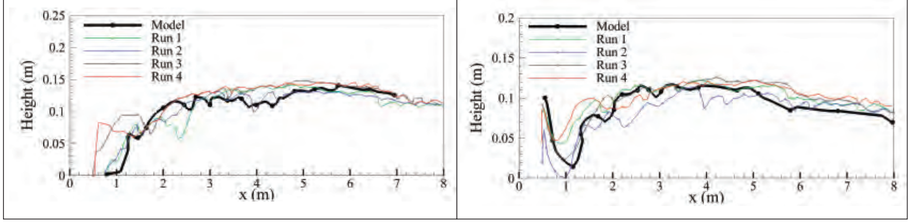
Figure 6 – 3-D erodible dam break: (Fourtakas et al., 2014)

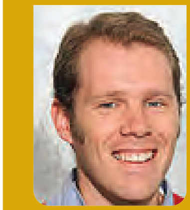


(a) Position of the bed

(b) Velocity field of the water

Figure 7 – Bed profiles at locations y1 and y2 of the experiment (Soares-Frazão et al. 2012) and comparison with the numerical results (Fourtakas et al. 2014)





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***Athanasios Mokos* is a post-doctoral research assistant at the School of Mechanical, Aerospace and Civil Engineering (MACE) in the University of Manchester. He obtained his PhD in 2014 developing a two-phase air-water SPH model to run on GPUs and is now working on applying this to bubbly flows.**

***Georgios Fourtakas* is a post-doctoral research assistant at the School of Mechanical, Aerospace and Civil Engineering (MACE) in the University of Manchester. He obtained his PhD in 2014 developing a two-phase water-sediment SPH model to run on GPUs and is now working on incompressible SPH.**

***Ricardo B. Canelas* is a post-doctoral researcher at CERIS, IST, Univ. of Lisbon. Main research focuses on high-performance computational fluid dynamics applied to fluvial and coastal geomorphic processes, particularly on the link from phenomenological to regional scales.**

***Alejandro J. C. Crespo* is "Ramon y Cajal" Research Fellow at Universidade de Vigo. His research activity is mainly focused on computational fluid dynamics and its application to coastal engineering. He works on the development of a novel meshless particle method (Smoothed Particle Hydrodynamics - SPH) to study free-surface problems with real-life applications.**

***J.M. Domínguez* is a research fellow at Universidade de Vigo. His research activity is mainly focused on HPC (High Performance Computing) applied to Computational Fluid Dynamics, in particular to improve a Smoothed Particle Hydrodynamics model in order to develop a SPH code capable of performing simulations of real-life applications at a reasonable time.**

***Corrado Altomare* is a post-doctoral researcher from Ghent University actually working as engineer/researcher at Flanders Hydraulics Research, in Antwerp (Belgium). PhD in Engineering and Chemistry for the Protection of the Ecosystems. He worked also in the Maritime Engineering Laboratory of the Technical University of Catalonia, in Barcelona, Spain.**

At present we have been developing multi-phase DualSPHysics for two separate types of multi-phase flows described briefly here: (i) liquid-gas mixtures, and (ii) liquid-sediment mixtures.

(i) Liquid-gas mixtures
Figure 5 shows a snapshot from a multi-phase dry-bed dam break simulation for the SPHERIC benchmark number 2 test case. The two-phase simulation uses nearly 4 million particles which includes both the water and air phases and particles to represent the boundary. The multi-phase simulation produces close agreement for the impact pressures measured on the block and captures the mixing of the two phases post impact. This case showed that multi-phase GPU simulations requiring millions of SPH particles can now be performed in a matter of hours rather than months using conventional codes.

(ii) Liquid-sediment mixtures
Many applications in the marine and coastal environment involve a mixture of liquid and sediment. DualSPHysics has been modified for this application by modelling the water as a Newtonian liquid within the standard weakly compressible SPH, while the sediment phase is represented by a non-Newtonian Bingham-type constitutive model (Fourtakas et al., 2014). Surface yield criteria are used to initiate movement of the sediment particles, while a sediment skeleton lithostatic pressure under the yield surface predicts the state of unyielded particles. Additional equations are used to represent the sediment shear layer at the surface and sediment suspension models and seepage forces.

The multi-phase model has been compared with experimental and 2-D reference numerical models for scour following a dry-bed dam break. Figure 6 shows snapshots from a simulation for the position and velocity of the bed sediment for a 3-D erodible bed dam break simulation. The water is released behind the constriction and erodes the sediment. Profiles of the sediment along the tank were measured in the experiment by Soares-Frazão et al. (2012) providing useful 3-D validation data.

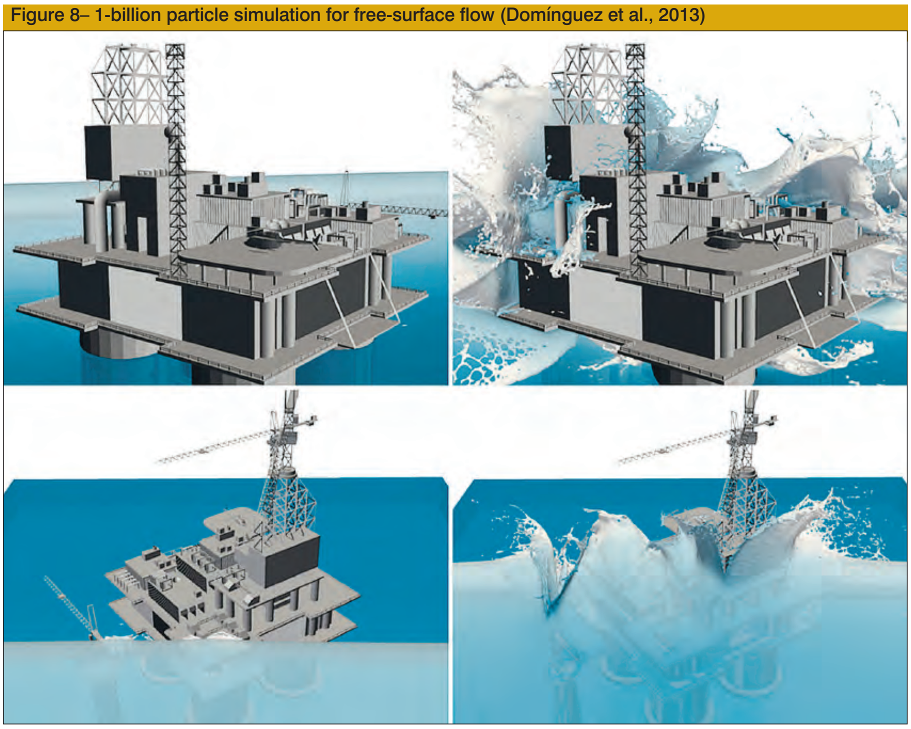
Figure 7 shows comparisons of the bed profile along two sections; the SPH simulation is shown in red and the repeated runs from the experiment in black. The agreement between the SPH and experiment is generally close and is promising for future application and development.

The need for Multi-GPU simulations

The memory of a single GPU card is finite. Hence, large simulations that require in excess of 100 million particles require multiple GPUs. We expanded the DualSPHysics code to a multi-GPU implementation. With many clusters now being constructed from a range of different hardware types, the multi-GPU DualSPHysics was modified to be suitable to heterogeneous clusters leading to the world's first 1-billion particle simulation for free-surface flow as shown in Figure 8.

With SPH simulations accelerated using GPUs, the intention now is to expand the future development of DualSPHysics for a greater range of physical processes and applications incorporating the latest developments in multi-phase, boundary conditions and numerical accuracy. The newest developments are being prepared for general release as open-source codes which will be available to be downloaded from the DualSPHysics website in 2015.

Figure 8– 1-billion particle simulation for free-surface flow (Domínguez et al., 2013)



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MODELLING WATER WAVES WITH GPUSPH

BY ROBERT A. DALRYMPLE, ROZITA JALALI FARAHANI, ALEXIS HÉRAULT, GIUSEPPE BILOTTA AND EUGENIO RUSTICO

The Smoothed Particle Hydrodynamic method has been applied to water waves since Monaghan (1994), who showed, with a few thousand particles, that a numerical wave train on a sloping beach would form a plunging breaker (albeit with very few particles in the plunger). At Johns Hopkins University (JHU), the emphasis has been on determining the ability of this particle method to model all aspects of water waves as they undergo transformation from offshore to the beach.

The model that we currently use is the computer code GPUSPH (Hérault et al., 2010), which is available as open source at www.gpusph.org. The model is very flexible in terms of kernels, viscosity types, as well as kinds of boundary conditions, and has the attractive attribute that it was designed specifically to run on GPUs (Graphics Processing Units), thus greatly accelerating the computations.

Early work on waves at JHU included the impact of a tsunami on a structure (Gómez-Gesteira and Dalrymple, 2004), which was based on the physical experiments of Arnason et al. (2009), showing the wave runup on the front of a square pier, and waves on a beach (Dalrymple and Rogers, 2006). This later paper showed that a plunger in a breaking wave splits into two jets, one that circles around in the tube of the plunging wave and the other jet that splashes forward with water from the toe of the wave. In addition, large vertical vortical structures were associated with the wave front and trailing the breaking wave. The modeling of these waves was done with the computer code SPHysics.

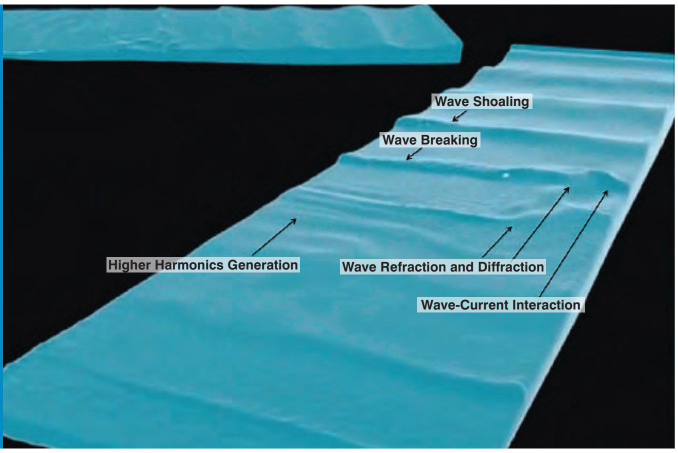


Figure 1 - Two views of water surface modeling the Drønen test. The incident waves are from the upper right and propagate to the beach at bottom. Sand bar located on the left side of the tank. Note the wave-current interaction at the right side of the tank where the rip current is affecting the incident wave train as well as the nonlinear harmonic generation on the left over the bar

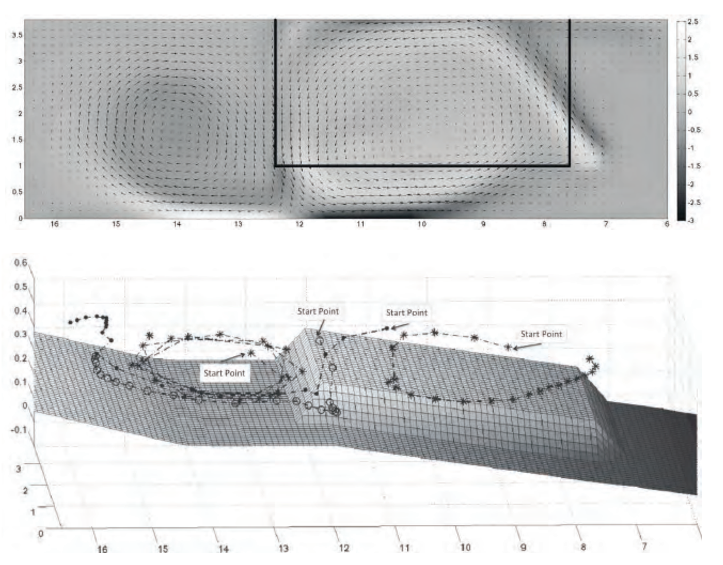


Figure 2 - Top: Velocity vectors and grey-shaded vorticity (s-1) for Drønen test. Box outlines location of sand bar. The two circulation gyres are readily seen; one over the bar and one near the beach. Bottom: Trajectories of particles released at mid-depth

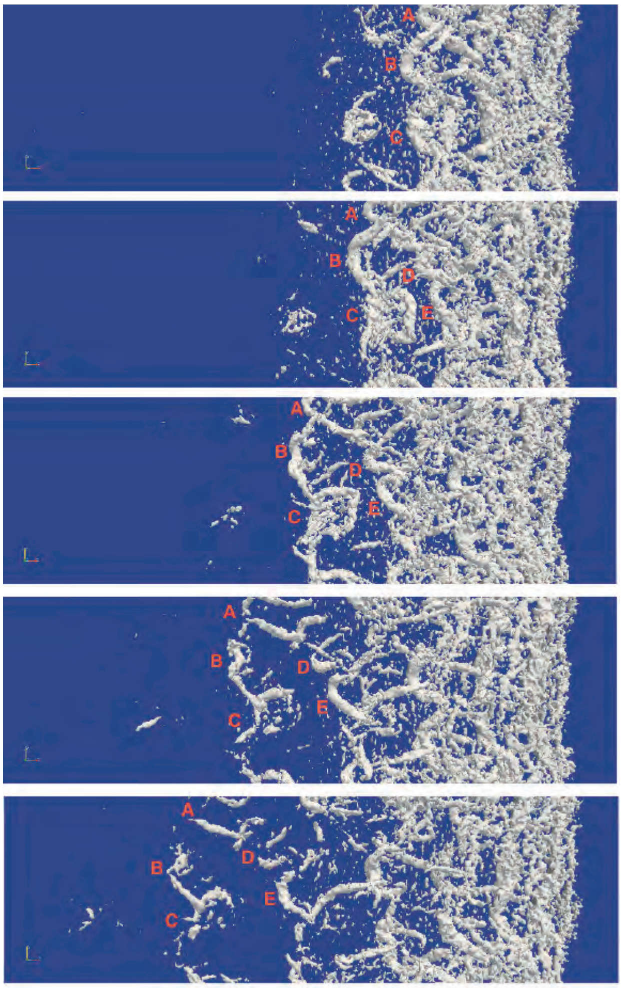
For waves on a beach, the numerical model produced a mean water level set-up at the shoreline, as occurs in real life, therefore the question arose about whether GPUSPH could predict the occurrence of longshore and rip currents that are caused by variations in wave radiation stresses along a beach (which are nonlinear quantities, theoretically). A physical model by Drønen et al. (2002) was used as a test case. This wave tank model consisted of a sloping beach fronted by a channel and then by a rip channel and a 'sand' bar, which caused the incoming waves to break. The breaking process, which reduced the ability of the waves to transport momentum, created both a mean water level variation and driving forces for mean currents. The results are two mean circulation gyres (one over the bar and one inshore) and a rip current flowing out the rip channel. So, GPUSPH can model the waves (with refraction, shoaling, diffraction, breaking and wave-current interaction), but also the momentum-driven flows, such as the nearshore circulation patterns and rip currents.

One of the interesting processes associated with breaking waves is the formation of obliquely descending eddies (ODEs) as presented by Nadaoka et al. (1989). These eddies are found trailing breaking waves in the surf zone, descending from the bubble cloud down into the water column. These 'tornadoes' tilt towards the shoreline, hence the descriptor 'obliquely'.

These structures were also seen in our study of shoaling solitary waves (which are a zeroth order approximation to a tsunami). Validating against the laboratory study of Ting (2006), we found that the spilling solitary wave left a large number of trailing hairpin vortices, as shown in Figure 3.

The source of the hairpin vortices is the turbulent roller region at the face of the spilling

Figure 3 - GPUSPH simulation of the spilling solitary wave of Ting (2006) at different times. Note the trailing vortices as seen moving with the wave front. The letters are used to identify a particular vortex. The lambda-2 criterion was used to visualize the vortices (lamda-2 is defined as the second (in magnitude) eigenvalue of the matrix $S2 + \Omega2$, where S and Ω are the rate-of-strain and vorticity tensors, respectively)



solitary wave. Conceptually we can envision the generation of the hairpins in the same way as hairpins are pulled from a turbulent bottom boundary layer by the flow above it. In our case, the turbulence is at the top, but, when moving with the wave, there is a strong current below with the magnitude of the wave speed. This current pulls the hairpins from the roller region into the mean flow. These hairpins migrate under their own power down into the water column with the curved head down and the legs obliquely oriented towards the roller region – hence these are the obliquely descending eddies.

Conclusions

SPH and GPUSPH can model waves and wave processes, including nonlinear effects. Nearshore circulation, consisting of the time-averaged flow, including rip and longshore currents can be readily seen in SPH models. Coherent turbulent structures known as obliquely descending eddies are explained by the GPUSPH modeling as hairpin vortices dragged out of the turbulent roller region of breaking waves.

Additional modeling, not reported here, shows that GPUSPH can replicate wave forces on structures well and can model nonlinear three-wave interactions, such as subharmonic generation of edge waves.

Acknowledgments

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FLOOD RISK IN LIEGE AREA: A TRANSNATIONAL PERSPECTIVE

BY BENJAMIN DEWALS, PIERRE ARCHAMBEAU, SÉBASTIEN ERPICUM AND MICHEL PIROTTON

Liege is located at the heart of the Meuse basin, which covers parts of France, Belgium, Germany and the Netherlands. Considering explicitly this transnational context when conducting flood risk analysis in the area of Liege sheds light on specific features and management opportunities which might otherwise be overlooked. Within a basin-wide collaborative approach, future flood risk was estimated along the course of the Meuse and adaptation measures were evaluated, particularly for the protection of the city of Liege.

Liege is characterized by a complex setting of rivers and artificial waterways, involving the Meuse, its main tributary river Ourthe, a major derivation channel, as well as the Albert canal connecting the Meuse to the harbour of Antwerp. The main structure controlling the flow is Monsin dam (see photograph) situated downstream of the city.

In the context of the European project AMICE, a basin-wide approach has been developed for flood risk analysis. As the focus of the project was primarily on impact analysis of climate change, transnational climate scenarios were derived for two time horizons (2050 and 2100) and, by means of hydrological modelling, they were translated into hydrological scenarios (Dewals et al. 2013). From this early stage of the research, the main stakeholders (e.g., water authorities) were involved and shared their views on the modelling approach.

> **“Liege shows a significant flood risk for the time horizon 2100”**

Next, existing models were coupled to perform the first coordinated hydraulic modelling from the headwaters to the mouth of the river Meuse. Compared to the development of a new basin-wide harmonized hydraulic model, this approach lead to a higher acceptance by the water authorities, as the results rely on tools they have been familiar with for many years. For a “wet” climate scenario, the computations revealed increases in flood levels significantly

Monsin dam downstream of Liege during floods in February 2002

Benjamin Dewals **is an Associate Professor in Hydraulic Engineering and Water Resources Management at the University of Liege where he received his PhD in 2006. His main research interests cover flood risk management, fluvial hydraulics and reservoir sedimentation. He conducted research in several leading European institutions, including at EPFL (Switzerland) and in Germany. He is a member of the IAHR Europe Regional Division leadership team and of the IAHR Flood Risk Management Committee.**

Pierre Archambeau **obtained his PhD from the University of Liege in 2006, for several new contributions to physically based hydrological modelling and flood hazard modelling. He is continuously working on several hydraulic and hydrological modelling projects and is currently the main developer of the WOLF modelling system, which simulates hydrological flow, fluvial processes and flow on hydraulic structures**

Sébastien Erpicum **obtained his PhD from the University of Liege in 2006, where he is now an Assistant Professor. He is also in charge of the Engineering Hydraulics Laboratory, an experimental facility of about 1500 m² in which composite modelling is largely promoted for studying flows and transport processes of interest in environmental and civil engineering. He is a member of the IAHR Hydraulic Structures Committee Leadership Team.**

Michel Pirotton **obtained his PhD from the University of Liege in 1994. He is currently Full Professor and vice-president of Aquapôle, an interdisciplinary research centre in water sciences and engineering. He coordinates a group of about 15 researchers contributing to the development of the modelling system WOLF and to experimental research in hydraulic engineering and fluvial hydraulics.**

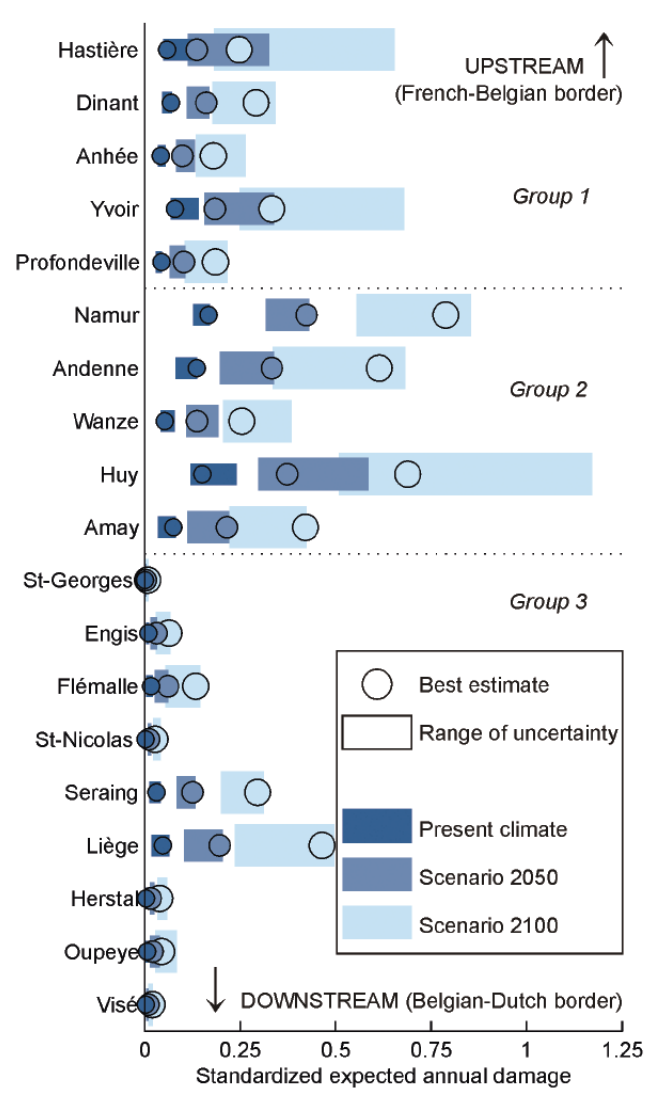


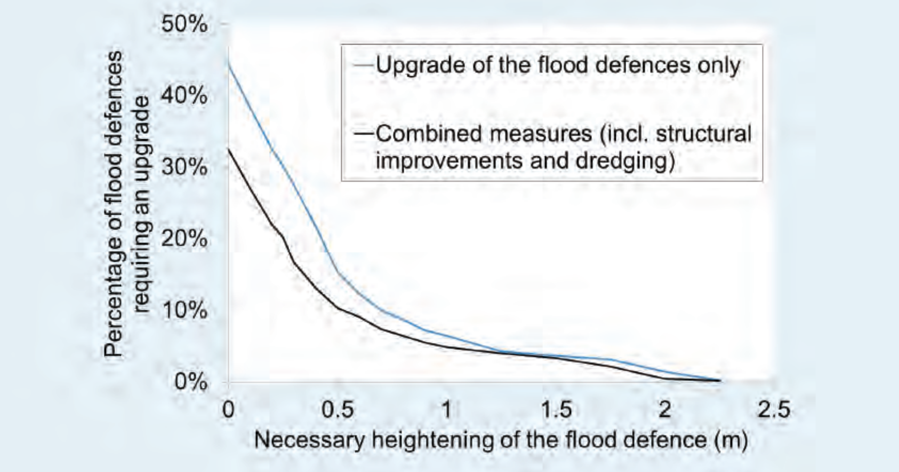
Figure 1 - Expected annual damage per municipality along the river Meuse in Belgium for the "wet" climate scenario. Values at the municipality level were standardized with respect to the total damage in the present climate. Adapted from Detrembleur et al. (2015)

higher in the central part of the Meuse basin compared to the upper and lower parts. This results from the narrower shape of the valley as the river crosses the Ardennes massif close to the French-Belgian border and in most of the Belgian part of the Meuse.

The hydraulic modelling results were subsequently used for damage estimation and computation of flood risk (e.g., Ernst et al., 2010). The distribution of flood risk across all the municipalities along the river Meuse in Belgium is displayed in Figure 1 (Detrembleur et al. 2015). Flood risk is generally higher in the upstream municipalities (groups 1 and 2), in which the protection levels are relatively lower and inundations are more frequent. Nonetheless, Liege shows a significant flood risk for the time horizon 2100 ("wet" climate scenario), due to (i) the high values of future flood discharges (about 30 % higher than in the present climate) and (ii) the very high water depths in the floodplains in case of flood protections overtopping, as a result of mining subsidence.

Flood risk analysis is inherently affected by a substantial level of uncertainty. A distributed uncertainty analysis conducted at the level of the municipalities along the Meuse reveals that both the magnitude of the uncertainty and its main origin vary significantly in space and in time (Figure 1). In most locations, damage estimation and flood frequency analysis were the main sources of uncertainty, while inundation modelling contributed less to the overall uncertainty (Detrembleur et al. 2015). Different adaptation measures were analysed for flood risk management in the city of Liege. An adaptation of the existing flood defences appears technically feasible to preserve the current protection standard of the city under the future "wet" climate projected for 2100. Indeed, only 45 % of the defences need some upgrade, among which only 10 % require a heightening exceeding 70 cm (Figure 2). Dredging of the main riverbed and structural improvements to increase the hydraulic efficiency of Monsin dam (see photograph) constitute useful complementary measures but are not sufficient on their own to protect the city of Liege (Figure 2). Computations also showed that dynamic storage upstream of the city is not a realistic option as the storage capacity of the floodplains is far too low. Similarly, large dams situated further upstream in the basin were shown to have a vanishing effect in Liege (Bruwier et al. 2015). Spatial planning may also play a vital role in reducing flood risk, but mostly in less densely urbanized municipalities, in which new developments may account for up to one half of the estimated future flood damage (Beckers et al. 2013).

Figure 2 - Portion of the overall flood defences in Liege which require an upgrade exceeding a given heightening to preserve the current protection standard of the city under the future "wet" climate



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PROFESSIONAL SPECIFICATIO NUMERICAL STUDIES IN ENVI

BY EUROPEAN WATER RESEARCH INSTITUTES

1. Purpose

This document sets out the professional requirements to be expected for studies in environmental hydraulics, which may include aspects in water quality, sedimentology or geomorphology. Specific consideration is given to:

- The main stages of a physical and/or numerical study;
- Requirements in terms of profiles and competences.

The focus is on studies undertaken on a funded or commercial basis for a client. Whilst these may be undertaken by a research laboratory or institute, a consultancy, or a contractor, these different types of organisation are collectively referred to in this document as the 'consultant'.

2. Main stages of physical and/or numerical studies

This section outlines a series of steps that most modelling studies should be expected to follow.

2.1 Stage 1: Collection and analysis of available data

The following steps help to ensure that the modelling studies are informed by existing knowledge and data:

- Collection of data:
  - provided by the client;
  - available from third parties;
- Bibliographical analysis of previous studies;
- Specification of additional measurements or data discovery (when needed);
- Collation of the collected data with sufficient meta-data to facilitate archival and retrieval;
- Analysis of the collected data;
- Synthesis of these activities to establish a conceptual model of the problem.

2.2 Stage 2: Choice of model

- Using the understanding developed in formulating the conceptual model, the modeller should:
- Justify the modelling choices needed to address the problem;
- Justify how these choices are to then be implemented using specific physical and / or numerical tools[1];
- Highlight the limitations in the proposed approach.

2.3 Stage 3: Development of the model(s).

To ensure that the modelling is being undertaken on a sound and peer-reviewable scientific basis and capable of meeting the client's needs, the consultant needs to demonstrate and document that the choices made are:

- Capable of modelling all the relevant phenomena;
- Valid in terms of the underlying theory and all the assumptions made in the model formulation;
- Consistent with the conditions prevailing at the study site;
- Using models, methods and tools that have been subject to appropriate benchmark testing.

It should be noted that a modelling approach can, in some circumstances be used out of its accepted range of validity. In such case, a thorough discussion of the chosen approach, justification of why this should be considered an acceptable application of the model, any conditions or caveats that need to accompany the results, and a discussion of the alternative options are essential, to enable the model outputs to be correctly interpreted and used by the client.

2.3.1. Stage 3.1: Design of the model(s)

The description of each model should include:

- The geographical span of each model;
- Description of the choice of the boundary (or forcing) conditions of each model, with clear statements on the assumptions that led to the choices made;
- Details of how particular features of the bathymetry and topography are to be represented;
- For a numerical model:
  - The grid characteristics and their suitability with respect to the phenomena to be represented;
- For a physical model:
  - The choice of phenomena to represent;
  - The dimensionless numbers to be conserved and their relevance with respect to the phenomena to be represented; when dimensionless numbers cannot be conserved, yet are critical for the study, a specific discussion is required to justify the validity of the model, stating the expected value of the dimensionless numbers and their impact on the physics;
  - The hydraulic facilities to be used to deliver the model.

2.3.2. Stage 3.2: Construction of the model(s)

For numerical models:

- Where options are available, or specific routines or capabilities are made use of, these need to be documented. Similarly any changes to the code, simplifications, or adjustments to the grid or model set-up, should all be documented.

For physical models:

- Any changes or simplifications that might have some impact on the model scaling, or the ability to interpret the model results should be documented.

2.3.3. Stage 3.3: Calibration and validation of the model(s)

The calibration and validation of a model[2] will necessarily vary depending on the type of model, the use and the data that is available to test the model. This should include some or all of the following:

- During the calibration stage model parameters are adjusted to improve the match to one or more measured data sets. Whilst usually necessary, it is acceptable for this stage to be omitted if the model parameterisation can be demonstrated to be acceptable from a prior application;
- Where model parameters are to be adjusted to improve the calibration, it is essential that only parameters that are invariant in the intended model application should be adjusted;
- To validate the model, outputs generated by

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[1] When using a combination of physical and numerical models this should include an explanation of the role of each approach and their inter-dependencies.

[2] Here validation of the model refers to testing the applicability of the model for a particular application, as distinct to validating the software to substantiate the general applicability and accuracy of the model. See IAHR, 1994, 'Guidelines for documenting the validity of computational modelling software' for further details.

NS FOR PHYSICAL AND RONMENTAL HYDRAULICS

the model are compared with one or more validated model-generated or measured data set. If the model has been calibrated against some measured data it is essential that the validation uses different, independent data;

- The process adopted for calibration and validation must be fully documented;
- The documentation should include a discussion covering:
  - quantitative and qualitative summaries of the comparisons made, with particular attention given to any aspects that are not well reproduced and the relevance of these differences for the intended application;
  - how well the validation supports the choices made in the design of the model (Stage 3.1);
  - any changes that are now needed to the overall conceptual model;
  - any outstanding concerns arising from the validation that might influence the application of the model and interpretation of the simulation results;
- Sensitivity tests should be used to enhance the understanding of how selected model parameters or model forcing conditions influence the modelled response;
- Whilst some projects may require a minimal set of outputs, the need to address uncertainties in: knowledge; available data; and future conditions, means that an investigation of the influence of these uncertainties, and where practical an attempt to quantify them, will provide a more robust context for interpreting model findings.

It should be noted that a calibrated and validated model is reliable for the range of events with which it has been calibrated and validated. It may lose its reliability if it is exploited for events which are out of this range.

2.4. Stage 4: Application of the model(s)

The models should be applied in a manner that allows the results to be reproduced at some later date if needed. This requires:

- Definition of simulations to be carried out;
- Recording of the software version used, model input and output files used for each simulation, changes made (and why) as each simulation is undertaken;
- Collation of the model output with sufficient meta-data to enable the case to be re-run, and to ensure secure archival and retrieval.

Where an understanding of the inherent uncertainty is important, consideration should be given to using an ensemble of models, or using a probabilistic framework to propagate uncertainty in the model.

2.5. Stage 5: Analysis of model outputs

- The data generated during the modelling process should be analysed using validated analysis tools and models.

2.6. Stage 6: Deliverables

The needs of individual clients will vary. High level summaries, a results database and various forms of visualisation or interactive documentation may also be needed depending on the intended audience. The following set of deliverables is suggested as a minimum requirement of good practice, with the aim of ensuring that others can audit or assess the modelling results.

- A full report of stages 1 through 5, analysing the results with respect to the problem posed by the client, illustrated by post-processing of the results according to the specifications of the client;
- Supply of the electronic files of post-processing enabling the figures and tables provided in the report to be recreated;
- Supply of a documented digital archive of the modelling study that will include some, or all, of the following:
  - meta-data of all data used in the study;
  - data set used in the study, subject to any license conditions that may apply;
  - meta-data of all model runs undertaken as part of the study;
  - and for numerical model studies
  - the files needed to recreate the model runs, model code and source code modifications, as required by the specification and subject to any license conditions that may apply.

The documented digital archive will be subsequently treated according to the quality management procedures of the consultant, and/or delivered to the client according to their contractual agreements.

A common shortcoming is to limit the study to the presentation of model results.For the model results and any subsequent analysis to be of use to the client, there is often a need for some interpretation of the results. For major developments the effort involved in the interpretation will often equal or exceed the modelling effort.

A project close-out meeting between the client and the consultant is strongly recommended. This should ensure that all deliverables have been supplied and that there is a common understanding of the study findings.

Notes:

- This methodology may be adapted according to the special needs of the client.
- Contractual concerns, such as (i) intellectual property (property of data, prior knowledge relevant to the study, data or software) and (ii) potential conflicts of interest should be discussed and resolved at the beginning of the study.

3. Competences and organisation

3.1. Knowledge of the consultant

Requirements in terms of profiles and competences are two-fold:

3.1.1. Essential knowledge

Lack of this knowledge is likely to compromise the realisation of the study. The consultant should possess a thorough knowledge, experience, and auditable know-how relating to the study problem. Individuals may address the relevant processes and their theoretical and experimental treatment, or the application of suitable numerical or physical modelling techniques but the collective skills of the consultant must be able to deliver both.

It is expected that the experience and know-how of the consultant should be based on the regular use of software or laboratory facilities to be used in the study. It is also essential that the consultant has in place an established quality control and audit process, specific to the needs of modelling. This will include, inter alia, software version control, regular validation of software as new versions are introduced, and planned calibration of instruments in the laboratory.

3.1.2. Desired knowledge

This is an element which will add value to the service offered and can be used as a basis for comparing different modelling consultants. This will include a background in the particular type of problem that the client is studying and hence the broader context of the modelling work. For many studies this is likely to include design or impact assessment experience, knowledge of the regulatory environment, socio-economic decision making processes and experience of multi-disciplinary collaborative team working. One particular skill for the correct use of models is the ability to interpret the model results in a wider context. Such synthesis usually requires extensive experience with a mix of modelling and science/engineering skills.

3.2. Commitment of the consultant

The consultant is expected to provide:

- Experience and know-how to conduct the study;
- Quality control at each stage of the study;
- Execution of its obligations to produce the expected deliverables;
- Respect of the lead times defined by the ordering party;
- Sufficient resources and necessary competences to carry out the study;
- Compliance to the rules concerning confidentiality and intellectual property laws;
- Participation in the feedback analysis at the end of execution of the service.

3.3. Commitment of the client

For each service request, the ordering party provides:

- Technical specifications of the service specifying the expected deliverables;
- The time limit for the realisation, as well as the other possible constraints;
- Evaluation criteria of the study.

In some cases the nature of the study is exploratory. In such cases the client should aim to clearly set down the objectives of the study, accepting that the approach to developing a solution may be iterative based on an ongoing dialogue between client and consultant.

3.4. Commitment to offer a service

For each request for service, the consultant provides:

Firm price and delivery schedule on the basis of the specification;

Technical offer clarifying the following points:

- A description of tools and methods to be used in the analysis;
- Summary of the expected results of the study;
- Any limits or conditions on the service offered.

Where the study is exploratory in nature, as noted in 3.3, there may be a need to have a more flexible arrangement for payment and delivery, which should be clearly defined and agreed between the parties at the outset.

3.4.1. Technical principles

Service offers indicate the technical principles set up to satisfy the constraints expressed in the specifications (technical choices, tools, methods etc.), as detailed in Stages 1 to 6 above. For those who carry out this type of modelling work on a routine basis the client should expect the relevant procedures to be embedded in the consultant's ISO 9001 work processes.

3.4.2. Proposed organisation

Service offers include a description of the project team, with skills and experience.

3.4.3. Special difficulties

If necessary, the service offer should state and justify those particularly difficult aspects in response to the specification. These might include: significant difficulties for realisation; possible simplifications; assumption that the consultant chooses not to select or to modify; and penalising impositions in terms of cost.

3.4.4. Schedule

The service offer should clearly state the completion dates of the various stages and the time schedule compared to the project start date corresponding to the engagement of the consultant.

3.5. Additional aspects

3.5.1. Continuity of service

During realisation of a study, any change in the team in charge of the study shall not affect the initial time schedule.

3.5.2. Means

Software licenses and computational facilities are the responsibility of the consultant.

3.5.3. Follow-up of the study

The need of the client for a follow-up of the study will be stated in the study specifications.

3.5.4. Obligations

The final acceptance of a deliverable is not the end of a consultant's obligations. In cases where a mistake or error is subsequently detected in the study, there is a moral (and possibly contractual) obligation to solve the problem. Where appropriate, the contract may involve the specification of how errors will be rectified and the timescale for doing so.

4. Related sources of information

4.1. Generic guidance

- IAHR/AIRH, June 1994, Guidelines for documenting the validity of computational modelling software.

4.2. Topic specific good practice guidance

- CADAM Dambreak modelling – Good Practice Guidance
- Dick P. Dee, 1995. A pragmatic approach to model validation. Quantitative skill Assessment for Coastal Ocean Models. Coastal and Estuarine Studies Volume 47, pages 1-13. American Geophysical Union.
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SUMMARY OF RECOMMENDATIONS FOR POLICYMAKERS ON **ADAPTION TO CLIMATE CHANGE IN WATER ENGINEERING**

This report is a contribution of the IAHR Working Group on Climate Change to the scientific and technical debate on this global challenge in the water sector. Some experts in different fields, from our Association, reviewed and recommended structural and non-structural adaptation measures being taken or to be taken in the hydro-environment engineering community to mitigate the impact of climate change on humans, nature and infrastructures.

Trend analyses and changes detection in space-time data

Public bodies dealing with the policy and management of water resource systems, should investigate adaptation measures to face the following issues related to observed trends:

- Understand and quantify short- and long-term trends in hydroclimatic variables especially precipitation and streamflow and other essential climatic variables
- Evaluate the occurrences, variability and sudden changes of extremes (considering frequency and magnitude) in space and time and develop sustainable and climate-change sensitive hydrologic designs
- Assess the influences of climate variability on streamflow and precipitation changes at different spatial and temporal scales considering the extent of regional climatology influences
- Understand changes in trends and attribute or separate them based on natural variability or anthropogenic influences

Rainfall and Runoff

Climate change is expected to cause a shift to more intense individual storms and fewer weak storms as temperatures increase. Return periods are projected to be reduced by about 10-20% per degree Celsius (°C) over most of the mid-latitude land masses, with larger reduction over wet tropical regions. It is recommended that design flood estimation and planning for an asset or activity should consider: service life or planning horizon, design standard, purpose and nature of the asset or activity, screening analysis, climate change projections and their consequences of impact, and statutory requirement. It is also recommended to take into consideration also a class of worst case extreme events estimated to occur under climate change as survival critical or edge of survivability, partly because projected future changes in design value may have high uncertainty.

Downscaling and Adaptation to Urban Hydrology Scale

The main challenge in urban hydrology is to predict accurately the future variability of urban hydrologic processes (such as temperature, rainfall, and runoff) at the scale of the urban area in the context of climate change in order to build suitable scenarios for the operation and management of urban water systems. Various impact assessment procedures and adaptation measures should be developed and tested in order to find the most cost-effective method for management and control of the urban water environment. Examples of some existing adaptation measures are:

- Storage and infiltration devices together with re-naturalization of urban watercourses are more and more frequently considered and their use should be further enhanced. However, more research is necessary to optimize their application particularly if conditions are changing (drainage flow regime, sediment inputs, vegetation growth linked with temperature, etc.)

The competition between food, water and soil in drought-prone areas will become more severe in a warmer climate (photo: R. Ranzi in Southern Vietnam)

Roberto Ranzi, **and** ***Guinevere Nalder*** **contributed to homogenize and assembly this document.**

The individual sections have been prepared by the following members of the group

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James Ball, **Sydney University of Technology, Australia.**
Prof. Eiichi Nakakita, Disaster Prevention Research Institute, Kyoto University, Japan. Rainfall and Runoff
André Paquier, **IRSTEA, France**
Van-Thanh-Van Nguyen, **Mc Gill University, Canada. Downscaling and Adaptation to Urban Hydrology Scale**
Sang-Il Lee, **Dongguk University, Republic of Korea**
Carlos Galvão, **Campina Grande University, Brazil. Groundwater and Drought Management**
Gregory Shahane De Costa, **UNITEC, New Zealand. Impact on the Coastal environment and adaptation in coastal engineering**
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Elpida Kolokytha,**- Aristotle University of Thessaloniki, Greece. Trans-Boundary Watershed Management**
Yangwen Jia, **Institute of Water Resources & Hydropower Research, China**
Young-Oh Kim, **Seoul National University, Republic of Korea. Decision Making for Climate Change Adaptations and Water Resources Management**

Structural measures as reservoirs and irrigation channels can mitigate the effects of the projected enhanced variability of runoff. But also non-structural measures as improved tools for management, planning, and decision making in reservoirs operation can be effective for adapting to a changed water cycle

- Adaptation measures at individual scale (mainly storage or infiltration) should also be favoured but they are only efficient up to some given rainfall volume or intensity; so they should be included in the overall management plan at the municipality scale, which requires complementary tools to integrate water, social and economic issues

Adaptation in Groundwater Management and Drought Management

Groundwater will be increasingly critical in sustaining water supplies through periods of climate change as it will help balance the larger fluctuations in precipitation and increased water demands caused by high temperature and drought. Droughts are expected to have their patterns of occurrence and magnitude changed in the future. Policy leadership is required to support efforts toward identifying and funding adaptation measures and related research such as:

- ✓ Groundwater quantity and quality data collection
- ✓ Conjunctive use of surface and ground water resources
- ✓ Managed aquifer recharge
- ✓ Water reuse and brackish groundwater supplies
- ✓ Rainwater harvesting
- ✓ Protection of groundwater supplies
- ✓ Improved tools for management, planning, and decision making
- ✓ Water demand management
- ✓ Adaptation of policy, legal and institutional frameworks for water management

Impact on Hydropower Generation and Mountain Hydrology

The impact of projected rainfall and evapotranspiration losses changes at the global scale imply highly variable spatial patterns of runoff changes and resulting hydropower generation potential. More clear is the projected impact on mountain hydrology, with a projected shift of the snowmelt season to early spring months, a decrease of summer runoff and an increased variability of runoff regimes, thus enhancing the potential impact of droughts and floods on inflow to reservoirs. Public bodies dealing with the policy and management of water resource and energy should investigate and implement adaptation measures to face the following topics:

- increasing variation (distribution and quantity) on water incoming to hydropower reservoirs imply the need of an increase of storage volumes, in some cases.

- Increasing damages to the connectivity of water bodies and injures to the river ecosystems imply reservoir regulation paying more attention to environmental issues as an adaptation measure.
- Increasing demand and competition among different water uses imply more accurate planning and management optimization of the water resources and participation of stakeholders in decision making processes.

Climate Change, Sea Level Rise and its Impact on Land and Water

Sea level rise may also be ascerbated by storm surges and wave set up. In addition to causing loss of coastal land, these sea level variations will directly impact the surrounding ground water table. While construction of embankments, dikes, and dams etc., could be implemented in suitable areas to prevent land loss, the preferable approach would be to demarcate areas under threat and use them for recreational purposes, with very minor construction.

Trans-Boundary Watershed Management

The management of trans-boundary watersheds requires an integrated regional approach which should consider:

- the increase in future water variability.
- Changing social, economic and climate conditions which may alter current hydro-political balances, in terms of potential inability of states to meet their treaty commitments.
- Water scarcity as effect of climate change will have impact on international conflict and security.
- An effective international legal framework addressing future challenges of climate change is required.

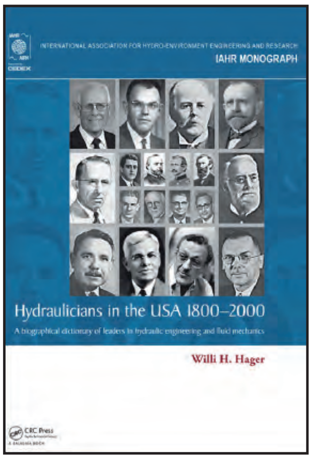
Decision Making for Climate Change Adaptations and Water Resources Management

The decision making process under a changing climate should be based on principles that can handle effectively primary attributes of climate change such as deep uncertainty and non-stationarity. Good decisions under climate change can:

- perform reasonably well over the entire range of uncertainty,
- allow various options through the entire decision making process,
- be iteratively refined as new information including trial errors is available,
- take into consideration a class of worst case extreme events estimated to occur under climate change as survival critical or edge of survivability.

Key aspects to be considered in the decision making process include:

- ✓ Climate change impact on water resources management
- ✓ Technical adaptations to Climate Change
- ✓ Institutional adaptations to Climate Change
- ✓ Legislation adaptation to Climate Change
- ✓ Capacity building improvement
- ✓ Public involvement improvement



New in the Series IAHR Monographs

Hydraulicians in the USA 1800-2000

A Biographical Dictionary of Leaders in Hydraulic Engineering and Fluid Mechanics

Willi H. Hager

This book provides one-page short biographies of scientists and engineers who have worked in the areas of hydraulic engineering and fluid dynamics in the USA. This volume includes almost 1,000 individuals, only two of whom are women. The book also provides a detailed index, and a two-page list of individuals (generally born in Europe) listed in previous volumes (1 and 2), but with a relation to this volume 3. The book also contains a map of the USA highlighting the major American rivers, with a close relation to projects carried out by several of the individuals presented in the book.

This compendium provides a beautiful overview of the many scientists and engineers who have contributed to the current knowledge in hydraulic engineering and fluid mechanics. The author made every effort in compiling the most important hydraulicians of the USA in this work as it will become much more difficult in future decades to find biographical details on them, in light of the current policy that sees so few memoirs or necrologies published.

- provides basic information for preparation of historical papers that is hardly available in current literature
- demonstrates the relation between current research and historical advances
- offers background information for educational purposes

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About the IAHR Book Series

This Book Series includes Design Manuals and Monographs. The Design Manuals contain practical works, theory applied to practice based on multi-authors' work; the Monographs cover reference works, theoretical and state of the art works.

Invitation

We are permanently planning the preparation of new books in this series, and are actively seeking contributions. For book proposals please contact the series editor Peter A. Davies (pub.nl@taylorandfrancis.com).

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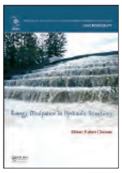

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NEW IAHR COUNCIL ELECTED FOR 2015-2017

“I am deeply honoured to have been elected President of IAHR at the recent 36th IAHR World Congress in The Hague.
As I stated in my candidature for President, one of my aims will be to create a truly global and cohesive organization, forging strategic partnerships, advancing integrated modeling, enhancing committee networking and promoting opportunities for young professionals. This is now more important ever given that the opening of the second office in Beijing.
My agenda will be to strengthen support to Divisions and Committees as well as to improve access in regions typically underserved by IAHR, and always taking in consideration that Young Professionals are the future.
On behalf of IAHR I would like to warmly thank our outgoing President, Roger Falconer, who has guided IAHR with a continuous and dedicated support in one of the most challenging periods for our Association.
I also would like to welcome the new members of the Council and to thank the leavers for their contribution. I also would like to extend my gratitude to all our volunteer leaders who have dedicated time for our community including, for example, the Editors of IAHR publications, the Committees Leadership Teams, and authors who donate their royalties to IAHR.
Your ideas and initiatives are welcome. IAHR is your professional organization but moreover it is a community composed of people who believe that water is the core for sustainable development and we should not miss this powerful energy!”

Peter Goodwin, IAHR President

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Dr. Peter Goodwin
Lead Scientist, Delta Stewardship Council
DeVlieg Presidential Professor, Director
Center for Ecohydraulics Research
University of Idaho
USA
(elected until 2017 R)*

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Professor of Hydraulic Engineering
Department Head Water Science & Engineering
UNESCO-IHE Institute for Water Education
THE NETHERLANDS

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CVG EDELCA
Hidroeléctrica Macagua
Departamento de Hidráulica
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Faculty of Engineering
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Chair of the Asia & Pacific Division
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KOREA

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

REPORT FROM THE IAHR WORLD CONGRESS
THE HAGUE, JUNE 28 – JULY 3

BY ARTHUR MYNETT AND CHRISTOPHER GEORGE

Conference news

The 36th IAHR World Congress was held in The Hague from June 28th to July 3rd, 2015, and was preceded by the annual IAHR Council Meeting held in nearby Delft, hosted by UNESCO-IHE and Deltares.

The Local Organising Committee consisted of quite a number of active members from UNESCO-IHE, Delft University of Technology, Deltares, and the Dutch Ministry of Infrastructure and the Environment. In addition a Delft Chapter was initiated of the IAHR Young Professionals Network, which contributed greatly to the preparation and organisation of the event.

The scope of the congress was on cross-cutting themes related to Deltas of the Future, looking at what happens upstream, linking hydro-environment research to engineering practice, and reaching out to the developing world. The technical programme comprised seven main themes:

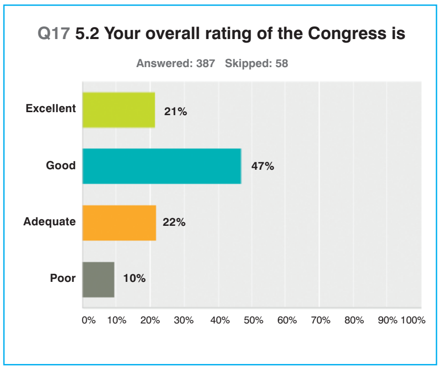
- Managing deltas,
- Hydro-enviroment
- Sediment management and morpho-dynamics
- Water engineering
- Flood risk management and adaptation
- Water resources and hydroinformatics
- Extreme events, natural variability and climate change

The Congress attracted 1370 participants from 72 countries, with a student participation of 25%, which can be considered a great achievement. Having received over 2000 abstracts, a total of 935 oral presentations and 319 poster presentations were accepted in the final programme.

Some highlights of the congress included the opening speech by the Honorary Chair Prof Henk Jan Overbeek, past IAHR Secretary-General, who reflected on the 80th anniversary of the association and welcomed the membership back to The Hague after 60 years. The programme contained 14 keynotes lectures and the Ippen Award lecture as well as technical excursions. The activities organized by the Delft Young Professionals network included a boat trip along the Rotterdam Harbour, sponsored by the Dutch Water Sector. The trip provided ample opportunity for networking as well as for enjoying the view and sunset over the harbour on a long warm summer night …

IAHR AIRH IAHR 2015

Supported by
Spain Water
and IWHR, China



A post-conference quality survey was carried out among the attendees, two-thirds of which awarded the congress an overall rating of "good to excellent". Many valuable comments were collected which will be taken into account for the next IAHR World Congress in 2017 in Kuala Lumpur, which (according to the survey) 38% are considering to attend.
On behalf of the Local Organizing Committee I would like to thank all participants, all members involved in the paper review process, all YPN volunteers, our PCO CIMglobal, Ster in Uitvoering, and of course our sponsors. We simply could not have achieved this success without you!

Arthur Mynett,
LOC Chair of the 36th IAHR World Congress

Roger Falconer at the Opening Ceremony

Musical interlude by Tim Busker at the Opening Ceremony

Delft YPN doing a great job

IAHR News

The IAHR World Congress every two years is the main meeting point of our association. It also marks many important changes in our Association, one of which is the election of the new Council by electronic ballot which closes during the Congress. The results were announced at a very well-attended General Members Assembly (GMA) on the closing afternoon of the Congress and are reported on page 96.

After four years at the helm of IAHR Prof. Roger Falconer gave his farewell address at the opening of the Congress and a personal vision for the future in which he sees much greater collaboration in the future between associations. At the GMA he handed over the baton to our new president Peter Goodwin from the University of Idaho in the USA who took over duties as President on August 1st 2015. Prof Goodwin has just finished his term as Chief Scientist of the California Delta Project and in autumn this year will start his presidency by visiting the two headquarters offices of IAHR in Beijing and Madrid and our sponsors.

Several amendments to the constitution were approved by the GMA in The Hague. These proposed amendments already approved by the Council were published in Hydrolink Issue 4, 2014 for comment.

2015 General Members Assembly

The 2015 General Members Assembly chaired by IAHR President, Roger Falconer, took place in plenary ahead of the closing ceremony of the Congress with over 200 people present. The GMA is where the activities of the association are reported

Approval of the minutes of the 2014 GMA

The Minutes of the 2014 General Members Assembly held in Porto 12th March 2014 and published on the IAHR website are approved.

2014 Financial Report

Our auditors, EY, have approved our accounts and the final results for 2014 show a profit of €37,136 for the association (following a loss of €35,712 in the previous year). Our membership during the year continued to increase with a total of 3780 members at year end compared with 3328 in 2013 (and 2122 in December 1999).

The major improvement in the financial outcome when compared with 2013 is a result of the ending in 2014 of the costly development and implementation of our new association management system, and to the fact that we also had to write off two years of bad debts (rather than one) in 2013.

Approval of Constitution Changes

Following decision of the IAHR 2014 Council several proposed amendments to the IAHR Constitution were published for consultation in Hydrolink Issue 4, 2014 in accordance with the Constitution and subject to GMA approval. The main proposed change relates to the appointment by council of a Secretary General to act as link with each of the IAHR sponsoring organisations. As of January 2015 IAHR has two secretariat offices – one in China supported by IWHR and the other in Madrid supported by Spain Water. Several other amendments are proposed to clarify the roles of Secretary General and Executive Director. A further proposal is for one of the up to three members

Arthur Mynett, Chair of the LOC

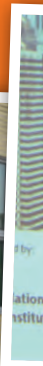
Damien Violeau at the Ippen Lecture

↑ Henk-Jan Overbeek, Member of National Advisory Committee Water Resources Management and Past Secretary-General IAHR

A representative cake to celebrate the 2nd Anniversary of JAWER

Willi Hager announcing the 2015 Willi H. Hager Best Reviewers Award Winners

↓ New IAHR President, Peter Goodwin (left) and Outgoing President, Roger Falconer (right)



which the new council can co-opt to appointed as a Vice President. The purpose of this change is to allow greater flexibility in the make up of the Executive Committee.

The GMA approves these changes.

Secretariat Report

The Executive Director, Dr Christopher George, reports of the opening in March of our second world secretariat office of IAHR in Beijing which operates side by side with the Madrid office. A full report on this was published in HydroLink Issue 4, 2014.

Dr. George also reported that IAHR is keen to work more closely with other associations and during the year meetings were held with the International Water Association (IWA), IAHS, WCCE, ICOLD and an MOUU was signed with PIANC.

Christopher George,
IAHR Executive Director

2015 IAHR AWARDS

12th John F. Kennedy Student Paper Competition

First Prize

David Ferras, Switzerland and Portugal
For the paper entitled: Fluid-structure-interaction in pipe coils during hydraulic transients: numerical and experimental analysis

Pablo Ouro, UK
For the paper entitled: Large-eddy simulation of vertical axis tidal turbines: study of the blockage effect

2nd IAHR Hydro-Environment World Heritage Award

Dutch Water Boards, The Netherlands

1st IAHR Hydro-environment Industry Innovation Award

Deltares

The rest of Awards have been published in Issue 2, page 66

2015 John F. Kennedy Student Paper Competition Winners

IAHR 2015 Honorary Members. From left to right, Arthur Mynett, Roger Falconer, Jean-Paul Chabard, Joseph Lee, Ramon Gutierrez Serret (on behalf of Mariano Navas) and Christopher George

Chair of the LOC of the 37th IAHR World Congress

Marian Muste, Former President of the IPD Division and Outgoing Member of the Council

Prince Sultan Bin Abdulaziz International Prize for Water

Recognizing Innovation

Invitation for Nominations

7th Award (2016)

Nominations open online until 31 December 2015

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