Flood modelling and forecasting challenges in industry workshop, June 11-12 2020

https://twenty65.ac.uk/events/flood

	Programme	
Time	**Title**	**Speaker (45 mins)**
11 Jun	**Day 1: Operational flood mapping & forecasting**	
9:30	Welcoming and workshop introduction	Georges Kesserwani & Vanessa Speight
9:45	Eliminating grid alignment sensitivity in fixed grid solver & Comparison of turbulence models for 2D hydrodynamic modelling	Duncan Kitts, **BMT Group**
10:30	Data assimilation in flood forecasting	Henrik Madsen, **DHI Group**
11:15	**Coffee break**	
11:30	Collaborative Flood Modeling - And Why Fine Resolution Matters	Brett Sanders, **California Irvine US**
12:15	Practical advances for stormwater management	Julien Lhomme, Innovyze
13:00	**Lunch (on site)**	
14:00	Flood demonstrator ‘Wetropolis’: from design to research in flood mitigation and control	Onno Bokhove and Tom Kent, **University of Leeds**
14:45	Modelling river flood risk for the whole continental US	Paul Bates, **University of Bristol**
15:30	Breakout session: what are the present and near future challenges in flood modelling and forecasting?	Vanessa Speight and Caroline Wadsworth, **TWENTY65**
19:00	Event dinner: Tapas at Cubana	
12 Jun	**Day 2: Also spans talks on ‘Flood resilience metrics including people response dynamics’**	
9:00	Flood incident management & modelling (awaiting title)	Sue Manson, Environment Agency
9:45	Development of an operational, risk-based approach to surface water flood forecasting.	Steven Stanbridge, **Food Forecasting Centre**
10:30	**Coffee break**	
10:45	Flood resilience: a systems approach?	Lindsay Beevers and Melissa Bedinger, **Heriot-Watt University**
11:30	Modelling challenges for strategic assessments	Jon Wicks, Phil Raynor and Richard Crowler, **JACOBS**
12:15	**Coffee break & lunch**	
13:15	Use of an agent-based model to improve emergency planning for floods	Darren Lumbrosso, **HR Wallingford**
14:00	The social psychology of flooding	John Drury, **University of Sussex**
14:45	Closure and optional tour for the ICAIR facilities	Georges Kesserwani, **University of Sheffield**
15:00	Tour for the ICAIR facilities	Simon Tait, **University of Sheffield**

Summary of the invited talks (last updated 13/02/2020)

11 June 2020
BMT Group (Duncan Kitts) **Eliminating Grid Alignment Sensitivity in Fixed Grid Solvers.** Fixed grid and flexible mesh solvers for the depth averaged Navier-Stokes equations (Shallow Water Equations) discretise a 2D domain into cells and faces. Many solution schemes consider the cells and faces to be flat-bottomed and either ‘wet’ or ‘dry’ depending on whether the water surface elevation exceeds the cell or face elevation. This representation is not as physically realistic as it could be, and causes errors in the results that depend on mesh size, and in the case of fixed grid solvers, mesh rotation angle, and in the case of flexible mesh solvers, mesh design. A more physically accurate representation is to consider ‘partially wet cells’, that is to use the underlying topography for each cell and face to build non-linear relationships. In the case of cells, between the cell water volume and the water surface elevation, and in the case of faces, between the water surface elevation and the face flux area. The benefits of ‘sub-grid-sampling’ appear significant and far-reaching. For whole-of-catchment models, response times and water retention are more realistic. For deep sided channels that are not mesh aligned, flow patterns have no “saw-tooth” effects and obey Manning’s formula. However, most significantly, the sensitivity of results to mesh size is greatly reduced and to grid angle is almost eliminated. This point is far-reaching in that fixed grid solvers can produce the same quality of results as a well-designed, high resolution, flexible meshes. The sub-grid-sampling methodology is presented, supported by benchmarking to theory, flume tests and calibrated case studies. **Comparison of Turbulence Models for 2D Hydrodynamic Modelling.** Turbulence within rivers plays a significant role in determining the mean flow velocity field and is integral to the overall energy loss mechanism. Unlike floodplains where depths are low and bed friction high, head-loss predictions for rivers can be sensitive to the treatment of turbulent eddy viscosity. With the continued advance of computational hardware, rivers are now frequently modelled in 2D using the depth averaged Navier-Stokes equations (i.e. Shallow Water Equations), often with higher order schemes and sometimes at cell resolutions less than the flow depth. With this trend, some treatments of turbulent eddy viscosity can lead to mesh size dependency in the results and significant errors in the prediction of water levels. Relying solely on inherent numerical dispersion is problematic, as also are turbulence models where the turbulent length scale is related to mesh size. The issue of mesh-size sensitivity and the convergence of model results to physical test data for three turbulence models has been investigated. The turbulence models considered were: the zero-equation Smagorinsky model with grid-size based length scale; the zero-equation Wu turbulence model with depth based length scale; and the one-equation Prandtl model with depth based length scale. Three benchmark case studies from laboratory to real-world scale are presented: a right angled flume bend; a dam breach into a channel with obstacle; a deep fast flowing meandering river with high quality historical flood recordings. In each case mesh-size sensitivity is examined and results compared with recordings. Recommendations are provided on best-practice application of the turbulence models.
DHI (Henrik Madsen) **Data assimilation in flood forecasting.** Data assimilation is an important part of river forecast systems to improve forecasts and increase forecast lead time. State-of-the-art operational forecast systems include assimilation of in-situ water level and discharge measurements for updating the hydrodynamic state of the river model. Integrated hydrological-hydrodynamic data assimilation approaches have been developed that utilise other types of hydrological data to update the

hydrological state variables and thereby benefit from the hydrological memory of the catchment to improve forecast skills. Likewise, the increasing amount of data becoming available from satellites and new data sources (such as from drones and crowdsourced data) offer new opportunities for data assimilation in flood forecasting. The presentation will review recent advances, challenges and opportunities in data assimilation for river flow and flood forecasting. This includes (i) data assimilation in integrated hydrological-hydrodynamic modelling systems that utilises catchment runoff, soil moisture and groundwater levels for hydrological state updating, and (ii) assimilation of satellite altimetry observations of water surface elevation for hydrodynamic model parameter estimation and state updating.

University of California Irvine (Brett Sanders)

Collaborative Flood Modeling - And Why Fine Resolution Matters. Existing needs to manage flood risk in the U.S. are underserved by available flood hazard information. This contributes to an alarming escalation of flood impacts amounting to hundreds of billions of dollars per year and countless disrupted lives and affected communities. Making information about flood hazards useful for the range of decisions that dictate the consequences of flooding poses many challenges. Here, we describe collaborative flood modeling whereby researchers and end-users at two coastal sites co-develop fine-resolution flood hazard models and maps responsive to decision-making needs. We find, first of all, that resident perception and awareness of flooding is enhanced more by fine resolution depth contour maps than Federal Emergency Management Agency (FEMA) flood hazard classification maps, and that viewing fine resolution depth contour maps helps to minimize differences in flood perception across subgroups within the community, generating a shared understanding. We also find that collaborative flood modeling supports the engagement of a wide range of end-users in contemplating the risks of flooding, and provides strong evidence that the co-produced knowledge can be readily adopted and applied for Flood Risk Management (FRM). Overall, collaborative flood modeling advances FRM by providing multiple points of entry for diverse groups of end-users to contemplate the spatial extent, intensity, timing, chance and consequences of flooding, thus enabling the web of decision-making related to flooding to be better informed with the best available science. This transdisciplinary approach emphasizes vulnerability reduction and is complementary to FEMA Flood Insurance Rate Maps used for flood insurance administration.

Innovyze Inc. (Julien Lhomme)

Practical advances for stormwater management
A review of methods recently implemented in Innovyze software for the purpose of improving the modelling and design of stormwater infrastructure; aims, challenges, results.

University of Leeds (Onno Bokhove and Tom Kent)

Flood demonstrator 'Wetropolis': from design to research in flood mitigation and control. Our tabletop flood-demonstrator 'Wetropolis', which we will showcase live here, is a conceptual model with river flow, flood plains, an upland reservoir, a porous moor, representing the upper catchment and visualising groundwater flow, and a city, which can flood following extreme rainfall. The supply of rainfall randomly via two asymmetric Galton boards is a novel and engaging aspect of the set-up. Its aim is to let the viewer experience extreme rainfall and flood events in a physical model on reduced spatial and temporal scales, thereby conceptualising the science of flooding (in particular return periods) in a way that is accessible to and directly engages the public, stakeholders, and flood-practitioners. Its design, which we outline in the first part of this talk, is based on simulations of a one-dimensional numerical model of the dynamics coupled with a stochastic rainfall generator. A kinematic model describes the river flow and a depth-averaged nonlinear diffusion equation models the groundwater flow. While the individual components, including canals and reservoir, of the mathematical and numerical model are not new in separation, their coupling via suitable interface and boundary conditions is non-trivial [1].

Although initially intended as a tool for outreach and education, Wetropolis also provides inspiration and a scientific test-bed for research in flood modelling and mitigation. Tasked with providing a simple tool to assist decision-making, we have established a new protocol and cost-effectiveness analysis based on the concept of flood-excess volume [2]. Further, we have developed the modelling with a view to conducting idealised experiments for flood mitigation via dynamic control strategies. There is strong evidence in the literature that model-predictive control (MPC) can be successful in flood control of river systems. In particular, researchers at KU Leuven, Belgium, have shown that MPC, in combination with a Kalman filter, is capable of advanced real-time flood control with hydraulic weirs and storage reservoirs. Motivated by this, our goal is to investigate real-time flood control in an idealised setting using MPC, data assimilation, and approximate efficient models (emulators) of the hydrodynamics; here, we outline preliminary work towards this goal.

[1] Wetropolis GitHub 2019-2020: https://github.com/obokhove/wetropolis20162020

[2] Bokhove, Kelmanson, Kent, Piton, Tacnet 2019: Communicating (nature-based) flood-mitigation schemes using flood-excess volume. *River Research and Applications* **35**, 1402-1414.

University of Bristol (Paul Bates)

Modelling river flood risk for the whole continental US. True hydrodynamic modelling at continental scales represents a revolution in hydraulic science and has the potential to transform decision-making and risk management in a wide variety of fields. Such modelling draws on a rich heritage of algorithm and data set development in hydraulic modelling over the last 20 years, and is now beginning to yield new insights into current and future flood risk. This seminar reviews this progress and outlines recent efforts to develop a 30 m resolution true hydrodynamic model of the entire continental US. The model is built using an automated framework which uses US National Elevation Dataset, the NHD+ river network, regionalised frequency analysis to determine extreme flow and rainfall boundary conditions and the USACE National Levee Dataset to characterize flood defences. Comparison against FEMA and USGS flood maps shows the continental model to have skill approaching that of bespoke models built with local data. The model is used to estimate current and future flood risk in the US using high resolution population maps and development projections.

12 June 2020

Environment Agency (Sue Manson)

Incident Management & Modelling challenges. Abstract text

Flood Forecasting Center (Steven Stanbridge)

Development of an operational, risk-based approach to surface water flood forecasting.

Surface water flooding occurs regularly across England and Wales, especially during the summer months. It is widely acknowledged that surface water flooding presents a particular challenge to forecasters because of the difficulties inherent in forecasting intense localised rainfall and the highly complex runoff and drainage processes which operate at the surface, particularly in urban areas.

The Flood Forecasting Centre (FFC) has a responsibility to provide guidance on the risk of surface water flooding to Category 1 and 2 responders across England and Wales. Consequently, there is the requirement for improved methods for forecasting surface water flood risk and the FFC is currently involved in developing and trialling a novel surface water flood forecasting system, the Surface Water Flooding Hazard Impact Model (SWF HIM).

The SWF HIM offers significant advances over existing surface water flood forecasting methods used by the FFC, including provision of a risk-based approach. The SWF HIM links probabilistic runoff forecasts from the Centre for Ecology & Hydrology's Grid-to-Grid model with a library of pre-calculated surface water impact information compiled by the Health and Safety Laboratory. These probabilistic runoff forecasts are combined with impact information to provide a forecast of surface water flood risk at a 1 km^2 resolution across England and Wales.

This presentation outlines the methodology together with some initial results from the early operational implementation of the tool. The work has been undertaken as part of the UK's Natural Hazards Partnership (NHP) and also benefits from the close working relationship between the Environment Agency and the Met Office through the FFC.

Heriot-Watt University (Lindsay Beevers, Melissa Bedinger)

Flood resilience: a systems approach? Catchments are complex systems with interrelated natural, social, and technical aspects. The exposure, vulnerability, and resilience of these aspects (separately and in combination) are the latent conditions which when triggered by a specific hazard (e.g. flood), result in catchment impacts. In complex catchment systems, resilience is the ability to bounce-back, the ability to absorb, and the ability to transform. When all three abilities are accounted for, we are forced to consider the interactions of the catchment system. In analysing recent research we have found that there are several gaps in current practice examining resilience to flooding. For example critical interactions which need further methodological study are the linkages between the natural-social-technical realms, as well as across spatial scales (e.g. households or communities) and time scales (e.g. days or years). In this presentation we propose a method called the Abstraction Hierarchy as a way to do just this, in order to frame complex catchment interactions on a large scale, in an accessible manner. We will demonstrate the Abstraction Hierarchy applied to an urban area and explore emerging properties of flood resilience.

JACOBS Engineering Group (Jon Wicks, Phil Faynor or Richard Crowder)

Modelling challenges for strategic assessments. The central ambition of the Humber2100+ project is to develop a strategy for managing tidal flood risk around the estuary that will best-support people, businesses and property and which enables sustainable development and delivers prosperity over the next 100 years. Critical to this ambition is the availability of extreme water levels around the estuary, under a range of extreme fluvial and tidal scenarios, and an understanding of how interventions could influence flood risk across the estuary both now and in the future.

A hydraulic model of the estuary and its tidal rivers was built to underpin the prediction of extreme water levels that will also be used as the basis for planning and development decision making for the foreseeable future around the estuary. The model was also used to test the strategic application of various flood risk management interventions, both spatially and temporally, the results of which have been used to collaboratively develop flood risk management interventions over the lifetime of the strategy.

Combining an estuary-wide model and a large number of scenarios with effective analysis of the results and accessibility and visualisation of model results was fundamental to developing a

shared appreciation of the mechanics of flooding across the estuary with partners and stakeholders and how a changing climate might interact with interventions to change flood risk. The presentation will provide background on the project objectives before focussing on the modelling requirements and how they are addressed, with an emphasis on the modelling challenges and where improvements in modelling methods, tools, processes and data could provide the greatest benefit for similar projects.
HR Wallingford (Darren Lumbroso) **Use of an agent-based model to improve emergency planning for floods.** Justification for evacuation and evacuation planning for floods and potential dam breaks is sometimes questioned. In many countries there is a need to develop approaches which justify the planning and associated expenditure with large scale evacuations and also in improving the resilience of communities to floods. Over the past 20 years a number of methods have been developed to estimate evacuation times and the risks to people posed by flood events. Many of these methods and models have been based on empirical methods based on limited experiments or historical events. This talk describes the use of an agent-based model known as the Life Safety Model (LSM). The LSM provides estimates of the number of people that are likely to be injured or killed as a result of a flood event, as well as the time that is required for them to evacuate the area at risk. It also allows the loss of life and evacuation times to be assessed for a range of types of flood events including slow rising floods, dam and flood defence failures, tsunamis and flash floods. The LSM has been piloted on a number of historical floods including the Mapasset Dam disaster that occurred in France in 1959 and the Great North Sea Flood of 1953 that inundated Canvey Island in the Thames Estuary resulting in the deaths of 58 people. It has recently been used to help to improve the emergency response of coastal communities in Canada to tsunamis and assist emergency planners in Lincolnshire in the UK.
University of Sussex (John Drury) **The social psychology of flooding.** The first half of this talk will explain the relevance of social psychology for understanding behaviour in the phases of a flooding incident, drawing on both the broad literature on disasters and specific research on flooding. Before a flooding incident, people do not always act upon information on risk. This is because perceptions of risk, and hence preparedness intentions, will vary with the salience of different group identities. Lack of compliance with instructions to leave one's home, which is sometimes characterized as irrational, is better understood as a function of nature of relationships (identification, trust) with the relevant authorities. During a flood, cooperation among affected members of the public is based on both social capital and emergent shared social identities arising from perceived common fate. The extent of responding to the authorities' advice on not entering floodwater is determined by the nature of relations with these authorities, which might in turn be affected by perceptions of who is to blame for failures in flood preparedness and response. After the flood, emergent disaster communities tend to decline at precisely the time that secondary stressors (such as dealing with insurance) are most acute and social support is most needed. In the second half of this paper, I describe a programme of research carried out with Public Health England which examined these dynamics of group identity and community resilience in the case of the York floods of 2015. Interviews and questionnaire surveys of affected residents examine experiences of the flood, activities (such as memorializations) to keep the disaster community alive, and predictors of mutual support.