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Reverse Flood Routing with the Lag-and-Route Storage Model

K. Mazi and A.D. Koussis

National Observatory of Athens, Institute for Environmental Research & Sustainable Development, Palea Penteli, Athens, Greece (akoussis@meteo.noa.gr)

This work presents a method for reverse routing of flood waves in open channels, which is an inverse problem of the signal identification type. Inflow determination from outflow measurements is useful in hydrologic forensics and in optimal reservoir control, but has been seldom studied. Such problems are ill posed and their solution is sensitive to small perturbations present in the data, or to any related uncertainty. Therefore the major difficulty in solving this inverse problem consists in controlling the amplification of errors that inevitably befall flow measurements, from which the inflow signal is to be determined.

The lag-and-route model offers a convenient framework for reverse routing, because not only is formal deconvolution not required, but also reverse routing is through a single linear reservoir. In addition, this inversion degenerates to calculating the intermediate inflow (prior to the lag step) simply as the sum of the outflow and of its time derivative multiplied by the reservoir's time constant. The remaining time shifting (lag) of the intermediate, reversed flow presents no complications, as pure translation causes no error amplification. Note that reverse routing with the inverted Muskingum scheme (Koussis et al., submitted to the 12th Plinius Conference) fails when that scheme is specialised to the Kalinin-Miljukov model (linear reservoirs in series).

The principal functioning of the reverse routing procedure was verified first with perfect field data (outflow hydrograph generated by forward routing of a known inflow hydrograph). The field data were then seeded with random error. To smooth the oscillations caused by the imperfect (measured) outflow data, we applied a multipoint Savitzky-Golay low-pass filter. The combination of reverse routing and filtering achieved an effective recovery of the inflow signal extremely efficiently. Specifically, we compared the reverse routing results of the inverted lag-and-route model and of the inverted Kalinin-Miljukov model. The latter applies the lag-and-route model's single-reservoir inversion scheme sequentially to its cascade of linear reservoirs, the number of which is related to the stream's hydromorphology. For this purpose, we used the example of Bruen & Dooge (2007), who back-routed flow hydrographs in a 100-km long prismatic channel using a scheme for the reverse solution of the St. Venant equations of flood wave motion. The lag-and-route reverse routing model recovered the inflow hydrograph with comparable accuracy to that of the multi-reservoir, inverted Kalinin-Miljukov model, both performing as well as the box-scheme for reverse routing with the St. Venant equations.

In conclusion, the success in the regaining of the inflow signal by the devised single-reservoir reverse routing procedure, with multipoint low-pass filtering, can be attributed to its simple computational structure that endows it with remarkable robustness and exceptional efficiency.