Wetropolis World of flood investigations

from PDEs via ML and info-gap theory to serious games

Vision

“Wetropolis World of flood investigations” proposes to investigate five objectives, to advance: basic research on the gains and limitations of Machine Learning in flooding, basic research on the robustness of flood-mitigation measures and plans using info-gap theory, serious saleable outreach games including a Wetropolis board game and a robust flood demonstrator, and graphical decision-making tools including ones for Nature-Based Solutions. All objectives are matched by two bespoke international workshops and transcend from the Wetropolis flood investigator: a portable fluid-dynamical visualisation of return periods of extreme rainfall and weather events. These objectives surpass the original Wetropolis’ outreach creation requests by the UK Environmental agency and JBA Trust.

Objective-1: At the fifth anniversary of the Leeds Institute for Fluid Dynamics (LIFD) the Met Office Director Prof Stephen Belcher gave a wonderful seminar on Numerical Weather Prediction (NWP) and machine learning (ML). Prof Belcher emphasised the big debate in the Met Office on advantages and disadvantages of ML, relative to “classic” NWP based on partial differential equations (PDEs) and data assimilation, and the need for thorough analysis and intercomparison (Bauer et al. 2015, Bi et al. 2023). Wetropolis World is a laboratory realisation and (numerical) modelling environment in which a random weather machine generates localised rainfall in a conceptual, physical river catchment, with reduced “daily” times scales of 10s and spatial catchment scales of circa 1.5×1.5m^2 with a main river, a porous groundwater moor, reservoirs and a city. The weather machine generates extreme rainfall and flooding events with averaged time scales or return periods of circa 50 seconds, 5 and 30 minutes (e.g., google “Wetropolis YouTube” to watch a video of circa 3min). While this setup exists, measurements and prediction tools for Wetropolis do not. My *first objective* is to investigate this reduced (relative to NWP) physical and modelling Wetropolis World to study the pros and cons of classical (P)DEs and data assimilation based flood predictions with ones arising from ML. Novel herein is the research application to the unique Wetropolis setting with its reduced spatial and temporal scales. The reason to study Wetropolis is its accessibility, facilitating in-depth analysis in a controlled experiment.

Objective-2: The 2015 Boxing Day floods of the River Aire in Leeds triggered both the creation of Wetropolis and, in unison, a graphical cost-effectiveness tool for assessing flood-mitigation measures. That new tool was created to analyse Leeds City Council flood-mitigation plans to protect against floods like the 2015 Boxing Day ones. The tool was since used in practice by engineers in France and ecologists in Slovenia (Piton et al. 2018, REF Impact Case Study Bokhove et al. 2021/2022). It excels in creating a visual comparison of possible flood-mitigation scenarios for decision-makers. A difficult issue is the valuation of the flood-mitigation measures proposed and the valuation of co-benefits such as extra-climate change uptake, ecological and recreational benefits of Nature-Based Solutions (NBS) as well as anti-drought benefits. A recent analysis in a case study on flood mitigation for “High Beck”, an idealised study based on a local stream, furthermore revealed that a lack of data hampered value-based decision-making (Poortvliet et al. 2019, Knotters et al. 2024). Nonetheless, two scenarios with unequal basic costs could be compared and co-benefits be attributed by using the threshold for which the two scenarios attained equal costs. Such attribution of unknowns is part of info-gap theory, which can be used for decision-making under uncertainty and insufficient data by considering the robustness of options (Ben-Haim 2006, 2012, Marchau et al. 2019, Di Baldassarre et al 2016). My *second objective* is to investigate info-gap theory in order to improve the cost-effectiveness tool for existing catchment-scale flood-mitigation schemes, as well as small-scale local flood-mitigation schemes planned, such as in the High Beck case study. The aim is to put a firmer basis under practical decision-making in the precense of information gaps.

Objective-3: Wetropolis was created by me with designer Wout Zweers after requests from the UK Environment Agency (UK-EA), JBA Trust and Pennine Prospects (stakeholders in the late EPSRC’s Living with Environmental Change Network “Maths Foresees”, 2015-2018, led by me as principal investigator -PI) to design a portable fluid-dynamics demonstrator that visualises return periods of extreme rainfall and flooding events. Its aim was to let the public, and especially flood victims, view in three dimensions that extreme events with certain return periods occur at random times, rather than at more-or-less regular time intervals. The requests were to achieve such a visualisation in a three-dimensional, portable setup rather than via a computer simulation. Notably, Wetropolis' design was based on a statistical, mathematical and numerical design model, comprised of coupled PDEs, ordinary differential equations and diagnostic relations, which had to be developed beforehand in order to facilitate its construction (Bokhove et al. 2020b, 2024a). Such a design model supports the design and is, and can be, simpler than a predictive model. The resulting Wetropolis demonstrator was showcased to thousands of people at numerous multiday (amassing to 22 days) and other events. In addition, it has been a hit with flood professionals, who have emphasized that it should be used as scientific tool, as here proposed in Objective-1. Wetropolis has floods, super- and mega-floods associated with return periods of 50 seconds, 5 and 30 minutes, climate change and drought options. My *third objective* is to create educational tools inspired by Wetropolis, to extend its reach, including:

(a) a Wetropolis board game, inspired by the board game "Drain of Thrones" of the Friends of Bradford's Becks (FoBB);
(b) development and dissemination of a quarter-scale industrially robust version of Wetropolis for sales to academic departments, meteorological, hydraulic and climate centres globally; and,
(c) marketing thereof, while safeguarding educational and scientific values.

Objective-4: My CrossFit Gym flooded in the 2015 Boxing Day flood, that flood causing major floods and damage in the Yorkshire area with three main rivers reaching records levels. By using nowcasting based on incoming in-situ river gauge data and threshold flood levels, I initiated the evacuation of this CrossFit Gym just in time. We saved circa £20k in gym equipment. That personal data-gathering experience and Wetropolis led to the novel graphical cost-effectiveness analysis tool based on Leeds Flood Alleviation Plans II (LFASII). The graphical nature of this tool is aimed at concisely and quantitatively informing decision-makers of their options. It either forms a bridge between complicated engineering calculations (used as such in France) or replaces these when such computations cannot be undertaken (used as such in Slovenia). My *fourth objective* is to further develop and promote user-friendly decision-making tools on flood-mitigation measures, including on the new scientific results gained through info-gap theory and uncertainty quantification in the second objective. Finally, we aim to create a Research Advice Centre on Fluid Dynamics within LIFD for SMEs and flood victims, here focussed on flooding/sewage overflows.

Objective-5: The *fifth objective* is dissemination in two workshops: (i) "Classical and ML predictions in flooding research" (for Objectives-1/3) and (ii) "Decision-making under uncertainty and knowledge-gaps in extreme events" (for Objectives-2/4), e.g., for some of the beneficiaries identified next.

Beneficiaries and (inter)national importance

Objective-1: The debate about the relative merits of classical prediction methods and ML in NWP underscores how timely it is to investigate ML in environmental fluid dynamics. Since such investigations in NWP require a massive team effort, I propose to investigate "Numerical Wetropolis Prediction" (i.e. "NWP") within the miniature yet realistic fluid-dynamical world of Wetropolis. Classical and ML predictions will be investigated both in Wetropolis as laboratory experiment and as mathematical/numerical modelling environment. Such an investigation is feasible to be undertaken by a small team and can contribute to the debate about the pros and cons of classical and ML predictions in environmental fluid dynamics. Like NWP, Wetropolis World requires data assimilation and parameter estimation of measurements in order to keep model predictions faithful to reality. Wetropolis' spatial and temporal scales are reduced but computer prediction times on a laptop or small computer must likewise be reduced on the order of (a fraction of) Wetropolis' 10s day. A definite target is therefore to have experiment and predictions running side-by-side in order to assess all prediction capabilities as well as invoke flood control interventions based on these predictions, such as to minimise flooding in the conceptual city. Instead of atmospheric dynamics, "NWP" will involve river level, groundwater and surface water level, as well as acquifer and reservoir level, predictions in space and time. To wit, Wetropolis World is set up to provide knowledge and insights beneficial to the NWP and geophysical/environmental fluid dynamics research communities, as well as to the ML research community in general. JBA Trust and Jacobs will be involved at early stages in the programme concerning links to their projects in both the physics-informed ML and the decision-analysis strands. The novelty lies in the application and intercomparison of (existing) prediction methods within the unique Wetropolis setup, unique because of its (real-world) combined extreme rainfall and flooding events.

Objective-2: The graphical cost-effectiveness theory we have developed in Bokhove et al. (2019, 2020ac) relates the flood-excesss volume that caused the flood damage, and thus needing reduction to zero to prevent flood damage, to the accumulative effect of the various flood-mitigation measures involved and their costs. It was recently extended by including the combined risk and cost of a mitigation failure, as well as cost-reduction by inclusion of auxiliary benefits of a measure ("High/Haigh Beck" case study in Knotters et al. 2024). The latter benefits can for example be extra flood-plain storage to deal with adverse climate-change effects, ecological or recreational benefits. While in an academic setting one can assign values to these risks and benefits, in practice such assignments are difficult or impossible to establish, but nonetheless a justifiable and value-based decision needs to be taken. Given two flood-mitigation scenarios with different costs and extra benefits, say, one option is to assign a threshold value to the benefits such that the costs become equal (cf. my presentation at the European Geophysical Union 2024). That is an example pertaining to info-gap theory, a quantitative theory of robustness when there is a disparity between what is known and unknown (Ben-Gaim 2006, Di Baldassarre et al 2016). Info-gap theory has been applied in flood-risk management in order to deal with the robustness of the (analytical or numerical) hydraulic or water-level predictions (e.g., Hine and Hall 2010, Hall and Solomatine 2010). I propose info-gap theory to be applied and further developed in a quantitative manner to advance cost-effectiveness and flood-mitigation scenario analyses. Such novel work aims to have direct impact in the many practical situations wherein cost-information is lacking, as is in the Haigh Beck case study and in recent (2022-2024) Natural Flood Management (NFM: Lane 2017, Hankin et al. 2021, Beven et al. 2022) plans for the River Aire (as proposed by a public-private company, UK-EA 2022). While creating cost-effectivess analyses, we have on several occassions revealed inconsistencies or errors in proposed flood-mitigation plans. These inconsistencies have been reported, including to the UK-EA, in order to safeguard plans and to facilitate further optimisations (Morgan and Henrion 1990, Bokhove et al., 2020a; Bokhove et al. 2021/2022, personal communication with the UK-EA in 2024). Notably our work has revealed that NFM often fails to scale up and only covers a small fraction of the flood-excess volume to be mitigated (e.g., Knotters et al. 2024). Given the expected increase in extreme flooding events due to climate change effects (Sanderson 2010, Love et al. 2018, Slater et al. 2021), the proposed work on further quantification of flood-mitigation cost-effectiveness under uncertainty by using and further developing info-gap theory is therefore both timely and directly relevant to society (e.g., concerning flood professionals and the public).

Objective-3: While the existing Wetropolis setup has served its purpose as outreach visualisation of return periods of extreme environmental events, the proposed board game and quarter-size version aim to bring such visualisations to a larger audience. The goal of the Wetropolis board game and demonstrator is to enjoy playful mathematics, statistics and environmental education and raise risk awareness of extreme rainfall, flooding events and flood defense works. Its reach will be increased by making Wetropolis more interactive and by including more risk aspects surrounding flooding, such as flood control, risk of failure of flood defense works, and sewage release and pollution during extreme rainfall events. Notably, the high frequency of combined sewer overflows in UK surface and coastal waters has seen high media coverage. Prototypes of both board game and the reduced Wetropolis demonstrator will be developed primarily in this fellowship and promotion for sales will be explored in separation once suitable prototypes have been established.

The quarter-size version of Wetropolis will be made more robust than its current larger setup, e.g. the volatile Galton boards will be replaced. Various improvements will be explored and chosen upon validation of their robustness, such as computer-drawn Galton boards visualised via an LED-screen, also allowing adaptation to different weather statistics by the users, and reservoir control to explore mitigation by flood-water storage. The three rainfall locations —moor, reservoir and lake (the latter added when climate change is turned on)— can furthermore be permuted to let the user assess other spatial-temporal configurations. Extreme droughts can also be added by further adaptation of the weather statistics (and effectively visualised) as well as a display of the in-situ weather statistics. Codes developed in the first objective will be used for the redesign. Target customers will be adults at environmental and meteorological institutes, universities and colleges world-wide. It will also be explored whether a setup can be established for visitors older than 12 years at science museums. Wetropolis outreach is set up to visualise return periods and understanding of fractions is assumed. Rather than focussing on increased accessibility by specific underrepresented groups, I have simplified and clarified the complexity of the fractions involved in order to increase overall understanding of return periods within Wetropolis. There is presently no intention to promote Wetropolis at primary schools given that required minimum understanding of fractions. However, children below the age of 12 have enjoyed playing with Wetropolis, as expressed by a junior visitor (as part of systematically collected written feedback): "*I love Wetropolis*".

The Wetropolis board game will be explored in various ways with the best options to be pursued. Staying close to the Wetropolis demonstrator, two 16-faced dice throws can replace the Galton boards in the game. Upon a base river flow along the games' channel, blue chips can represent rainfall release from moor, reservoir and lake into the river, stacked in the vertical to mimic flood peaks that travel downstream to the city. Dice throws of other multi-faced dice will establish the risk of dam, reservoir or flood-wall failures as well as sewage release, the latter possibly represented by grey or brown water chips. The city floods when the travelling flood peak is too high. Flood control can be added by raising weirs at the moor, reservoir and lake, but that will increase their risk of failure. Either players play the game as a team in a team-experience effort, cf. the cooperative game "Robin Hood", with as goal to limit flood and pollution damage against the weather odds, or single players can be marked by coloured water chips, swept away by floods waves and players need to minimise being swept by flood or sewage waves into the city (say). Or, vice versa, other players can enhance flooding in order to wipe out their opponents. Game rules will be related to the statistics and fluid dynamics in a playful manner, added as optional information in a secondary layer of complexity. Target audiences are families and pupils at secondary education level. Again, playful understanding and experiencing of numbers and resulting fractions from the various multi-faced dices will become an integral part of this environmental game.

Objective-4: In Bokhove et al. (2020a), our graphical cost-effectiveness tool in essence summarised a flood-mitigation plan into a few graphs and accompanying text in order to make the plan more comprehensible to decision-makers. In passing, we revealed and investigated inconsistencies. Recently, (potential) errors and a lack of cost-effectiveness analysis have been revealed in a flood-mitigation plan proposed by a company (e.g., UK-EA 2022), which plan aims to provide 5% extra flood-protection by NFM in order to offset adverse flooding effects due to climate change. These errors emerged in setting up our graphical cost-effectiveness analysis. Promoted at a cost of circa £4M, i.e. £0.8M per percent of mitigation, the evidence provided revealed only 2% extra flood protection, i.e. yielding instead a cost of £2M per percent. Such scrutiny of the plans' efficacy matters since money spent cannot be spent otherwise, while increased severe rainfall and flooding events will require more flood-mitigation investments. This apparent mismatch in the claimed and evidenced efficacy as revealed by using our tool is under investigation by the UK-EA (2024 personal communication). I will keep in active contact with the UK-EA but given the independent scrutinising role of the UK-EA no explicit and formal collaboration with the UK-EA is sought here. Our graphical cost-effectiveness tool has more than once revealed the overrated efficacy of NFM, see also the discussion on overrating the efficacy of either grey or green infrastructure in Knotters et al. (2024), and claimed co-benefits of NFM should be quantified better (Bokhove 2021). Such improved quantification will be developed with info-gap theory. We have critiqued our tool. The tool is based on one-point measurements along a river, either obtained from a hydrograph or from simulations, thus being zero-dimensional in space. However, a suitable hydrograph in flooding conditions represents the river state along a stretch of river at the most critical location prone to flooding, making it one-dimensional in space. The tool can be extended by using ensemble forecasts with a series of hydrographs each one at critical locations along a sequence of river stretches. In some cases one only has one flood hydrograph (case study in Slovenia, see Piton et al. 2018) while in other cases one has extensive hydraulic (ensemble) flood simulations (case study in France, see Bokhove 2021). Our graphical tool has the proven power to reveal when flood-mitigation plans have anomalies, despite or perhaps due to its by-design-straightforward character in order to be comprehensible by decision-makers (Bokhove et al. 2020c). It picks up errors and inconsistencies where other scrutiny efforts appear to have missed these. I aim to explore why the tool has this power and how it can be included in tools and manuals used by flood practitioners in the field. Hence, the translation of the novel cost-effectiveness tools, including those based on info-gap theory, into graphical decision-support diagnostics is timely, necessary and aims to be *globally impactful*. In effect, "*Jacobs are investigating the merits and applicability of the [our] graphs to practitioners*" (quote from director of Jacobs) and I aim to collaborate with Jacobs whether and how our graphical tools can be incorporated into their Flood Modeller software. In tandem with that collaboration, I aim to discuss with the UK-EA whether and how (improved versions of) the tool can be included in their flooding manuals, again to facilitate access by more flood practitioners.

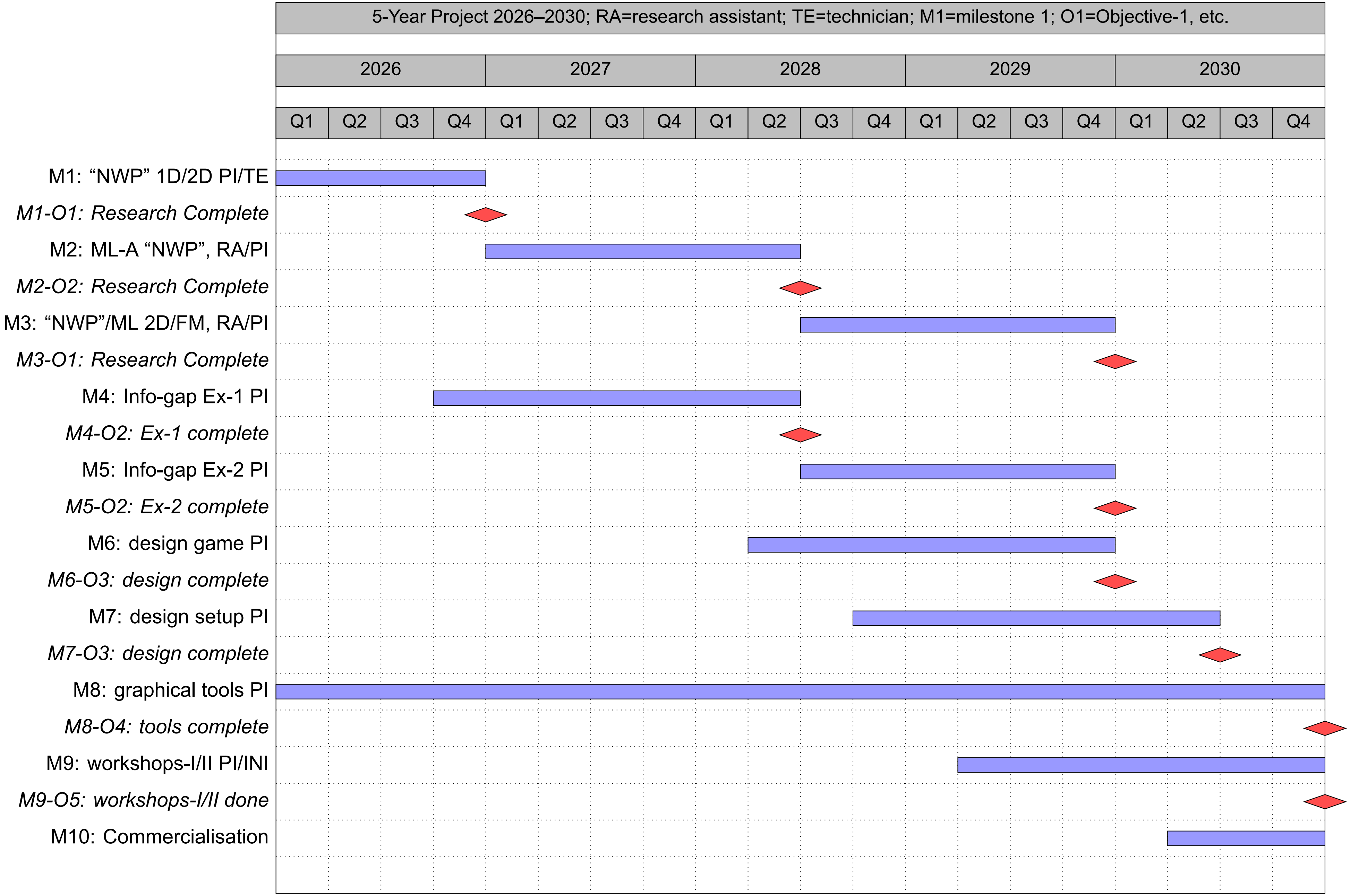
Approach

The *first objective*, to integrate and compare classical and ML prediction models for the Wetropolis' flood investigator, includes: mathematical and numerical modelling, laboratory experiments and data acquisition, flood-mitigation control as well as real-time operation. Data assimilation will be based on, e.g., our ensemble Kalman filter work (e.g., Kent 2016, Kent et al. 2022) applied here to river flow and parameter estimation. We have various simulation tools available such as Flood Modeller (via Jacobs) LISFLOOD (e.g., public DGFEM models of Dr Georges Kesserwani (Kesserwani et al. 2019, 2023)), Firedrake, as well as our own existing bespoke one-dimensional shallow-water and groundwater models of Wetropolis. These starting points make that interim goal *effective, appropriate* and *feasible*, with the modelling options spreading the *risk to delivery*.
Methodology: For the"NWP", just like in NWP, the methodology is to develop physics-informed ML models based on laboratory and classical numerical modelling data input. It is unlikely (or impossible) that extreme multiday extreme events in Wetropolis outside the data provided can be captured by ML without statistics/physics-informed ML. However, given these weather-machine inputs and hence the extreme rainfall events very fast (i.e., $\leq O(1\mathrm{s})$ ML predictions of the ensuing catchment fluid dynamics should be possible (e.g., Borrel-Jensen et al. 2021, Nazari et al. 2024). Subsequent comparisons between ML and "NWP" will be made as well as explorations of climate change-point dynamics, the effects of droughts, and flood control (e.g., Breckpot et al. 2013). An RA (research assistant) will focus for three years on ML for Wetropolis and a part-time technician will aid in the data-gathering support of Wetropolis. The Wetropolis setup will be enhanced and improved in the School of Mathematics fluid dynamics laboratory, a lab jointly co-managed with Dr Sam Pegler. The team herein consists of the technician, RA and PI, all embedded within Leeds' CDT Fluid Dynamics and LIFD. The above research *builds on past and current work*, as follows: (i) data-assimilation research and publications of two EPSRC and NERC Cases with the Met Office and Prof Steve Tobias; (ii) the EPSRC-fellowship project Data Assimilation for the Resilient City (DARE) of Prof Sarah Dance (Garcia-Pintado et al. 2015, Hooker et al. 2023); (iii) a current PhD project on data analysis and ML for a new volcanic-landslide tsunami-warning system (with Dr Arief Gusnanto); two finished MSc data-science projects on sewage and rainfall data with ML-predictions (with Prof Barney Lerner from FoBB and the Aire Rivers Trust); (iv) surrogate reduced-order modelling in a current PhD project on our novel wave-energy device in Leeds' CDT Fluid Dynamics (with Prof Harvey Thompson); and (v) a new PhD project on ML, river flooding and flood mitigation for the River Citarum, Indonesia (2025).

The *second objective*, to focus on uncertainty quantification and dissemination for enhanced decision-making in flood mitigation, will integrate cost-effectiveness tools, multi-attribute utility functions and info-gap theory. This work will be undertaken mainly by the PI, augmented by third-year and fourth-year Master-Math students projects thereon. It will *build on* the graphical cost-effectiveness tool developed by the PI in a team effort (e.g., Bokhove et al. 2024a), and research on "monsters of uncertainty in flood-risk management" (Knotters et al. 2024). Analysis of actual flood-mitigation plans from Bradford and Leeds city councils revealed a lack of information and lack of transparency on a lot of basic costs and risks of failure. The consequence is that transparent and informed decision-making becomes difficult or impossible. Our graphical cost-effectiveness tool has the proven ability to reveal inconsistencies, lack of information and (possible) errors in flood-mitigation plans (Bokhove et al. 2019, 2020a, personal communication UK-EA in 2024). The reasons for this lack of transparency and public information seem to be manifold: FOIs are simply dismissed because scrutiny is undesired; the organisations may not have the personnel, know-how, money and/or time to provide the information; or, the data may simply not have been gathered or exist. The preliminary High Beck case study shows that info-gap theory with its base in robustness (Ben-Haim 2006, 2012, Marchau et al. 2019) can quantify for which values of uncertain information a certain scenario outperforms others. Herein, the choice of reward or utility function provides the norm to quantify performance. Info-gap theory has been applied in various areas including in *previous work* on flood mitigation (notably in the UK by Hine and Hall 2010, Hall and Solomatine 2010), regarding hydrodynamic uncertainty (such as discharge modelling) in hydrodynamical predictions of flood-mitigation scenarios. In contrast and driven by the above identified and observed information gaps, info-gap theory is proposed here to be applied on the uncertainty in costs, failure risks and co-benefits of flood-mitigation measures (such as in NFM and NBS). Depending on the reward function chosen, these uncertainties can be combined. That is a logical, *effective, appropriate and feasible* research route. I aim to assess info-gap theory in (a) a hindcast of an implemented flood-mitigation plan and (b) in a future flood-mitigation plan. Both implemented and future plans will be chosen in correspondence with the UK-EA, JBA Trust and Jacobs. As risk mitigation to delivery, two such plans may be partially hypothesised in order to facilitate such an analysis, such as in the High Beck case study in Knotters et al. (2024). Simplified graphical summaries of this new info-gap analysis will be developed and used as part of the fourth objective (Van der Sluijs 2005, Defra 2018, Poortvliet et al. 2019, Van der Bles et al. 2019, Perosa et al. 2021). Embedding within Jacobs' Flood-Modeller software, JBA's desired template case and into UK-EA manuals will be promoted where possible (pertaining to *impact facilitation*). To further *translate outputs and outcomes* associated with this objective, a bespoke workshop will be organised.

The *third objective* is to create more reach for Wetropolis innovative way of visualising return periods and understanding aspects of flooding by the creation and promotion of both a bespoke board game and a reduced, robust version of the Wetropolis demonstrator. Board games and bespoke setups as *engagement mediums* aim to have a much larger target audiences than the current Wetropolis setup. Intended audiences are families and groups interested in flooding age 12 years or older as well as environmental institutes, universities and colleges, respectively. This creation and promotion route aims to ensure *effectiveness and appropriateness*. The foreseen board game will include Wetropolis' creative and innovative weather or rain machine as key novelty via multi-faced dice. In the game, discrete weather patterns and (other) risks will be generated and released instead by dice throws representing daily risks and probabilities. Various game plans will be investigated and trial versions tested, as inspired by the Wetropolis setup. Investigations will be undertaken by the PI, via students projects and interactions with PhD students in the CDT Fluid Dynamics, who already assisted in showcasing Wetropolis in the past. Trial versions will be *tested and evaluated* at game workshops and conferences, within the School of Mathematics, with the stakeholders, via the FoBB given the experience with their board game, alongside Wetropolis showcasings, during outreach events of the CDT Fluid Dynamics, and within LIFD, pertaining to the breadth of our *research environment and the support therein*. After evaluating these trials, iterative improvements will be realised. In addition, I will seek collaborations on both the board game and reduced Wetropolis setup with the British Science Museum and Maths-City (2024). I have begun discussions with people from both museums, given contacts from FoBB and LIFD. Once suitable prototype designs have been established and built, promotion and commercialisation will be explored, in separation from the financial support in this proposal. The variety of groups involved and their different roles demonstrate the *access I have to services, advice, trial groups* and as such the *spreading and limiting of risks* involved.

Finally, the EPSRC Open Plus Fellowship Wetropolis World would allow me to bring together multiple strands that I have developed during my research career, enveloping 28 years of research on computational fluid dynamics and data assimilation in environmental and geophysical fluid dynamics, 15 years of delivering outreach demonstration experiments on fluid dynamics –ranging from a slice-of-beach (Thornton et al. 2014), the steel soliton splash artwork (Bokhove et al. 2019), a coastal wave tank to Wetropolis (Bokhove et al. 2020b)– and 8 years of creating graphical cost-effectiveness tools that dissect and translate real-world flood-mitigation plans for and to decision-makers.


5-Year Project 2026–2030; RA=research assistant; TE=technician; M1=milestone 1; O1=Objective-1, etc.
2026
2027
2028
2029
2030
Q1
Q2
Q3
Q4
M1: “NWP” 1D/2D PI/TE
M1-O1: Research Complete
M2: ML-A “NWP”, RA/PI
M2-O2: Research Complete
M3: “NWP”/ML 2D/FM, RA/PI
M3-O1: Research Complete
M4: Info-gap Ex-1 PI
M4-O2: Ex-1 complete
M5: Info-gap Ex-2 PI
M5-O2: Ex-2 complete
M6: design game PI
M6-O3: design complete
M7: design setup PI
M7-O3: design complete
M8: graphical tools PI
M8-O4: tools complete
M9: workshops-I/II PI/INI
M9-O5: workshops-I/II done
M10: Commercialisation