HR Wallingford
Working with water

Fluid thinking, smart solutions

Research strategy 2015-2020

Our research

As an independent, non-profit distributing, commercial research organisation, HR Wallingford delivers practical solutions in civil engineering, environmental hydraulics and water management. For more 70 years our research in hydraulics and related fields has enhanced the global understanding of the natural and built environment.

Our research streams \ Our research challenges	Broadcasting excellence	Adapting to a changing environment	Progressing through complexity	Observing & assimilating
Observations of the natural and built environment	✓	✓	✓	✓
Physical processes and laboratory modelling	✓	✓	✓	✓
Numerical processes and scientific computing	✓	✓	✓	✓
Integrated, knowledge-based adaptive management	✓	✓	✓	✓
Enabling technologies	✓	✓	✓	✓

"Bridging academia and industry, our unique perspective allows us to anticipate and engage in global research challenges to deliver enhanced understanding of the natural and built environment.

Constructive interaction between our research activities and our specialist consultancy is essential to our business. Success in research is vital to maintain our international reputation and our leading edge in consultancy, thereby ensuring sustainability, and our ability to attract and retain high calibre staff. Success in specialist consultancy is key to profitability, which provides funds for investment in staff, facilities and research, and to providing direction for future research and development.

Our research strategy demonstrates the objectives we share with global research programmes, outlines the key research challenges we foresee and the research streams we will navigate to address them. It also showcases a selection of our ongoing research projects, many of which highlight the importance of collabration with partner organisations around the globe.

Research remains at the heart of what we do. We will continue applying rigorous scientific methods to create and share new knowledge for the benefit of our clients, industry and society as a whole."

Dr Giovanni Cuomo
Research Director

Contents

Our vision

For 70 years water has been our world. As an independent, non-profit distributing organisation, HR Wallingford is a globally acknowledged leader in civil engineering, environmental hydraulics and water management.

Our aims

- Be a world leader with a strong international reputation in research, development and innovation.
- Deliver sustained profitability to ensure financial resilience and independence, and to support our investment in research.
- Produce sustainable growth in revenue and staff numbers, so as to develop our capacity to meet market needs and our aspiration to be seen internationally as leaders in our field.
- Maintain and enhance our reputation as a reliable, value-adding supplier of choice to public and private sector clients.
- Provide a world class workplace for motivated staff, proud of the company they work for, the job they do and the contribution they make.

We will continue to apply the unique skills and insights of our talented team of people to create and share new knowledge, delivering our vision for the benefit of our society.

Our advice informs clients and assists decisions in many different situations. From delivering smart solutions to challenging technical problems to informing policy and long-term planning, we provide expertise and knowledge in the water sector in the form of research, development and specialist consultancy.

Our goals

Our activities are underpinned by a comprehensive research, development and innovation programme, which has three broad goals:

- Advance sustainable management of the water environment
  The water environment is vital to the health, security and cultural and economic well-being of our society. As a leading international research organisation we have a key role to play in advancing what we understand about the water environment and how it can be better managed, preserved and improved for future generations.
- Improve all aspects of our service
  We want to provide our clients with the most reliable and effective information possible in a timely manner to underpin their decision making. This includes offering scientifically robust opinion, evidence and advice in a way that can be clearly understood and acted upon. Our research programme allows us to advance our differentiation, improve and extend our services and supports our ability to deliver smart solutions to clients worldwide.
- Enable our staff to be at the forefront of knowledge
  We want our staff to be curious and questioning, advancing their knowledge for the benefit of themselves as well as others. Our truly international, inspiring and challenging working environment promotes a creative approach to problem solving. This involves creating real and virtual environments for vibrant engagement with colleagues and collaborators, fostering international co-operation, promoting staff exchange and making our centre of excellence accessible to enthusiastic, high calibre researchers.

Our world, our responsibility

As a society, we are increasingly aware of the fragility of our planet, and of the responsibility we carry for its well-being.

Population growth and rapidly expanding economies place increasing demands on water and energy. According to the Organisation for Economic Co-operation and Development, in the absence of a radical policy shift, the world's population will reach over 9 billion and the economy will nearly quadruple by 2050. Global water demand is expected to increase by 55 per cent, with water resources becoming scarcer, leaving over 40 per cent of the world's population in severely water stressed river basins. By 2050, global energy demand will be 80 per cent higher than today, 85 per cent of which will be supplied by fossil fuels. This would increase greenhouse gas emissions by 50 per cent, accelerating climate change and exacerbating global biodiversity loss. These 'consequences of inaction' call for a greater understanding of how the environment can be protected, managed and sustainably used for the benefit of society.

At the Rio+20 United Nations conference in June 2012, the world's governments agreed to produce a set of sustainable development goals. The themes they proposed are relevant to HR Wallingford's world, in particular:

- Integrated water management
- Energy for sustainable development
- Food security
- Sustainable and resilient cities
- Healthy and productive oceans
- Enhanced capacity of natural systems to support human welfare
- Improved efficiency and sustainability in resource use.

Our research strategy resonates with the approach of other organisations who share this vision.

Embracing global challenges

Our research strategy embraces the global policy commitments of organisations such as OECD, UNESCO, UN-WATER, WMO, WHO, UNEP and UNISDR. We recognise the grand challenges they are trying to meet and we want our research to make a contribution towards addressing their goals.

Our strategy engages in a number of the challenges identified by the WMO and WHO scientific and technical programmes, with a focus on observing and modelling systems, data management, analysis and assimilation, forecasting of extreme weather and support to management of emergencies, polar and tropical regions' dynamics, water availability, accessibility and security, public outreach and capacity building.

We will continue to engage with the strategic objectives of global organisations such as the UNISDR, with the aim to improve our capacity to model and forecast risk into the future; attain a better understanding of hazards, vulnerability and risk, and ultimately promoting resiliency of ecosystems, communities and the built environment.

The research themes targeted by the ICSU's Future Earth programme are significant for us, particular the understanding of the observed and projected trends in the Earth system and the links between global environmental change, sustainable development and human well-being.

Water, energy and food are inextricably linked and access to safe, sustainable and secure resources is globally recognised as central to economic growth and social progress. We aim to contribute to water/energy/food security nexus related global strategic initiatives such as the "Securing sustainable water for all" launched by UN-WATER and the "Thirsty Energy" launched by the World Bank to help government prepare for an uncertain future.

Innovation, competitiveness and sustainability

We have engaged with the European Commission's (EC) research programme for over 25 years. We support its research aims via participation in its flagship funding programmes and competitions such FP7 and Horizon 2020 (H2020) and LIFE.

Research and innovation under the challenges set by the H2020 Programme support nations in contributing to food security, climate protection and sustainability, whilst increasing competitiveness and improving well-being. Promoting environmental integrity, resilience and sustainability, they contribute to enable ecosystems and society, as well as infrastructures, the built environment and transport systems to adapt to climate change and other environmental changes. Among the challenges set by the H2020 Programme, the following are particularly relevant to our strategy:

- Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy
- Secure, Clean and Efficient Energy and Transport
- Climate Action, Environment, Resource Efficiency and Raw Materials

Conscious that the well-being of people, industry and economy also relies on access to safe, secure and sustainable energy, we support the EC Energy 2020 strategy which sets a path to competitive, sustainable and secure energy.

Supporting society though science

Our research strategy supports those of the UK research bodies on a number of levels. We embrace the diversity of topics pursued by research bodies such as ESPRC and NERC. This includes science policy and strategy as well as science and engineering itself. We undertake fundamental research and develop research ideas into useful tools. We will continue to engage with UK research participating in funding competitions, supporting university researchers and PhDs and through our staff as visiting professors to universities.

The UK Research Council's portfolio emphasises twelve strategic research themes; those on Global Uncertainties, Energy, Mathematical and Physical Sciences, Living with Environmental Change, Engineering, and Information and Communication Technology, are particularly relevant to our activities.

Our strategy will help to meet the societal challenges identified in 'The Business of the Environment'. This is NERC's strategic vision to place environmental science at the heart of responsible management of our planet, by improving understanding and prediction of how our planet works, and promoting a responsible management of the environment, while pursuing innovation, economic growth and societal well-being.

We are committed to delivering policy-relevant, high quality and robust advice and will continue to work in partnership with others to do so in the delivery of our research strategy. We will engage with research challenges of strategic relevance for public bodies such as the Environment Agency and Defra, and in particular with those identified by the Flood and Coastal Erosion Risk Management R&D programme, and the Joint Water Evidence Group.

Among the goals and priorities set by the National Oceanography Centre in its "Setting Courses" vision statement for the future of marine science, the following are particularly relevant for our strategy:

- Improve natural resource and ecosystem services security, resilience and sustainability of exploitation;
- Better understand and manage the impacts of human activities in the marine environment;
- Understand and quantify the risk and impact of global and local environmental change for improved risk management;
- Enhance quality of life, prosperity, and jobs through sustainable use of the marine environment.

Security of energy supply and reduction of carbon emissions are also central to the UK Government's energy policy, as is maintaining a suitable mix of future energy resources. We will continue to invest in R&D to support development and deployment of reliable renewable energy devices and assessment of the impact of their operations whilst contributing to improve effectiveness and safety and reduce environmental footprint of the exploitation of more traditional resources.

Helping industry manage the environment

Through our research we actively engage with many industrial partners, mainly in the water, energy and mineral sectors. We support their aims for sustainable development by delivering new approaches and ideas to balance our future resource needs with the protection of the environment.

From oil and gas, to thermal, nuclear and renewables, we promote research that aims to increase safety and efficiency in the energy sector. We will continue to contribute to advancing science and technology to support innovation and reliability of energy projects, and inform the understanding and management of water-based risk for the energy sector.

As exploitation of resources in deeper water and colder regions becomes viable, supporting safe exploration of, and operations in, new remote and extreme environments poses increasingly challenging scientific and technical questions.

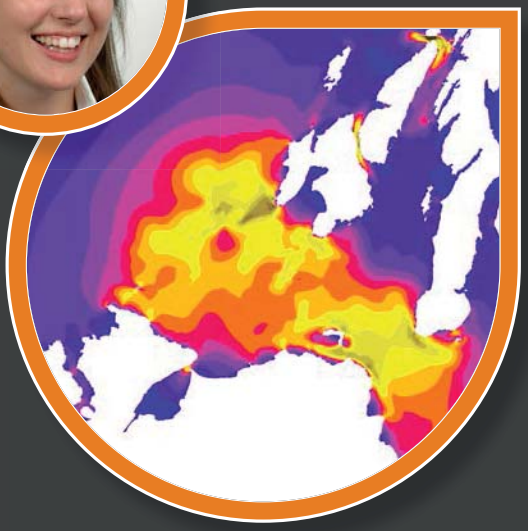
Building capacity, broadcasting excellence

We will continue to strengthen our collaborations with other research institutes across the globe, to provide unrivalled services to worldwide customers and win international challenges. We will engage in new partnerships with industry and research institutes worldwide to promote international collaborations, develop national and international centres of excellence, share knowledge and ideas, and build capacity. We are committed to growing science and innovation capacity beyond the UK; as part of this strategy, we will increase our engagement with research institutions in emerging countries and foster collaborations through international frameworks.

research spotlight

SMART support for tidal energy

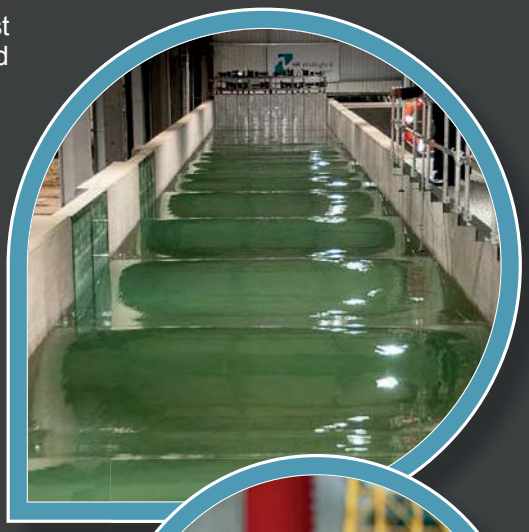
Samantha Dawson



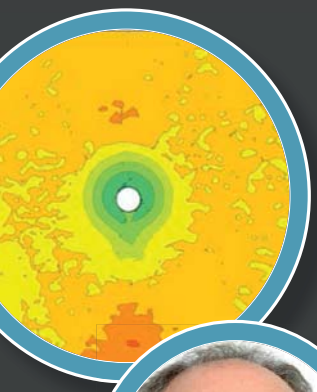
We developed SMARTtide (Simulated Marine Array Resource Testing) with the support of the ETI to help tidal energy companies to assess potential sites for new developments. SMARTtide is a unique suite of hydrodynamic modelling tools that covers the northern European continental shelf. The models are based on the TELEMAC system and can be used to assess regional and cross border effects of the design and development of tidal barrages and tidal farms.

The Fast Flow Facility

Prof Richard Whitehouse



The Fast Flow Facility is one of the world's largest marine test facilities. We developed and launched the Fast Flow Facility at the end of 2014 to enhance our modelling capabilities and help us to expand our role in the offshore, subsea, maritime and coastal sectors.



This dual-channel, race track shaped flume is a unique large-scale modelling facility offering wave, fast tidal current and sediment capabilities.

The 75 metre long, eight metre wide flume can hold up to a million litres of water, generate one metre high waves, produce fast tidal currents and has a 1 m deep sediment pit (with a volume of 16 m^3) to simulate the complex ways in which waves, tides, sediments and structures interact.

The size of the Fast Flow Facility means that we can also test devices in array, looking at how the turbulence moves from the leading device through to the next and so forth to optimise spacing between devices.

Understanding the complex way waves, currents and sediments interact is vital to the successful delivery of projects in the marine environment. The Fast Flow Facility allows our scientists and engineers to examine these interactions at a larger scale and in more detail than has previously been possible, helping us to more effectively optimise designs for our clients and minimise the water-based risks for their projects.

In addition to extending the capabilities available for our commercial projects, the facility is also suitable for researchers investigating problems related to hydraulics and sediment transport.

Optimising LNG terminal design

Aurora Orsini

As part of an engineering doctorate, completed with support from the University of Surrey, we have developed a decision support system for LNG terminal concept designs. The system allows engineers to quickly search for designs that simultaneously optimise capital and operating expenditure, berth downtime and risk.

The tools optimisation algorithm identifies a range of layouts that trade-off capital and operating expenditure, and berth downtime, offering a viable range of alternates during early stage design. Uncertainties in the design inputs can be handled in parallel through a Monte Carlo simulator, effectively providing an additional trade-off of uncertainty. This tool will help our engineers to rapidly assess preliminary design concepts for our clients in the LNG industry.

Assessing climate change risk for the UK

Helen Udale-Clarke

HR Wallingford led pioneering work for the UK Government to assess climate change related risks up to the year 2100 and we continue to deliver research supporting the evidence base on climate change risks.

The first UK-wide Climate Change Risk Assessment (CCRA) was laid before Parliament in 2012 and presented a comparison of a wide range of climate change risks based on their economic, social and environmental consequences. We led a large team of experts covering science, economics, stakeholder engagement and communications to produce the assessment on behalf of the UK Government.

As this was the first assessment of its kind anywhere in the world, a major aspect of the project was to develop a method and seek widespread agreement on the risks that needed to be considered. HR Wallingford continues to support the UK Government in its annual assessment of climate change risk indicators and in developing the evidence base in preparation for the second CCRA.

Simulating attrition of dredged materials

Daniel Barber

Many coastal construction projects involve dredging and re-use of dredged material, leading to complex questions over how the processes of excavation, handling and transport affect the surrounding environment and the final condition of the material itself.

Predicting the effects of the cutting and pumping processes on soil/rock during dredging can aid planning that may be key in determining the optimal project methodology, design and mitigation measures. This reduces unforeseen risk and maximises project efficiency.

Our long-term research has developed understanding of these processes for a range of material types, and it is continuously supported by new datasets or qualitative information from on-site activities.

Our research challenges

Over the next five years our research programme will address four major challenges.

Observing and assimilating

Progressing through complexity

Adapting to our changing environment

Broadcasting excellence

Observing and assimilating

Acquiring and assimilating data is key to our success in understanding complex physical processes, predicting their evolution and reducing uncertainty in predictions. The gathering, management, interpretation and assimilation of data within models provide precious insights into the complexity of the phenomena and create fertile ground for curiosity, creativity and discovery. Data challenge, strengthen and improve our understanding of the world we live in and our appreciation of its complexity and variability. This enables the continuous improvement of our modelling tools, increases awareness of their limitations and strengthens our confidence in their validity, enhancing our ability to provide reliable forecasts and solving complex problems.

For these models to be successful, and to allow us to understand and forecast system evolution and related risk, high-resolution, multi-scale observations with near-real-time data streams and processing may be required. High fidelity, high resolution models access, assimilate and generate unprecedented volumes of data; this in turn requires more powerful and flexible, often remotely operated, data management, analysis and visualisation tools. Increased resolution and complexity of our models, their associated assimilation systems and outputs drives the requirements for access to High Performance Computing (HPC) resources.

Progressing through complexity

Advances in science and technology enable us to appreciate the complexity of the world we live in. Understanding, modelling and predicting the dynamics of complex systems is both possible and necessary; this inherently leads to the need to include more unknowns and greater uncertainty. Modelling of such systems is a core skill for HR Wallingford and it is important, both for us and for our clients, that these skills are maintained and advanced.

We aspire to a more comprehensive representation and thorough understanding of whole systems, including an appreciation of their variability and associated uncertainties. This requires modelling coupled system components at the appropriate spatial and temporal scales within a probabilistic framework to predict the evolution of the system as a whole.

Accurately representing multi-physics problems requires coupling models of different processes at appropriate scale. Important instances of multi-physics problems include interaction of waves and currents with structure and their soil foundations, the dynamics of moored floating bodies, debris-flows, and the hydraulic performances of structures during extreme events, including hydrodynamic loading of marine structures and overtopping of coastal and flood defences.

Complex systems evolve over a range of time and space scales and their efficient representation requires a system-approach to modelling of coupled dynamic phenomena, which interact non-linearly across different scales. Agent-based modelling provides an additional level of complexity. This leads to (a) challenges in the choice of appropriate modelling scale, and (b) the need to include and propagate uncertainties over the modelling cascade and the development and application of optimisation algorithms.

Adapting to our changing environment

Coastal areas are densely populated (being home to around 40 per cent of global population) and face pressure from coastal erosion, sea level rise, climate change, pollution, infrastructure growth and reclamation of coastal habitats, use of ocean resources and sea bed. Away from the coasts, over 50 per cent of the world's population lives within 3 km of a surface freshwater body; these provide drinking water, food, transport routes, drainage and much more. Thus as well as our coasts and seas, our rivers and lakes are central to our well-being. Integrated, knowledge-based adaptive management of resources is central to research aimed at increasing security and resilience.

The concept of sustainable development contains environmental, social and economic dimensions; finding practical ways to balance the three is widely regarded as a key challenge. At all levels water is central to the issues. Providing adequate and sustainable access to clean water and sanitation while minimising the impact on the environment calls for a substantial amount of research. Population growth, economic expansion and changes to natural hazards will lead to altered risks to people, infrastructure, the economy and the environment. We will continue to contribute to the development of adaptation strategies that meet the needs of society.

Disaster risk management and disaster risk reduction require characterisation and quantification of the hazards and impacts that may influence a community or society. Such information is essential for identifying critical facilities and infrastructure, and for the preparation of emergency plans.

Broadcasting excellence

As the challenges we face become more complex, we will increasingly need to engage stakeholders, and share information at all levels. Engaging with an informed and educated public is key to building global improved capacity to make scientifically informed decisions.

HR Wallingford undertakes and applies research. Our international and national funders commission research because of the benefits it will bring. These benefits extend outside the context of the research teams and beyond the timescale of the research project. Our funders recognise the imperative of translating knowledge and understanding from scientific and technological advances into practice.

Our position, undertaking both research and specialist consultancy, places us in an ideal situation to work in knowledge-transfer partnerships with academic and professional organisations. Such collaboration often entails tailoring and piloting research outputs to demonstrate the benefits of research.

research spotlight

Assessing the state of the nation's flood risk

Mike Panzeri

Following flooding in the UK in late 2013-early 2014, we have been helping the Environment Agency update the National fluvial and coastal Flood Risk Assessment (NaFRA). This is known as 'State of the Nation'.

Within State of Nation we are improving different components of the NaFRA methodology and updating the input data to the modelling system ahead of the new national analysis. The improvements include refining the inundation model and developing and implementing a state-of-the-art coastal flood risk modelling chain that combines multivariate extremes analysis, wave transformation and coastal flood defence overtopping models. We are also updating the EA's flood risk modelling software with these improvements.

The Environment Agency will use the State of the Nation results and the updated software to support a variety of flood risk management decisions, including long term investment and asset management plans. HR Wallingford has been supporting the national flood risk assessment since 2004.

Exploring e-tech elements

Dr Mark Lee

E-tech elements, such as cobalt and tellurium, are essential for emerging renewable energy technologies and a low carbon society. These elements are in short supply, yet they are formed through natural Earth processes and occur in high concentrations throughout the world's ocean basins in metal rich crusts.

Recent estimates of the potential global tonnage of the crusts suggest that ~200 billion tonnes exist on the seafloor. China and Japan are applying for mining licences.

We are part of a prestigious international project team, led by the UK National Oceanography Centre, to investigate the origins and formation of these crusts and to study the potential impacts of their mining. The team will undertake a research cruise to study crusts *in situ* on a seamount, involving work at thousands of metres water depth.

HR Wallingford will survey and monitor currents, water quality and sediment movement (including sediment plumes). The measurements will be used to help validate our current and sediment plume models. We will also consider what plumes might be generated from commercial extraction activities, and how these plumes might behave. This information will be used to help inform environmental impact studies.

Improved scaling of porous materials

Andrea Polidoro

In order to improve the way we represent porous materials when modelling structures and beaches, we developed new methods to increase realism and accuracy when scaling granular materials.

Work carried out as part of our internal research programme allowed us to further improve the representation of flows in un-saturated porous media, morphological modelling of beach evolution as well as run-up, overtopping of coastal defences and breaching of mixed material and/or partially compacted beaches. The project has provided novel tools for the prediction of wave run-up on shingle beaches, as well a wide range of new data on beach responses to bimodal sea states; this work has already been translated into an improved beach evolution model.

Modelling wave energy

Prof William Allsop

We are part of an international research team looking at oscillating water column (OWC) wave energy converters. The HYDRALAB-IV funded project includes experimental work in the large wave flume in Hannover, Germany.

Working in a large-scale laboratory has provided us with an opportunity to collect unique calibration data for our internal research project, where we aim to numerically model compressible air flows to simulate water and air movements within and around OWC devices. Access to the large scale physical model test results and the development of advanced CFD capabilities in the modelling of OWC wave energy converters will allow us to develop and validate scale correction methods by comparing small scale and large scale physical model test results.

Pioneering use of observations from space

Nigel Tozer

HR Wallingford led the WaveSentry project to examine the value of a new prototype satellite instrument for providing ubiquitous global information on ocean waves.

GNSS data signals (used in positioning systems such as GPS and Galileo) are used to provide XYZ positioning, however other information in this signal can provide information a measure of undulations such as surface waves and winds. We tested how such data could be used to provide advanced wave forecasts anywhere on the globe. This information supported the business case for the launch in 2014 of the first operational satellite: TechDemoSat-1.

Our research streams

Observations of the natural and built environment

Physical processes and laboratory modelling

Numerical processes and scientific computing

Integrated, knowledge-based adaptive management

Enabling technologies

Observations of the natural and built environment

Observations are essential for a deeper understanding of the physical and living world. We recognise the fundamental value of field data and will seek to collaborate with other research institutes worldwide engaging in innovative field measurement campaigns. Data and knowledge acquisition extends to the laboratory: measurements gathered under controlled conditions reduce complexity and aid understanding. We acknowledge and promote relevant interplay between observations and system models, and will continue developing models and data assimilation systems that allow effective use of the observations to make useful analyses and reliable forecasts.

New technologies and techniques

The discipline of field-based hydraulics is presently undergoing something of a revolution. Technology is the driver for this very exciting and important period of change leading to development of reliable, effective, economical, unmanned, *in-situ* and remote survey systems.

Where once data collection may have been inconceivable or high risk, it is now practical, and previously well-defined boundaries and limitations no longer apply.

We will continue to explore, develop, adopt and exploit emerging and developing technologies and techniques both directly, by means of contributions to the design, development and supply of measuring instruments and unmanned vehicles; and indirectly, by advising clients and partners to facilitate their uptake of technological advances with minimum risk and maximum benefit.

New environments

Exploration of deeper waters is fostering a new blue economy, creating new opportunities to secure precious renewable energy (from wind, wave, tidal and oceanic currents), sustain the food chain (fisheries and aquaculture) and in mining and dredging.

Companies operating in the power, mining and oil and gas sectors are extending their activities in deep water and the polar regions, targeting exploitation of the potential of these new environments in the short to medium term.

Data collection, analysis and assimilation are urgently required to better understand the dynamics of these, until recently unexplored, environments together with the nature of their resources, and the remaining scientific and technological challenges

We will work with national and international academic and government institutions to investigate deep sea mining (thousands of meters) of raw materials that will allow for cleaner and more efficient energy production and usage globally. We will survey, monitor and model the physical characteristics of these environments, and inform environmental assessments of potential mineral extraction sites which must be resolved to enable their sustainable exploitation.

Smarter data

The nature of data acquisition and sharing has changed markedly over the last two decades, with the advent of greater computing power, greatly improved communications, and the development of smart and remote sensing. This has led to the availability of large amount of high resolution data rapidly and accurately collected over space and time; this trend is continuing apace, with an estimated increase at a rate of 30 per cent per year.

For this information to be translated into improved knowledge and understanding, and to maximise efficiency with respect to data gathering, management and exploitation, it is essential that data needs are assessed and effectively specified, and data are accurately and precisely gathered, and assimilated, at all levels.

We will explore smarter ways to access, generate, manage and assimilate data for research and consultancy studies, including:

- how specific stores of validated data can be established;
- re-using data across and between different activities;
- reducing the time needed to find and obtain data;
- accessing data in real time;
- dealing with big data;
- data inter-comparison to achieve greater certainty;
- using new or non-traditional data to solve new problems.

In this scope we include data from different sources, including models, instruments, remote sensing, databases and media.

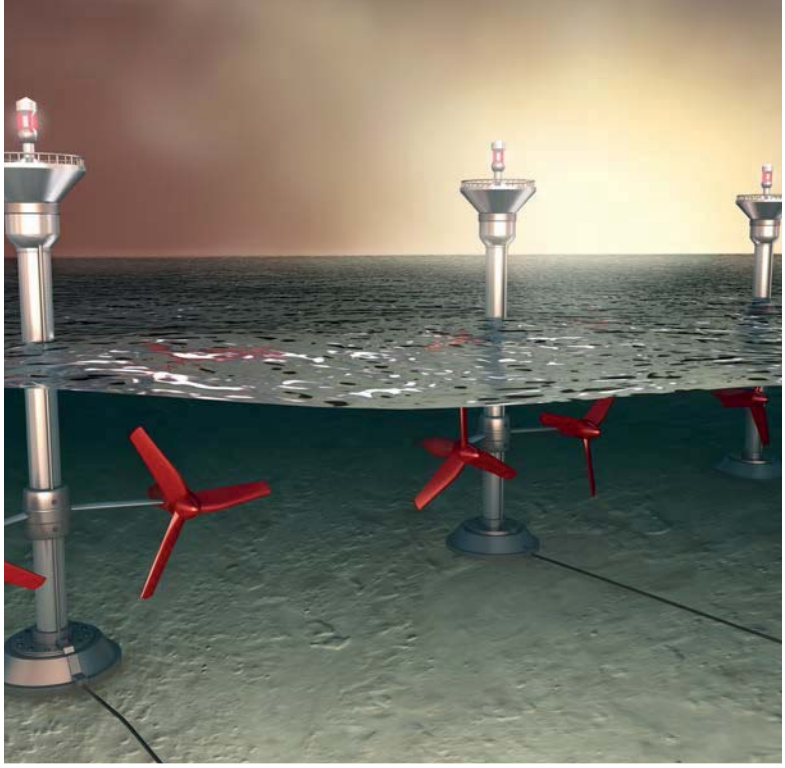
Bridging the gap between reactive numerical models and the changing world

Emerging technologies are changing the way we access, process and broadcast information. This research theme explores new ways of providing improved forecasts to promptly and effectively inform operational, monitoring and emergency procedures and enable better real time control.

We aim to enhance the accessibility and usability of real-time, real-world and model-generated information by directly projecting computer-generated information onto real objects, acquiring live sensory and imagery data from the physical world and assimilating them into responsive numerical models.

We will explore and exploit electronic components and sensory and augmented reality technologies to create linkages between the physical environment and the virtual world of numerical modelling and computer based reporting.

The principal objectives are twofold: to provide a more complete service to the industry with interactive modelling results mapped directly onto the real world; and to acquire and assimilate live sensory and imagery data and observations from the physical world and laboratory experiment into adaptive and responsive numerical models and databases.



Physical processes and laboratory modelling

For more than 70 years, we have developed, maintained and continuously improved our world class physical modelling capabilities. Providing consistent and reliable assessments of the hydraulic, geotechnical and structural performances of marine, coastal and hydraulic structures is a core element of our business and requires understanding and accurate, robust and rigorous modelling of complex phenomena evolving over a cascade of spatial and temporal scales, beyond the capability of existing numerical models.

Knowledge derived from laboratory measurements hastens scientific and technological advances, and allows development of innovative and reliable solutions to technical challenges. By means of a systematic and controlled exploration of the parameter space, laboratory modelling provides an unrivalled tool to assess the performance of complex systems under frequently occurring and extreme conditions.

Research undertaken within this stream will provide:

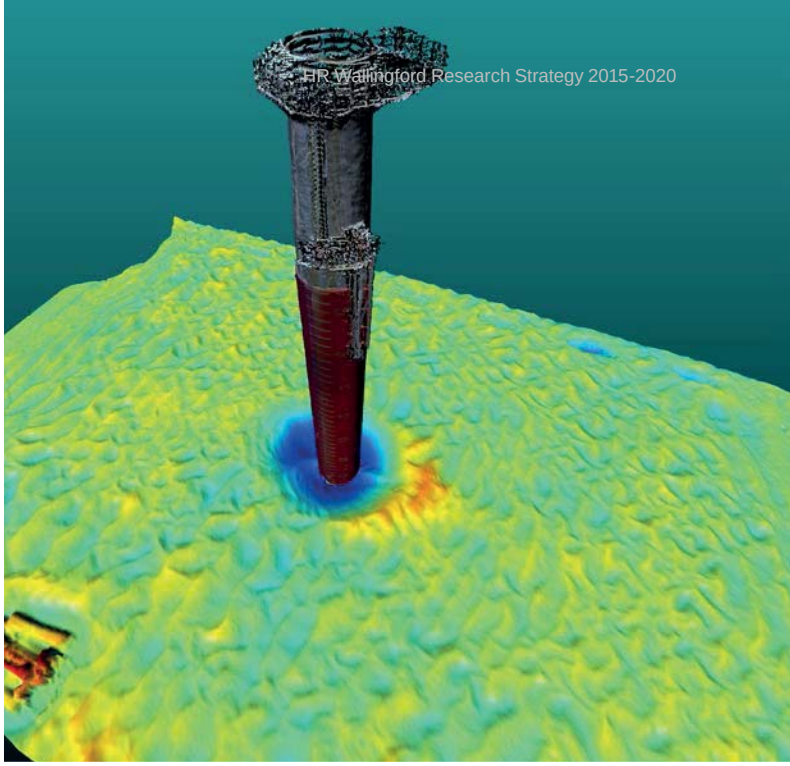
- illuminating insights on the discovery and understanding of physical and environmental processes;
- validation data for new or improved numerical models and empirical relationships;
- advanced modelling tools and techniques to validate and optimise the performance of engineering structures in the fluvial and marine environments.

Complex sediment dynamics

Accurately reproducing complex sediment dynamics requires modelling of multi-physics, multi-phase processes as extensions beyond the capability of existing numerical models. Fine sediment transport, erosion, settling and consolidation affect natural sedimentation, attrition/abrasion during dredging, dispersion of plumes from dredging and the performance of slurries in pipelines and pumps. These processes are of considerable importance to any coastal or marine infrastructure project involving dredging, reclamation or natural sediment transport (including coastal erosion) as they affect environmental impact and infrastructure performance.

Our Fast Flow Facility, opened at the end of 2014, provides us with a unique opportunity to gather insights on the:

- evolution of scour around fluvial and marine structures in space and time;
- dynamics of mixed sediment transport in non-steady or non-uniform flow conditions;
- nearshore transport of sand and gravel in the coastal environment.



Scaling the dynamics of complex systems

HR Wallingford is actively contributing to advance knowledge, share understanding and promote development and uptake of improved scaling methods. Scaling of the dynamics of mixed sediments, multiphase flows in porous media, vortex dynamics, impact pressures and overtopping discharges are example of important scientific questions that have not yet been comprehensively answered. This will require an integrated multiple-modelling approach.

The combined and complementary use of small and large scale physical modelling facilities, computational models and field data provide us with a unique combination of reliable tools and effective methods to assess and account for the effect of scaling in modelling, which in turn translates in to increased understanding and minimised risk for our clients.

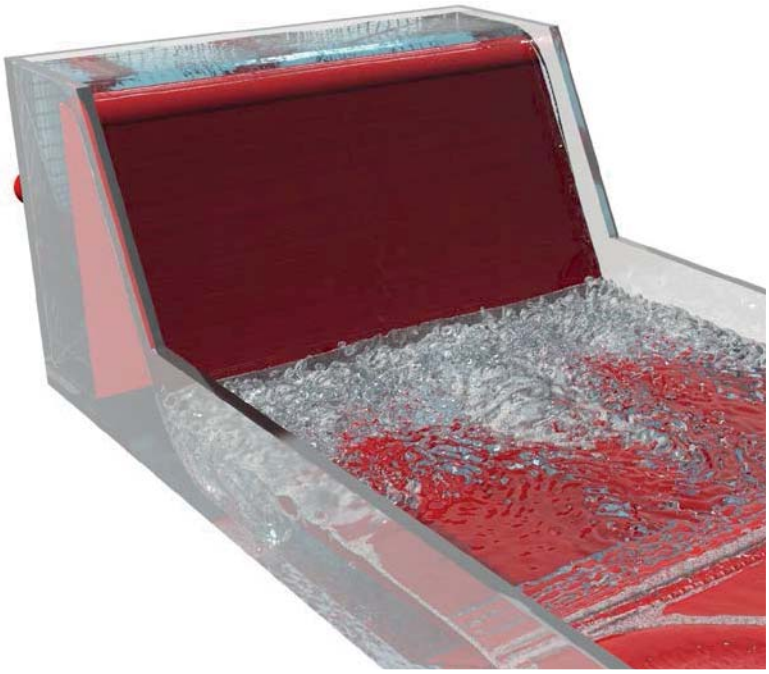
Analysis of complex hydraulic problems

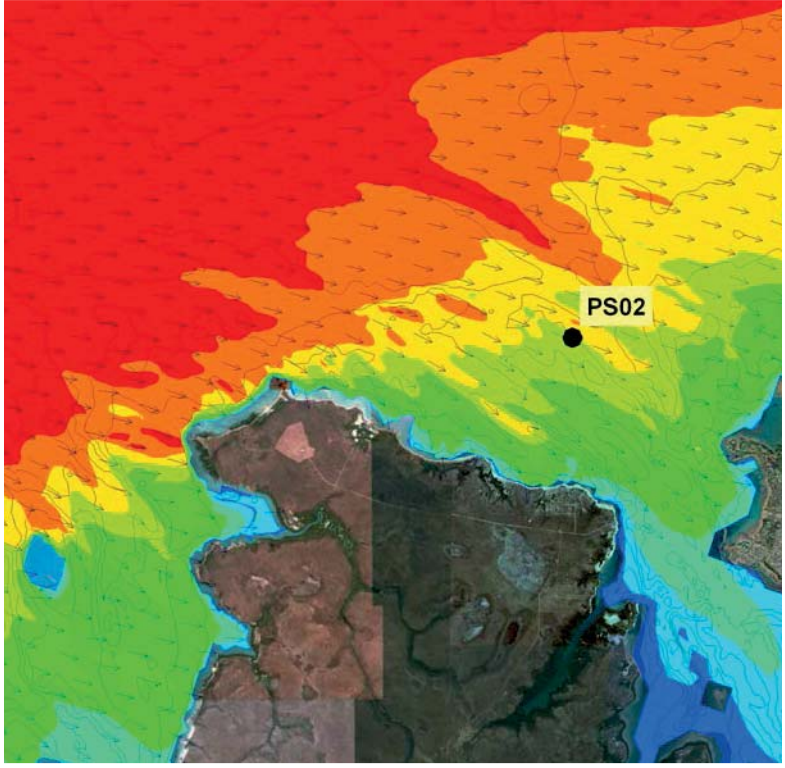
Optimising performance of complex hydraulic systems, such as intake and outfall structures and pumping stations, under frequent and extreme conditions are some of the many water-related problems involved in the different phases of the design, construction and management of industrial process and power plants. Increasing demand for safety and sustainability of operation, and efficiency and continuity of services results in increasingly challenging questions. Our research in this area will advance the understanding of:

- interaction of current and waves with structures, including marine intakes and outfalls, pipelines, foundations and marine renewable energy devices;
- multiphase flows in intakes, pumps, risers and pipes;
- hydrodynamics of complex hydraulic structures, such as spillways, tunnels, and drop-shafts.

State of the art modelling facilities

Providing clients and the international research community with access to world-leading knowledge and technology is one of our priorities. Deeper water, intense currents and extreme weather conditions call for accurate physical model testing of increasingly extreme conditions. Building on our “tradition in innovation”, as part of this stream we will explore and develop new equipment (hardware and software) for use in the laboratory. We aim to further advance in-house developed technologies and extend their application to other instruments to provide even more flexible, fast and accurate control and measuring systems.





Numerical processes and scientific computing

Numerical processes and scientific computing are central to HR Wallingford and support our international market position and reputation. Research undertaken within this stream aims at differentiation, a strategic path in line with HR Wallingford's tradition of leading edge innovation.

Our principal objectives are to:

- maintain innovative research and development by growing intrinsic knowledge of the models in use;
- increase resilience by participating in collaborative networks with key international experts and institutions;
- increase both operational efficiency and capacity to provide affordable yet reliable state-of-the-art numerical modelling directly applicable to our research objectives and consultancy services;
- increase and diversify our range of consultancy studies supported by numerical modelling activities in order to provide thorough advice over a broader range of service to our clients.

Global responsive modelling

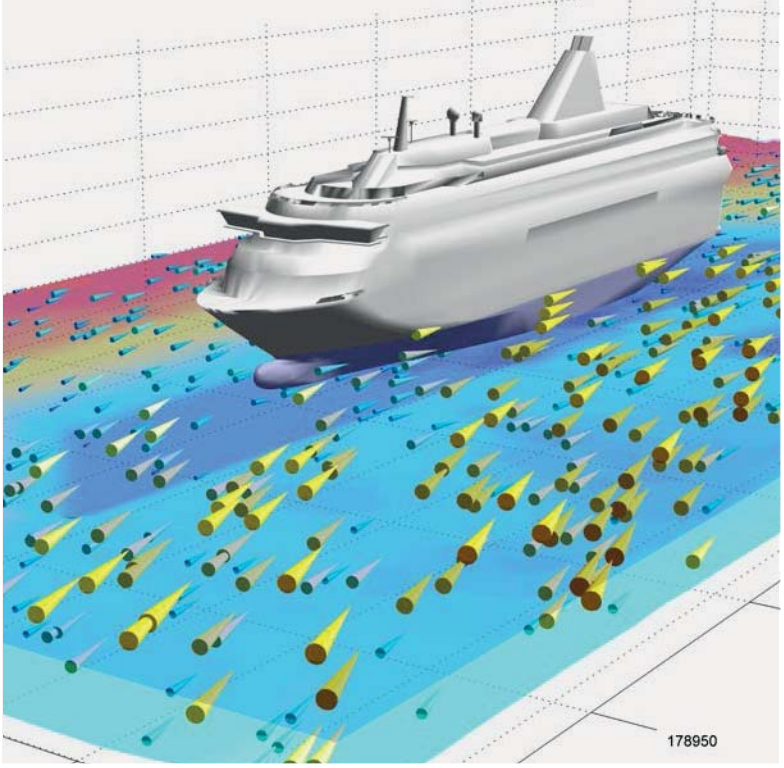
Increased scalability of modelling systems translates in unprecedented capacity to predict the evolution of complex multi-scale phenomena, providing a consistent level of accuracy over a cascade of spatial and temporal scales.

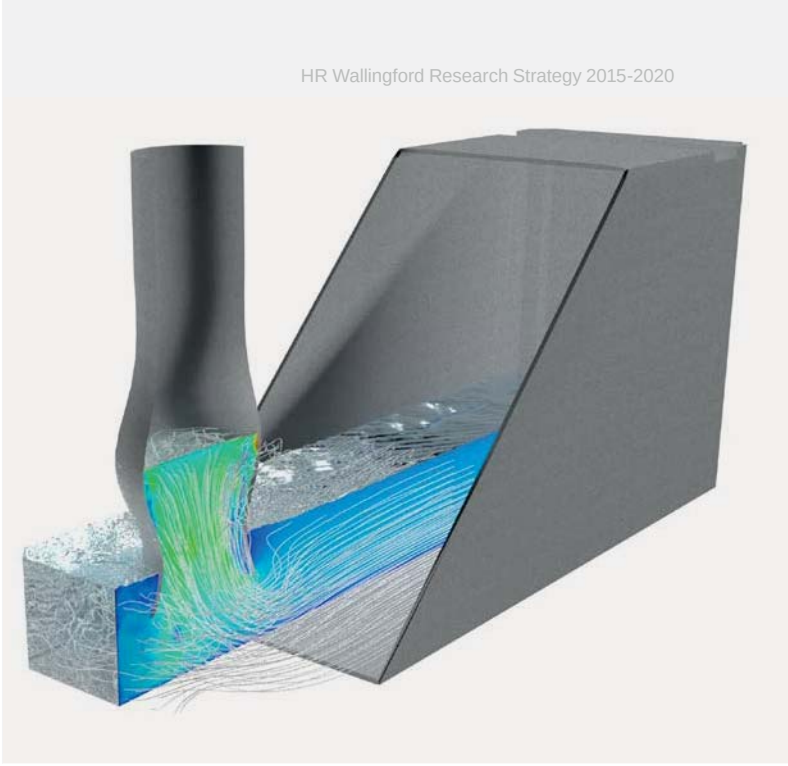
Our primary aim is the development of a modelling platform capable of generating synthesised information and predictions concerning key system properties, linked and supported by assimilation of data from both space-borne and *in situ* observations. This translates in the development of a detailed Earth modelling strategy, integrating the oceans and marginal seas, the deepest fault lines and the polar regions

Agent-based emergent behaviour modelling

Agent-based models are increasingly being used to model social interactions and behavioural change with a view to making significant contributions to the development of new policies.

Our research will improve the representation of agent-based processes, with particular emphasis on the effects of the behaviour of the agents (defined as individuals or groups of given characteristics and capable of behavioural responses) on the dynamics of system as a whole when stressed or stimulated by changes in external factors. This is often described as "emergent behaviour" modelling.





Agent-based models inform adapting management of complex dynamic systems such as:

- water resource management;
- flood risk management;
- evacuation and emergency management;
- ecological impact management.

Integrated and advanced modelling

The complementary use of our physical and numerical modelling tools allows the key processes involved in flow-wave-soil-structure interaction to be represented as accurately as is currently possible.

Continuous improvements in our in-house modelling capacity have made increasingly sophisticated physical and numerical modelling tools available that are more and more integrated within our flow, wave and sediment modelling strategy.

The primary objectives of this theme are to:

- maintain R&D of new processes within a wide range of comprehensive multi-scale and multi-physics models;
- expand the range of application of these models to newly identified gaps with a focus on interaction or transition between processes;
- expand the type of models considered with a particular emphasis on the integration of reduced order methods as well as particle driven processes;
- broaden networking between communities of experts working on different fields of applications.

Optimisation, adaptation, assimilation

Modelling and predicting the evolution of the dynamics of complex system dynamics requires methods and tools capable of data assimilation, parameter estimation, uncertainty quantification, system optimisation, and multi-physics, multi-scale optimisation.

Stochastic methods have so far been used to create large ensembles of predictions for which hundreds, thousands and hundreds of thousands of simulations are assembled to feed iterative optimisation procedures, restricting the predictive models to fast but simplified models. Contrarily, adjoint modelling adapts at once every input parameter to best fit the predictive solution to every target values and because it uses only a small sample of simulations, adjoint modelling provides access to computer intensive predictive modelling suites.

With the arrival of automated/algorithm differentiation, adjoint modelling has the potential to create a paradigm shift in the range, the complexity and the type of answers one would typically get through applications such as design optimisation, data assimilation, parameter estimation, shape optimisation, reverse engineering of initial conditions, automated calibration, adaptive procedure management, and uncertainty analysis. We will explore and exploit now accessible adjoint models to provide designers, stakeholders and decision makers with timely, robust and comprehensive information.

Integrated, knowledge-based adaptive management

At the national and international level there is a long-standing commitment to seek decision pathways that lead to sustainable development. As such, these combine environmental, social and economic factors considered over generational timescales. Since there are gross uncertainties in future environmental, social and economic conditions – especially in the long-term – concepts such as robustness, resilience and reversibility are important factors in making decisions that aim at sustainable development.

Confronted with significant uncertainty, decision makers and risk managers need robust methods that enable them to make choices with confidence. Adopting a whole systems approach best enables a holistic view of complex issues and problems, particularly those that include human activity and/or managing incomplete, partially understood processes. Dealing with highly complex interactions, sparse reliable information, or with very low probability processes, poses significant challenges.

Critical amongst the environmental issues is the potential for change in the global, regional and local climate and the consequent hydro-meteorological forcing upon the systems we assess. Coupled to these uncertainties is the potential for change in the future social and governance context of any appraisal, with such change being either autonomous or non-autonomous in response to the environmental drivers.

We will continue to inform, advise and facilitate debate on:

- impact assessment in connected physical, biological and social systems;
- potential adaptations to change (environmental, social, economic);
- decision making under gross uncertainty – seeking no-regrets courses of action.

This requires us to assess impacts and reactions in complex systems and interact with professionals and other stakeholders from a variety of disciplines and potentially conflicting world-views.

Representation and communication of uncertainty

Representing and communicating uncertainty in differing contexts and to differing audiences remains a significant challenge in making effective decisions that achieve widespread support and acceptance. Long-term planning is set in the context of gross uncertainty for future conditions whereas the public expectation may for the continuation of normal experience and variability or some slow underlying trend of change. By their nature extreme events are not common experience. The challenge is to develop measures of uncertainty and variability that are scientifically justifiable and are credible to, and understandable by both professional and non-professional audiences. Communication will involve the choice of language used to describe concepts and scenarios as well as visualisation technologies to explore and interact with alternative futures.

Integrated environmental modelling framework

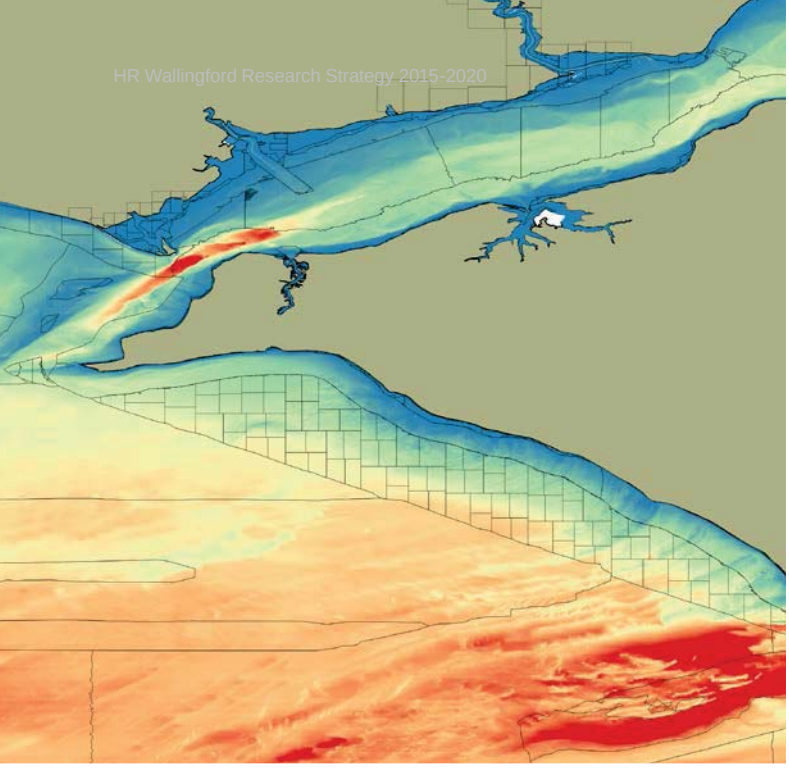
Integrated modelling has long been on the research agenda with applications to real life regarded as being possible. As the complexity of what can be addressed in models increases, we need to understand how best to represent the interventions, changes and interactions of land-use, land management, regulation and socio-economic and scenarios within an integrated environmental modelling framework. Such integrated modelling may guide decisions by professionals and demonstrate the potential interactions within the system and its responses to options and alternatives. This might, in turn, be used to inform public and stakeholder dialogue during the public engagement that is now required in many decisions about publicly funded planning, infrastructure development and management.

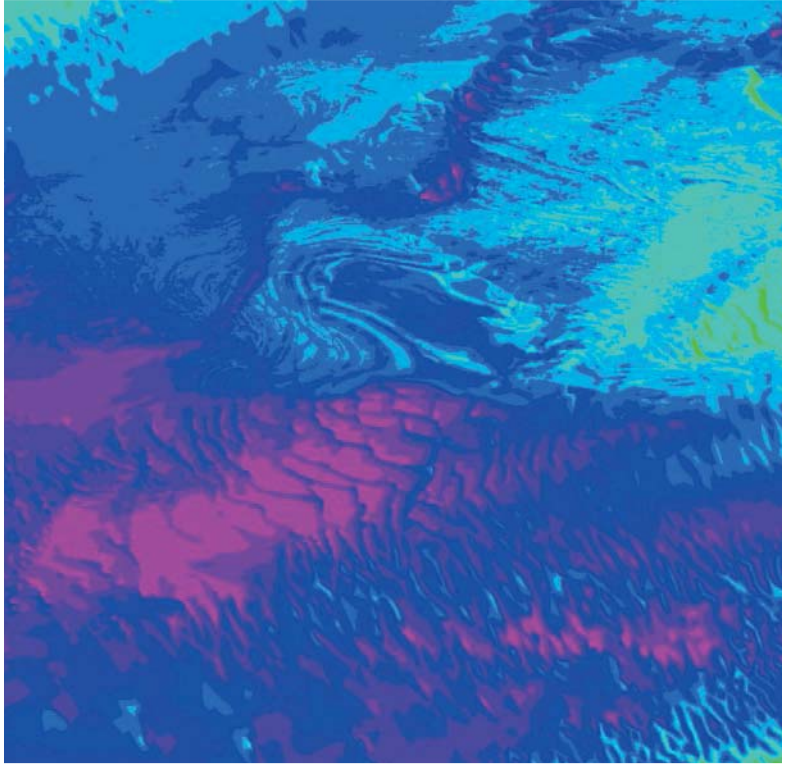
Modelling and understanding compound hazards

Many hazards are mediated through water either by the propagation of the hazard itself (e.g. a flood or tsunami) or as a vector which spreads the hazard. Of particular interest is modelling complex low probability-high consequence (LP-HC) natural or man-made hazards and the related topic of catastrophe modelling. This modelling assesses the threat to growing, densely populated, urban areas and the increasingly interlinked global economy. Understanding LP-HC events and catastrophes requires an exploration of a potential web of consequences and interactions that are not documented as having happened, but are credible. Through collaborations with others who specialise in natural hazards and risks, this research will support the commitment of many countries to disaster risk reduction (DRR) under the ISDR Hyogo Framework for Action and the post 2015 priorities for DRR.

Dynamic risk assessment and management

We have successfully developed and applied sophisticated flood risk analysis models that operate at national, regional and local scales. These approaches are well-suited for long-term investment planning and appraisal. Recent floods have, however, highlighted the need to extend the traditional view of extreme events to provide a richer and dynamic understanding of the temporal and spatial variability of hazards, vulnerabilities and risk. In the longer term, methods to incorporate the dynamic risk arising from the combination of climate, societal and economic damages are required. This research will extend traditional stochastic and hydrodynamic modelling, rapid appraisal methods and agent-based modelling of human components of the risk system.





Enabling technologies

The pace of society has a profound impact on what we do. How we organise ourselves is changing and this reflects how we do research. On-going development of Information and Communication Technologies (ICT) is transforming the way in which the public, academia, industry and government share, access, manage and use resources, information and data. Enabling technologies are means to not only undertake our research, but also advance our entire research community to deliver better solutions, more quickly and at a reduced cost. Ubiquitous and mobile computing for example means an acceptance of new ways of delivering information and expectations that risk and uncertainty management is inbuilt in all we do.

Creating infrastructures to provide access to knowledge from data and information is an essential component of our research. As part of this enabling research, we will explore and exploit emerging technologies, typically from the field of IT (e.g. Big Data, open data and cloud computing), research how their application can advance and improve the services we deliver to partners and clients, and enable smarter ways of solving more complex problems.

Data services and smart documents

Changes in technology fundamentally impacts what we can deliver. With advancing computing techniques we can work with bigger datasets and more complex simulations as well as better ways to visualise and interpret the results. This research theme examines new approaches to how information is made accessible, to enable and inspire greater interaction with the larger data sets and the richer information provided.

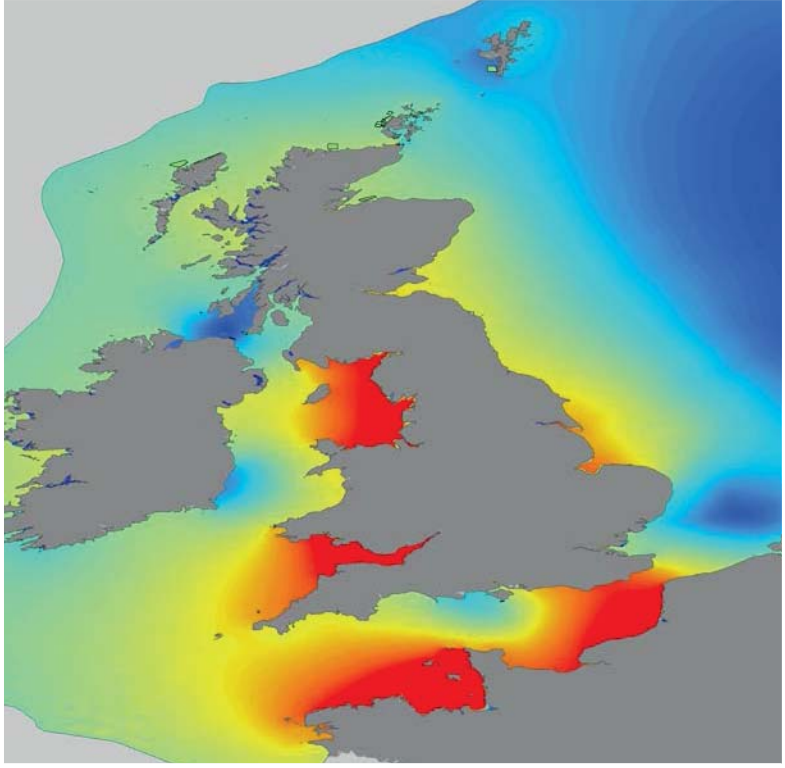
We aim at developing new standards for faster, better, smarter and more efficient ways for users to access and interact with data in the water industry. Building on recent advances on big spatial data, smart documents, augmented reality, wearable user interfaces, data production and data visualisation, this research theme will further explore, develop and exploit both hardware and software components of information systems.

Data security, scalability, traceability, trust and quality assurance in information generation are central to this theme, as are streamlining and facilitating data access, mining, visualisation and manipulation.

Big data

Data itself has become a research challenge. Increasingly it is becoming too big to lend itself to the types of desktop analysis that were performed a decade ago. Big data is characterised by four Vs: volume, velocity, variety and veracity.

- Volume means data is now too large for routine analysis, e.g. LIDAR point clouds of several terabytes.
- Velocity means it is changing quickly, for example social media feeds.
- Variety means data is delivered in a plethora of structures, formats and encodings which all need to be embraced.
- Veracity means data traceability, quality and provenance are unknown and variable. In addition different licence and intellectual property regimes



Variety and veracity were known problems with 'small data' however when the data becomes big the problem is magnified

We plan to research approaches to big data so that management of the water environment benefits from the increased data available and is not hindered by it. Aside from looking at the technology that enables big data to be stored and accessed, we will focus on developing approaches that enable relevant information to be extracted and utilised and research approaches to documenting and tracking data provenance and quality, especially when data is comprised of data from multiple sources.

Exploitation comes as standard

Targeting information to user requirements enables the delivery of our potential, improves understanding and decision making and fosters engagement. The aim of this topic is to facilitate exploitation of model results, data and information by tailoring development of tools, software and methodologies to user communities, enabling our research to generate more impact, more quickly. With this in mind, we will continue to develop persistent tools, software and models that go beyond HR Wallingford. This is the case for our contribution to the development of the TELEMAC modelling system within the Open-TELEMAC Community, or the development of OpenMI within the Open Geospatial Consortium or our EC funded work on data standards that have supported the development of the INSPIRE directive.

Software as a service

To meet multiple client needs, modelling has traditionally been a bespoke, offline process in response to particular clients requests. This research topic will look at modelling frameworks, system architectures and system deployment for the next generation of numerical modelling to ensure HR Wallingford stay at the forefront of modelling and simulation.

As part of this research we want to take a fundamental examination of what is possible both technically and commercially for future numerical modelling services to clients. This includes models we develop ourselves, but also the concept of community models that can be advanced and developed by different groups.

Social media

Understanding is still developing of the potential for use of social media in supporting, influencing and dissemination of technical appraisals. Topics for research and integration into practice include mining of data in near real-time on topics or situations of interest, and development of web based social media tools to support participatory modelling and stakeholder engagement in decision making. Care will be needed in ethical aspects of the mining and use of data and information from third-party sources.

research spotlight

Water security for Africa

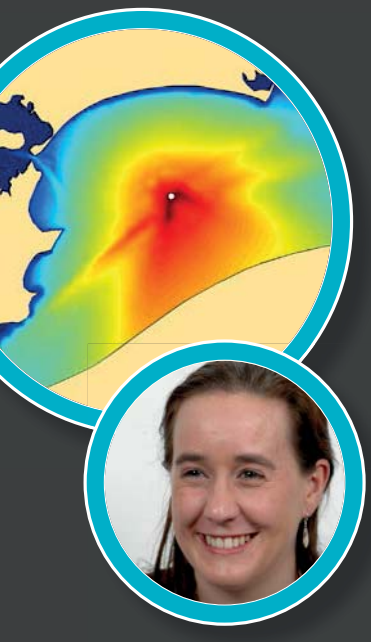
George Woolhouse

Improving water security across Africa will be key to the continent's continued development, especially in the face of future climate change. We led the development of a Strategic Framework for water security and climate resilient development in Africa, supported by a series of information briefs and a technical background document to underpin its application.

The Framework was developed for the Global Water Partnership as a key knowledge product to inform a five year Water, Climate and Development Programme (WACDEP) across eight African countries and five transboundary river basins. It provides tools to support the integration of water security and climate resilience into development planning, with a focus on prioritising no or low regrets' investments and financing strategies.

Assessing underwater noise

Dr Diane Jones

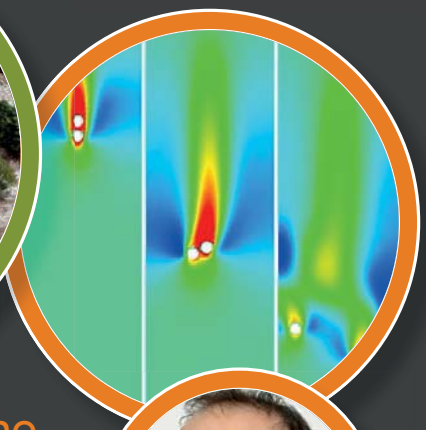


Human activity in the ocean and at the coast can create a lot of noise underwater. As part of the consenting process, developers need to minimise the impact of their activities on the marine environment. To do this effectively they need to understand how noise can affect fish, mammals and reptiles and other marine life.

As part of our internal research programme we developed HAMMER (Hydro-Acoustic Model for Mitigation and Ecological Response), a tool to both model the way noise travels underwater and assess how marine life might respond to it. Noise propagation underwater is complex. Our propagation model considers the local bathymetry, seabed sediment type, water temperature, salinity and depth and differing attenuation of discrete frequencies.

Further development of the behavioural response model has been undertaken in partnership with Exeter University through a NERC-funded KTP. Field and laboratory studies are providing data on the behavioural response of commercially and conservationally important fish to underwater noise to be used to parameterise the model.

HAMMER provides our clients with insights into the potential long term impacts on marine life exposed to anthropogenic noise.



Distributed research infrastructure for hydrometeorology

Quillon Harpham

Predicting weather and climate and their impacts on the environment remains one of the main challenges of the 21st century. Ready access to hydro-meteorological models and data is at the heart of this challenge as is the need to foster collaboration between meteorologists, hydrologists and earth science experts.

The DRIHM project is applying our expertise in modelling infrastructures, supporting standards, models and data to build an eInfrastructure which will allow scientists to study flash flooding. Using our FluidEarth 2 framework, we are delivering numerical models configured in an OpenMI composition to allow international researchers to study the severe and fatal flash flooding events which occurred in Genoa, Italy in 2011 and 2014.

Modelling the way fluids and structures interact

Dr Aggelos Dimakopoulos

The PICIN model is a state-of-the-art hybrid Euler-Lagrangian approach to solving Navier Stokes equations; retaining most of the functionality of Smooth Particle Hydrodynamics (SPH) code, it has the potential to run several orders of magnitude faster. Due to its use of an underlying Cartesian mesh, with cut-cell representation of arbitrary topography, the approach has huge potential for optimisation. Through an on-going collaboration with Bath University, this project aims to develop a parallel implementation of the PICIN model and validate it for use in simulation of two-way fluid structure interaction with an emphasis on floating bodies and wave energy generation.

Second generation tsunami simulator

Dr Ian Chandler

We are working in partnership with University College London to develop a second generation tsunami simulator as part of the URBAN WAVES project. Once installed in our Fast Flow Facility, the device will be the largest tsunami simulator in Europe.

Our first generation tsunami simulator proved the concept of using pneumatic device to generate realistic tsunami time series. The original device is probably unique in its ability to reproduce stable trough-led tsunami waves, and we have used it to successfully reproduce the 2004 Indian Ocean tsunami (Mercator time series) at a scale of 1:50.

Work is underway to develop a second generation tsunami simulator to enhance our tsunami generation capabilities. The new simulator will be installed in the 70 m long, 4 m wide main channel of our Fast Flow Facility and will improve the quality of both crest-led and trough-led tsunami generation and so the results obtained.

Construction of the second generation tsunami simulator is due to begin in the Fast Flow Facility in 2015. Once complete, a team from HR Wallingford and University College London will test coastal defences and urban environments for their tsunami resilience under the URBAN WAVES project, funded by the European Research Council. This work will ultimately lead to improved engineering guidance which will aid disaster management worldwide.

The deployment of the tsunami generator in the large Fast Flow Facility will allow flow around clusters of buildings to be evaluated for the first time.

Collaboration, dissemination and empowerment

Our people are key to our success. As a research organisation, much of our intellectual assets reside in the knowledge, understanding and expertise of our talented staff.

We will continue to provide a vibrant work place to foster questioning, independent minds. At our UK headquarters, more than 20 countries are represented in our technical teams, and we are open to and enriched by visiting researchers from all across the globe, creating a truly international working environment. We reach out to clients and partners through our network of international offices.

Our challenges are global; collaboration is the key to success. Many challenges require interdisciplinary research and industry consolidation and evolution means centres of excellence are emerging. We encourage our staff to engage in collaborations with strategic partners to deliver world-leading excellence. We will actively engage with cutting edge research through JIPs.

Our ensemble of talented people and advanced modelling capabilities resonates through our links with academia and industry to provide public and private sector clients with timely and reliable solutions to their complex problems.

We participate in the network of European hydraulic laboratories, which draws together all the major European institutions in our field. We have many established links and collaboration outside Europe embracing research institutes and universities worldwide.

We will carry on encouraging timely translational research and knowledge exchange, to ensure that research is quickly and efficiently translated into quality information that meets society's evidence needs and contributes to sustainable investment and sound policy decisions by business and governments. We will proactively disseminate research output and continue to foster awareness and understanding of the importance of water related science with key decision makers to exert influence on the development of hydraulic sciences worldwide.

Through our links to academia and professional institutions, we will promote professional development of our staff and adoption of research in practice, organise and host research focused events, including conferences and seminars, provide training programmes, courses and summer schools.

Higher Educational Institutions

We maintain strong links with universities, Higher Eduction Institutions (HEIs) and research organisations, both in the UK and internationally.

We are a member of the Affiliated Research Centre (ARC) Programme of the Open University. This enables students to study towards an Open University research degree (PhD) qualification at HR Wallingford. Through this programme we have extended our own high quality core research outcomes, furthered research excellence, developed staff capacity and new collaborations. Our ARC arrangements draw each supervisory team from our own staff and researchers at other university centres of excellence. It is our aim to maintain a body of PhD researchers on site at HR Wallingford, including new entries each year into the ARC programme.

Developing and maintaining working links with HEIs is of key importance to our R&D Strategy. HEIs are able to carry out research at a more fundamental level, which can be incorporated and further developed within our own work. We coordinate these linkages strategically, so that the range of links is balanced, and comprise:

- in-kind or financial support to HEI projects;
- supporting our staff as research fellows or visiting professors;
- provision of direct research funding.

We are proud of our truly international working environment.

Our technical teams include representatives from more than 20 nations.

HR Wallingford hosts students funded through the various MSc and fellowship initiatives from the EC, or those from specific universities with whom we have long-term partnerships to support their under- and post-graduate programmes.

Professional institutions

HR Wallingford encourages members of staff to become members of professional institutions, such as the Institution of Civil Engineers (ICE), Chartered Management Institute (CMI), Chartered Institute of Water and Environmental Management (CIWEM) or the Institute of Marine Engineering, Science and Technology (IMarEST).

We have a formal training scheme for graduates through the ICE. Under this scheme we provide semi-structured training to support staff from Initial Professional Development (IPD) through to Chartered Professional Review, when they achieve MICE and CEng status, while some of our staff go on to become Fellows of the ICE. Individual members of staff also contribute to the success of ICE by serving on the ICE Council on the Editorial Advisory Boards for ICE Journals and on the advisory committees of ICE organised professional conferences.

Our staff also contribute to the success of the associated professional societies hosted through ICE, including the British Section of PIANC (through which we contribute to the development of international PIANC guidelines) Central Dredging Association, British Dam Society, the British Hydrological Society and the Irrigation and Water Forum (linked to ICID).

HR Wallingford has long supported and contributed to the professional activities of the International Association for Hydro-Environment Engineering and Research (IAHR). The IAHR provides a valuable network of researchers, access to state of the art knowledge and a means of raising water issues in international debate. Our support to IAHR is at national, European and international level through membership of working groups and committees and participation in the IAHR international and European congresses. We support the knowledge dissemination functions of IAHR by preparing papers and articles and by assisting with the editorial process of the IAHR publications. In a wider sphere, staff are members of the Editorial Boards of a range of other peer review journals and technical publications and widely contribute to peer review activities for journals, conferences and the outputs from research programmes.

Responsible research and innovation

We are committed to research and development in order to maintain and enhance product technology and retain a competitive position in the market. We have endorsed the RCUK Policy and Code of Conduct on the Governance of Good Research Conduct and the Concordat to Support the Career Development of Researchers.

We embrace the Responsible Research and Innovation (RRI) inclusive approach fostered by the EC to ensure that societal actors work together during the whole research and innovation process to anticipate and assess potential implications and societal expectations.

We share EPSRC commitment to developing and promoting responsible innovation to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest through the AREA framework defining a RRI approach as one that continuously seeks to anticipate the impacts, reflect on the purposes and motivations, engage and act to influence the direction and trajectory of the research and innovation process itself.

HR Wallingford
Working with water

HR Wallingford
Howbery Park
Wallingford
Oxfordshire OX10 8BA
United Kingdom

tel +44 (0)1491 835381
fax +44 (0)1491 832233
email info@hrwallingford.com

www.hrwallingford.com