Interactive comment on “HESS Opinions “Classification of hydrological models for flood management”” by E. J. Plate

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The paper by Prof. Eric Plate is an interesting paper which aims at providing an engineering oriented view to the hydrological rainfall-runoff models to be used in flood risk assessment and reduction both in the planning and in the operational phases of flood risk management.
After a presentation of what is required to reach successful planning and operation, the paper concentrates on rainfall-runoff models, which are divided in models for planning and models for management.
Although, the scope of the paper is highly relevant and important to provide the right perspective on the use of hydrological models when dealing with flood risk, I must admit that the discussion only touches the surface of several problems. There is in fact a number of issues that the author might consider deepening.

The first issue relates to the introduction of the concept of the “holistic approach” to flood risk management, which was introduced after the great August 1993 Mississippi flood. This concept was further elaborated within the frame of several EU funded projects, such as RIBAMOD (http://www.hrwallingford.co.uk/projects/RIBAMOD/), ACTIF (http://www.actif-ec.net/), FLOOD-Site (http://www.floodsite.net/), etc.
For instance, Figure 1 refers to the planning phase and Figure 2 refers to the operation phase.

Figure 1. The Planning Phase of the Holistic Flood Management Approach

Figure 2. The Operation Phase of the Holistic Flood Management Approach

It would be of great value to discuss this approach, which is today taken as a rule, as opposed to the use of the “sustainable flood management” approach described in Figure 3:

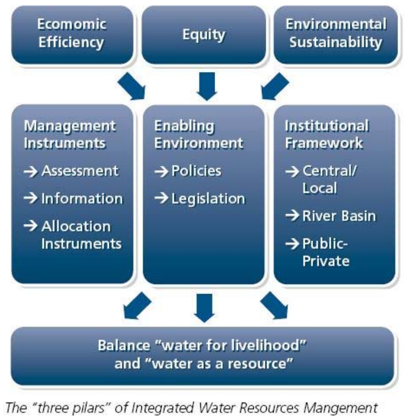

Figure 3. The Integrated Water Resources Management.

also commonly referenced as Integrated Water Resources Management (IWRM), as advocated by Green (2004), which broadens the holistic flood risk management not just to include a wide variety of non-structural interventions, such as for instance restoration of wetlands, re-forestation, dry land-farming, but to radically change:

- How we think about floods
- How we make choices as what to do
- What options we seek to adopt
- How we implement these options

I am saying this because, conditional to the taken approach, the needs for hydrological models may greatly vary.

A second point to be clarified and expanded is the one relevant to the quoted "Water Resources Directive of the European Union (WRDEU)". In the paper it is not clear if the author wishes to refer to the "Water Framework Directive (WFD) – 2000/60/EC" or to the more recent "Flood Directive (FD) -2007/60/EC)".

As a matter of fact, although advocating that water management should be carried out at the whole basin scale (as mentioned by the author in the present paper), the WFD was mainly focused on the sustainable management of water resources, while floods were only considered as "*temporary deterioration in the status of bodies of water*" as well as "*circumstances of natural cause or forcemajeure which are exceptional or could not reasonably have been foreseen* " that allow for "*exemptions*" and that "*shall not be in breach of the requirements of this Directive*".

Therefore, since the WFD did not include explicit flood risk management aspects, the European Commission has recently proposed a Directive on the assessment and management of floods. Its aim is

> *…" to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community"* (2007/60/EC, Article 2).

The central characteristics of this Directive are, first of all, a transboundary approach and secondly flood management on a river basin scale and thirdly an integration of other developments in the catchment in relation to flood risk and its assessment with regard to the potentials of reduction. But the main point is that the FD has to be seen in close connection with the WFD.

A three-stage process is proposed in the FD:

1. preliminary flood risk assessment
2. the development of flood hazard maps and flood risk maps and finally
3. flood risk management plans which should include inter alia protection measures such as restoring flood plains and wetlands.

which more or less corresponds to the planning phase described in this paper.

I think that the paper would greatly benefit of a small discussion on both the WFD and the FD over the planning phase and their potential requirements in terms of the hydrological models to be used.

A third point to be discussed is the one relevant to the different types of models. I think that the paper should not limit the discussion between the use of continuous time models versus event based ones. The discussion should be expanded to lumped or semi-distributed models vs the distributed ones and between the use of physically meaningful models vs the data driven.
This is because several aspects may be clarified such as why operational forecasting centers prefer to use physically meaningful models instead of the simpler, and operationally more efficient data drive models. This is only partly due to the difficulty of verification of the data driven models beyond the measurement ranges. The problem is that the physically oriented models may more easily be modified (also in real time) to study management alternatives: this is hardly possible with the data driven models, which would require new calibrations. With respect to the different types of models, I also believe that the author should quote the paper by Singh and Woolhiser (2000), which is an excellent compendium of the presently available watershed models. Finally the author should mention the problem of extending the models to ungauged catchments and the discussion on scales (point, micro, meso, macro) should lead to the question of how point equations (typically used to study the physics problems at the infinitesimal scale) may or must be modified when applied to finite scales of increasing size to account for the effect of space and time lumping.

The fourth point relates to the question of assessing planning and prediction errors. This problem is generally known as the “predictive uncertainty” estimation problem, which is not necessarily limited to drawing quantile bands around a prediction, but it requires determining the entire probability density of what may occur conditional to our best available knowledge, which is generally encapsulated either in a model “prediction” (when the predicted value is at a time $t \le t_0$, with t_0 the present time) typical of a planning phase, or in a model “forecast” (when the forecasted value is required at a time $t > t_0$) as in real time flood forecasting.
In the planning phase it is necessary to determine the predictive density in order to balance costs with the expected value of uncertain outcomes such as reduced damages. For instance one would raise the level of a dyke until this cost (a deterministic quantity once we decide to spend it) would exceed the “expected value” (a deterministic quantity) of the reduction of flooding costs (which are inherently random as a function of the possible flood that may occur).
In the operational phase, following the decision theory (Raiffa and Schlaifer, 1961; De Groot, 1970) , a similar comparison must be made using the forecasting uncertainty either to estimate the probability of overtopping a warning or a flooding threshold or by finding a compromise between the deterministic cost of activating an emergency plan and the expected value of a Bayesian utility function which expresses the flood manager risk aversion (Todini, 2009).
Although I do not expect the author to analyze the problem of predictive uncertainty in detail or to discuss the complex problem of linking hydrological models to meteorological quantitative precipitation forecasts (not to mention ensemble forecasts), I think that a certain discussion of this theme is necessary to understand which types of watershed models may be needed and how they can be used both for planning and operationally manage floods, also in consideration of the problem of real time data assimilation and updating.

Finally, I find the sequence of the paper sections not fully structured to best deliver the message.
Therefore, in order to enhance the possibility of dissemination of the concepts included in the paper I would like to suggest the author to convert the original sections, which I have here reported:

Classification of Hydrological Models for Flood Management
0) Abstract
1) Hydrological tasks for flood risk management
    1.1) Flood protection and risk management
    1.2) Models for operation vs. models for planning
    1.3) Forecast and prediction

2) Rainfall-runoff models for flood management
    2.1) Components of RR-models
    2.2) Types of rainfall-runoff models for flood calculations
    2.3) RR-modeling in different landscapes
    2.4) Hydrological scales and their significance in flood calculations
        2.4.1) Point scale
        2.4.2) Micro-scale
        2.4.3) Meso-scale
        2.4.4) Macro-scale
3) Comparison of flood models for planning and forecasting
    3.1) Advantages and disadvantages of flood models for planning
    3.2) Advantages and disadvantages of forecast models
4) Conclusions
5) References

into the following ones:

Hydrological Models for Flood Risk Management

0) Abstract
1) Hydrological tasks for flood risk management
    1.1) The flood risk management cycle
    1.2) The planning and preparedness phase
        1.2.1) Development of flood risk maps
        1.2.2) Definition of the most appropriate risk reduction and alleviation strategies
        1.2.3) Design and implementation of structural and non-structural measures also including:
            1.2.3.1) Design and implementation of the real time data acquisition system
            1.2.3.2) Design and implementation of the real time flood forecasting system
            1.2.3.3) Design and implementation of the forecasting dissemination system
        1.2.4) Assessment of the effectiveness of the chosen strategy(ies)
        1.2.5) Models required for the planning phase
            1.2.5.1) Statistical (extremes)
            1.2.5.2) Hydrological (RR)
            1.2.5.3) Hydraulic routing (1-D)
            1.2.5.4) Hydraulic inundation (1D-2D)
        1.2.6) Assessment of modeling errors (epistemic, input measurement, etc.)
    1.3) The operation and emergency management phase
        1.3.1) Implementation of the established risk reduction and alleviation strategies
        1.3.2) Operational use of the flood forecasting systems
        1.3.3) Models required for the planning phase
            1.3.3.1) Meteorological (LAMs)
            1.3.3.2) Hydrological (RR)
            1.3.3.3) Hydraulic routing (1-D)
        1.3.4) Assessment of predictive uncertainty
        1.3.5) Assessment of operational effectiveness of the flood forecasting chain.
2) Hydrological rainfall-runoff models
    2.1) Components of the rainfall-runoff models
    2.2) Types of rainfall-runoff models
        2.2.1) Physically meaningful vs data driven
        2.2.2) Continuous time vs event based
        2.2.3) Lumped or semi-distributed vs distributed
    2.3) Rainfall runoff modeling in different landscapes
    2.4) Hydrological scales and their significance in flood calculations
        2.4.1) Point scale
        2.4.2) Micro-scale
        2.4.3) Meso-scale
        2.4.4) Macro-scale
3) Rainfall-runoff models for the planning and for the operational phase
    3.1) Planning requirements for rainfall runoff models and choice of the appropriate ones
        3.1.1) Descriptive of the design flood
        3.1.2) Extendable to ungauged catchments
        3.1.3) Capable of assessing environmental impacts
        3.1.4) etc.
    3.2) Operational requirements for rainfall runoff models and choice of the appropriate ones
        3.2.1) Timeliness
        3.2.2) Possibility of integration in the flood forecasting chain
        3.2.3) Data assimilation and updating capabilities
        3.2.4) Capacity of evaluating predictive uncertainty
        3.2.5) etc.
4) Conclusions
5) References

Please note, that this is only a suggested guideline (definitely over detailed) aimed at supporting the author to present the original content of the paper in a more appealing way. Please also note the slight modification proposed for the title.

References

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