Hydrogeios is an integrated, GIS-based application, suitable for complex hydrosystems, where natural processes are significantly affected by human interventions. It optimizes the operation of a water management scheme, using automatic parameter estimation tools, based on multiple error criteria and a robust optimization method, adapted for both single and multiobjective calibrations. It provides a systems-oriented management scheme, to ensure a faithful representation of hydrological mechanisms and, hence, a rational water management policy. It assesses the actual surface and groundwater yield at various control sites.

**Input data**
- Raw geographical data: terrain model, soil properties (e.g., permeability), land cover, monitoring stations
- Surface hydrology components: hydrographic network (river nodes and segments), sub-basins, hydrological response units (HRUs)
- Groundwater components: aquifers, springs, boreholes
- Water management components: channels, pipes, demand sites, irrigated areas, borehole groups, water uses and priorities, operational costs and constraints
- Time series: precipitation & potential evapotranspiration (for each sub-basin), water needs, control series (discharge measurements, observed aquifer levels)
- Scenario data: computational parameters for simulation and optimisation procedures, error criteria for calibration

**Groundwater hydrology processes**
- A Darcian multi-cell scheme is established, based on a non-rectangular discretisation of the groundwater system.
- Each cell is represented as a conceptual tank, of which the stress components are: (a) percolation from each sub-basin and HRU combination, (b) infiltration losses from each river segment, and (c) pumping from each borehole. Springs are modelled as tanks with very large base.

**Surface hydrology processes**
- Real evapotranspiration
- Lagged flow (satisfaction)
- Quick flow
- Direct flow

**Water resources management: A network optimisation approach**
- basin and spring runoff, assumed point supply
- groundwater yield (= pumping capacity)
- water needs, constraints and priorities
- real capacities and unit cost values of hydrosystem components

**Objectives**
- Establishing a physically-based approach while keeping a parsimonious structure, by conceptually relating the hydrological responses of a watershed with its geomorphological and physiographic characteristics.
- Taking into account all available spatial and hydrological data.
- Understanding the main physical mechanisms along a river network, and their interactions under a specific hydroclimatic scenario or management policy.
- Assessing the actual surface and groundwater yield at various control sites.

**Simulation flowchart**
- A parsimonious structure, with six parameters per HRU

**Real hydrosystem**
- Digraph representation
- Calculation of all hydrosystem fluxes, by transforming real components to digraph components, assigning virtual inflows, costs and capacities, and solving a LP problem
Case study: The Boeotios Kephisos river basin
- **Watershed area:** 1955.6 km² (the largest of the Eastern Sterea Hellas water district)
- **Altitudes:** 469 m (average), 2400 m (maximum)
- **Geology:** heavily karstified limestones (mountainous areas), alluvial deposits (plain areas)
- **Hydrographic network:** a main branch of length 100 km; last 35 km segment is an artificial channel, diverting flows to the neighbouring Lake Hylike (the basin has no physical outlet to the sea)
- **Hydrology:** mean annual precipitation 765 mm, mean annual runoff 172 mm
- **Groundwater:** due to the karstic background, significant percentage (~50%) of runoff is baseflow, arising from large springs in the upper and middle part of the basin; unknown amount of groundwater is conducted to the sea
- **Water uses:** (1) abstractions from both surface and groundwater resources for irrigation (220 hm³/year); (2) abstractions from Lake Hylike and water supply boreholes lying in the middle part of the basin, directed to Athens

Surface hydrology

- **Permeability class**
- **Slope**
- **Hydrological response units**

Groundwater hydrology

- **Multi-cell model schematisation**
- **Sub-basins and HRUs union**

HYDROGEIOS: Software implementation

- Monthly or daily simulation
- Flow routing procedures, in case of daily time steps
- Multiple goodness-of-fit criteria, for discharge and groundwater level series
- Automatic calibration of selected parameters or groups of parameters
- Parameter uncertainty assessment, through multiobjective techniques
- Detailed (step-by-step) water balance for all hydrosystem components
- Visualisation of results and export to spreadsheets

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