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Combining dynamic and conceptual models for managing water quality in reservoirs: Guidance from three case studies

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Abstract: Dynamic biogeochemical and ecosystem models are important tools for managing water quality in reservoirs, however, they are computationally expensive, especially when spatially distributed; require significant model development time; may not represent water quality parameters of interest for a reservoir management problem; and may not provide interfaces designed for specific water quality challenges. In contrast, surrogate and conceptual models are faster to develop, apply and execute, and are more readily contained within dashboards designed for management decisions. Despite these benefits, the calibration of conceptual models under data paucity is a challenge, and they may be less reliable when extrapolating beyond observed conditions. Consequently, the combined use of dynamic and conceptual models is valuable. This presentation surveys the following three applications where dynamic and conceptual models have been combined, providing guidance for future endeavours.

Water quality risk from recreational activities at reservoir sites. Establishing recreation at reservoir reserves to provide community access to green, open space must be balanced with the provision of safe, clean drinking water. To quantify this fundamental criteria, three-dimensional hydro*dynamic* ecosystem models are often used to characterise the fate and transport characteristics for both pathogens and viruses under a range of climatic and inflow conditions. Requiring days for model runs precludes their use in workshops, creating a barrier for dialogue between scientists and decision makers. To address this barrier, this application used the linear, first-order differential equation governing pathogen and virus dynamics as a basis for a surrogate model containing a database of hydrodynamic model results that were coupled with a quantitative microbial risk assessments and presented in a dashboard. This enabled the testing of a multitude of recreational access scenarios in real-time during workshop sessions by decision makers and scientists, to explore how visitor numbers, activities, compliance rates and other variables known to influence water quality risk would pose water quality risks.

Water quality responses from reservoir management strategies. Cyanobacterial growth may produce compounds, such as geosmin, that negatively impact water quality and aesthetics. The concentrations of these metabolites are usually characterised in drinking water reservoirs from historical data. However, modelling approaches are needed when changes in reservoir management imply historical concentrations of cyanobacteria are expected to change. Tight project deadlines and the absence of models that simulate geosmin precluded hydro*dynamic* model development. Therefore, three independent surrogate models of cyanobacteria abundance and geosmin concentration were developed based on statistical relationships within analogue systems and process-based formulations, providing confidence in predictions and recognition of uncertainties.

Protecting fish health during dewatering operations. Lowering the water level of reservoirs results in fish populations existing in smaller volumes of water. While fish consumption is a small component of the overall dissolved oxygen budget, and therefore are not typically part of reservoir eco*dynamic* models, it becomes a significant component when dewatering, when oxygen levels in the water can decrease to a point where fish survival becomes tenuous. A conceptual model was developed of dissolved oxygen and fish health, based on Streeter Phelps dynamics and the partitioning of sediment, pelagic and fish oxygen demand. The conceptual model was cross-validated with hydro*dynamic* modelling and field data, with the combined model providing an improved basis for fish management decisions.

These applications demonstrate how simple surrogate models, developed using agile-approaches, support dialogue between scientists and decision makers. Further, due to the complexities of lake ecosystem dynamics, these simple models have required more investment in model formulation than anticipated, highlighting: the continued need for fast-running 1D lake hydrodynamic models that can easily be extended or adapted for specific lake management problems; and the value of more complex ecodynamic models for validation.

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