26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Uncertainty assessment in water quality modelling: towards fulsome practices

Tony Jakeman [a], **Xifu Sun** [b], **Barry Croke** [a], **Min Chen** [b]

[a] *Australian National University, Canberra, 0200, Australia*
[b] *Nanjing Normal University, Nanjing, China*
Email: tony.jakeman@anu.edu.au

Abstract: Water quality modelling (WQM) is pervaded by socio-technical uncertainties as it involves decisions around many choices in the modelling process. It has substantial technical challenges, even greater than those of quantity modelling, due to increased process complexity and typical insufficiency of informative constituent observations. Uncertainty assessment (UA) of assurance in the WQM exercise, and not just its output quantities of interest as occurs with 'uncertainty analysis', is therefore essential, be it for testing understanding and hypotheses inherent in model representations, appreciating the reliability of model predictions, and/or supporting evidence-based decision making.

We appraise the state of the art of UA literature and practices on the topic of uncertainty in water quality modelling by examining papers in 15 major relevant journals over the past decade. Only 15% of all papers on WQM in that literature mention the words uncertain or uncertainty, and of those just over half (225 papers) develop or apply any methods of UA, reinforcing the perception that UA is far from common practice. Those remaining papers still constitute a rewarding literature to be considered and an opportunity to identify improvements in the perception and practice of UA.

We begin with a listing of five different types of sources of uncertainty that should be considered in a modelling exercise and indicate to what extent the WQM literature has embraced them. We then examine the perceptions of the three main, traditionally-accepted, technical sources of uncertainty (data, parametric and structural) in WQM and the various methods used to address each of the sources, such as error modelling, probabilistic approaches, Bayesian methods and variants, ensemble techniques, and machine learning approaches. Assessment, however, is somewhat piecemeal in that not all major sources of uncertainty, both traditional and non-traditional, are respected and addressed in WQM exercises.

We also focus on how practices in WQM might progress to a more complete treatment of uncertainty including its social aspects in regard to choices made in the modelling process and with whom, more comparison of scale choices, increased exploiting of cross-validation and model residual analysis, scenario analysis especially for epistemic uncertainties, and contextual attention to communication and visualization strategies. We call for methods that promote computational efficiencies, such as machine learning and surrogate modelling in particular, adaptive sampling and convergence analysis of uncertainty outputs, to assist in covering the whole probability and plausible scenario space. We also see the need for standardized frameworks for documentation to improve uncertainty management and support evidence-based water quality decisions.

Keywords: *Uncertainty assessment, water quality, good modelling practice, uncertainty sources*

