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Modeller subjectivity and calibration impacts on hydrological model applications: An event-based comparison for a road-adjacent catchment in south-east Norway

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HIGHLIGHTS

- We compared 4 hydrological models regarding their capabilities to predict peak flow.
- The efficiency of models can vary based on the hydroclimatic conditions.
- Modeller subjectivity plays an important role in model performance.
- Models used in designing road must represent seasonal hydrological behaviour.
- Model calibration is a complicated process that is sensitive to modeller subjectivity.

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ABSTRACT

Identifying a 'best' performing hydrologic model in a practical sense is difficult due to the potential influences of modeller subjectivity on, for example, calibration procedure and parameter selection. This is especially true for model applications at the event scale where the prevailing catchment conditions can have a strong impact on apparent model performance and suitability. In this study, two lumped models (CoupModel and HBV) and two physically-based distributed models (LISEM and MIKE SHE) were applied to a small catchment upstream of a road in south-eastern Norway. All models were calibrated to a single event representing typical winter conditions in the region and then applied to various other winter events to investigate the potential impact of calibration period and methodology on model performance. Peak flow and event-based hydrographs were simulated differently by all models leading to differences in apparent model performance under this application. In this case-study, the lumped models appeared to be better suited for hydrological events that differed from the calibration event (i.e., events when runoff was generated from rain on non-frozen soils rather than from rain and snowmelt on frozen soil) while the more physical-based approaches appeared better suited during snowmelt and frozen soil conditions more consistent with the event-specific calibration. This was due to the combination of variations in subsurface conditions over the eight events considered, the subsequent ability of the models to represent the impact of the conditions (particularly when subsurface conditions varied greatly from the calibration event), and the different approaches adopted to calibrate the models. These results indicate that hydrologic models may not only need to be selected on a case-by-case basis but also have their performance evaluated on an application-by-application basis since how a model is applied can be equally important as inherent model structure.

1. Introduction

Hydrological models are useful tools for investigating how rainfall transforms into runoff. This is particularity useful when hydrological models are considered for practical applications, such as in designing hydraulic structures associated with roads. Very often, however, the

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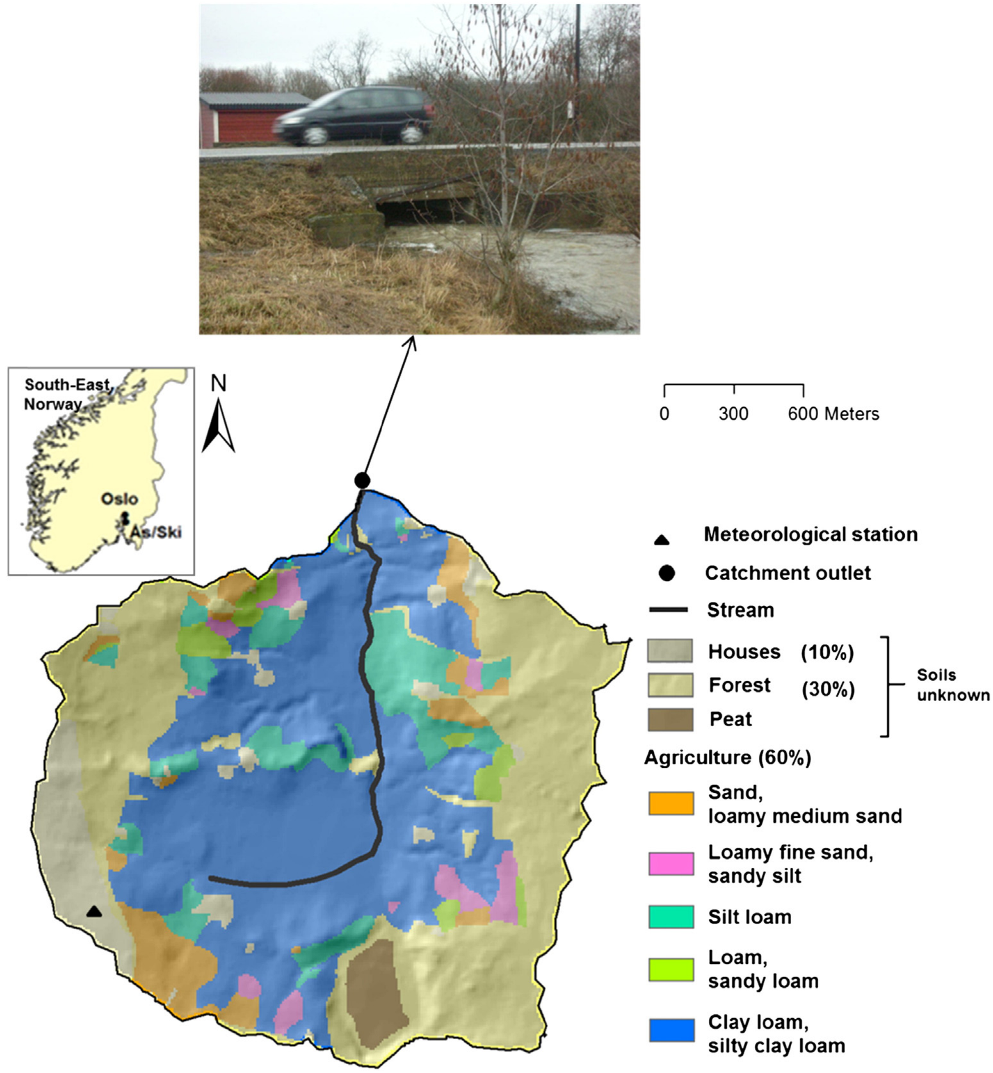

Fig. 1. Land use and main soil types of the Skuterud catchment with a photo of the outlet.

methods used for designing roads do not utilise state-of-the-science hydrological models. To date in Sweden for example, road drainage structures e.g. culverts and bridges in rural areas have typically been dimensioned for flows with a return period of 50 years adjusted to a changing climate by a simple static correction factor (Vägverket, 2008). However, these 50-year flows are calculated using the rational method which represents one of the oldest and simplest methods in hydrological engineering applications (Benzvi, 1989; Maidment, 1993). This method, based on statistical methods for estimating rain intensity curves and constant runoff coefficients, is in fact still quite popular world-wide owning to its simplicity. The rational method does not, however, have predictive capabilities to represent changes in climate conditions and land use coverages making it of little value in considering future impacts on road systems. This raises questions with regard to this simple method's utility as one of the main anticipated effects of climatic change is increased frequency of extreme weather events in various parts of the world (Green Paper EU, 2007; Schneider et al., 2007).

The current generation of hydrological models can potentially provide a better understanding of how weather events influence catchment-scale hydrology and peak flows (Jin et al., 2010) helping to improve road maintenance strategies and future road development (particularly in response to climate change). Independent of the modelling approach, the relative importance (or sensitivity) of a model's various parameters depend on the dominant hydrological conditions and processes in the region being modelled. For example, in cold regions the model parameters pertaining to soil freezing and thawing are important since infiltration rate can change due to changes in soil hydraulic conductivity, pore-size distribution in soil, and soil structure in frozen and partially frozen soil (Hillel, 1998). As such, the sequencing of frozen and non-frozen soil conditions, which determines the rate of water infiltration into soils (Hayashi et al., 2003), strongly influences the calibration and applicability of hydrological models in these regions.

Indeed, road design (and many other practical applications) could clearly benefit from using the current generation of hydrological models that have the possibility to include dynamic influences of (and potential future changes to) land use and climate when estimating peak flow. Care needs to be taken by the modeller, however, in exercising the subjectivity associated with not only selecting an appropriate model (i.e. one capable of representing the relevant processes), but also selecting the period/methodology considered for calibration as the latter potentially could have a large influence on the 'best' parameter set or the apparent model performance. For rainfall–runoff modelling of catchments, a wide variety of hydrological models are now available for implementation in road planning and construction. Numerous studies have compared the performance of hydrological models (Breuer et al., 2009; Clark et al., 2008; Deelstra et al., 2010a,2010b; Gurtz et al., 2003; Hollander et al., 2009; Loague and Vander Kwaak, 2002; Plesca et al., 2012; Reed et al., 2004; Refsgaard and Knudsen, 1996). Due to