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New developments on integrated watershed modeling

A. Papanicolaou (1)

1. IIHR-Hydroscience& Engineering, The University of Iowa, USA

(apapanic@engineering.uiowa.edu)

Watershed related processes are non-linear in nature due to complex interactions in pedology, geology, biology and hydrology and remain all-together a challenging problem with several societal implications. Some of the perplex questions associated to watershed processes include: (1) the effects of scale in monitoring and modeling; (2) the integration of all phases (i.e., surface and subsurface) in monitoring and modeling; (3) the effects of land-use on geomorphic changes in aquatic environments; (4) the cause and effect relation in the biotic and abiotic constituents of a watershed; and (5) the development of economic and environmental indicators for alternative scenarios and modeling assessment purposes.

Recognizing the critical need for developing an integrated and scientifically sound framework in watershed research, interdisciplinary groups began to emerge that expanded beyond traditional discipline -boundaries and reached out to other areas of expertise. For example:

-in the area of computational hydraulics efforts were undertaken to couple 3-D hydrodynamic models with Large Scale Gridded River Networks (e.g., Olivera and Raina, 2003).

-in the area of upland erosion efforts were undertaken to incorporate upland erosion processes-based models with GIS tools (e.g., Flanagan et al. 2004).

-in the area of eco-hydraulics new metrics were developed for quantifying the effects of natural and anthropogenic impacts on habitat (e.g., Papanicolaou et al. 2003).

-in the area of hydroinformatics pilot decision making systems were developed for real-time control of urban drainage systems (e.g., Abbott 1994; Goodwin 2000).

-in the area of watershed management environmental and modeling system were constructed for performing watershed assessments (e.g., Gassman et al. 2002).

-in the area of watershed modeling optimization algorithms for parameter estimation were deduced (e.g., Gupta et al. 2003)

At the governmental level, this integrative research was triggered by the NSF with programs such as the "biocomplexity in the environment" that promoted collaborative research for biological processes in aquatic environments; the IGERT program that fostered interdisciplinary graduate research and teaching in all disciplines including water resources; and the Information technology research (ITR) program focused on the creation of distributed grids and computer infrastructure for different disciplines. The watershed research program that was initiated by the US EPA and supported by the NSF and USDA constitutes the most known orchestrated effort in the United States, so far, for advancing understanding of natural phenomena and processes within a watershed (Diplas, 2002).

Although the above efforts have succeeded in promoting multidisciplinary interactions and prepared the grounds for future improvements in the simulation of complex processes such as watershed processes, a new paradigm shift that enables dynamic simulation of these processes is necessary. The novel capabilities to be sought here are application simulations that can dynamically accept and respond to on-line field data and measurements and/or control such measurements. This synergistic and symbiotic feedback control-loop between simulations and measurements is a novel technical direction that can open domains in the capabilities of simulations within watersheds that can facilitate the "capturing" of episodic catastrophic events.

Many watershed simulations today work in the batch world: an event is simulated based on a static set of field data. If newer data become available, the simulation is simply rerun. For example, hydrodynamic and sediment transport simulations to predict geomorphologic changes within a stream and the impact of these changes to the aquatic life are conducted by considering a constant sediment input value from terrestrial sources such as roads, floodplains, and other natural occurring disturbances (i.e., landslides, fires). As a result perturbations that exist in the system due to the spatial and temporal variability in the terrestrial sediment input are not accounted. Very few applications use real time data even if the capability to do so is available. A great effort has been recently devoted to run simulations faster than real time based on static data sets. However, this is highly inefficient and leads to multiple sediment predictions that are conflicting when major events are predicted. This lack of ability to dynamically inject data into simulations and other applications, as these applications execute, limits the analysis and the predictive capabilities of these applications.

The foregoing thoughts suggest that, despite the improved knowledge gained in the general area of watershed research and management (e.g., Diplas 2002), there remain several significant questions regarding dynamic simulation of these processes as it was defined earlier. Implementation of the current ideas for solving several practical problems of a watershed scale has not been straightforward.