Water balancing: Principles and importance

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In recent years, the scientific and practical importance of water balance has been highlighted by predictions of fresh water shortages in many areas of the world, due to industrial development, urbanization, and increase in agricultural production. The study of water balance of river basins, lakes, groundwater forms a basis for the hydrological sustainability of projects for the rational use, control and redistribution of water resource in time and space. Therefore an understanding of water balance is extremely important for the studies of hydrological cycle. Underlying principle behind water balancing is law of conservation of mass, often referred to as the *continuity equation*. This states that, for any arbitrary volume and during any period of time, the difference between total input and output would be balanced by the change of water within the volume (Sokolov *et al.,* 1974). In general, therefore, use of a water-balance technique implies measurements of both storages and fluxes (rates of flow) of water, though by appropriate selection of the volume and period of time for which the balance will be applied..

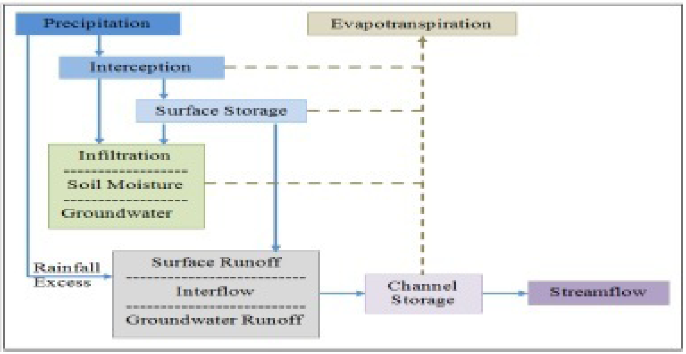

Fig. 1. Different components in water balance in a river basin

The water balance may be computed for water bodies of any size, but the complexity of computation depends greatly on the extent of the area under study. The water balance equation for any natural area indicates the relative values of inflow, outflow and change in water storage for the area. In general, the inflow part of the water balance equation comprises precipitation (P) like rainfall, snow, sleet etc. actually received at the ground surface, and surface (Q_{SI}) and subsurface (Q_{UI}) water inflow into the basin from outside. The outflow part of the equation includes evaporation (E) / evapo-transpiration (ET) from the surface and surface (Q_{SO}) and subsurface (Q_{UO}) outflow from the basin (Fig.1). When the inflow exceeds the outflow, the total water storage in the basin / water body (ΔS) increases and vice versa. To close the water balance equation it is essential to measure or compute all the balance elements, using independent methods wherever possible. Measurements and computations of water balance elements always involve errors, due to shortcomings in the techniques used. The water balance equation therefore usually does not balance, even if all its components are measured or computed by independent methods. The discrepancy of water (η) balance is given as a residual term of the water balance equation, and includes the errors in the determination of the components considered, and the values of components not taken into account by the particular form of the equation being used. A low value of η may indicate only that its component parts tend to balance out.

Consequently the water balance for any water body and any time interval in its general form may be represented by the following equation

$$P+Q_{SI}+Q_{UI}-E-Q_{SO}-Q_{UO}-\Delta S-\eta=0$$

For the application in water balance computations this equation may be simplified or made more complex depending upon available initial data, type and dimensions of water body, its hydrologic and hydrographic features, duration of the balance interval and the phase of the hydrological regime. For example in large river basins, Q_{UI} and Q_{UO} are small as compared to other terms since subsurface water exchange from the neighboring basin is assumed zero, therefore are ignored. Moreover there is no surface water inflow into the river basin with a distinct watershed divide, hence Q_{SI} is also neglected. But for the compilation of the water balance for short time intervals, the exchange in the total water storage (ΔS) in the small spring fed river basin may be subdivided into changes in the moisture storage of the soil (ΔM), in aquifers (ΔG), in reservoirs and lakes (ΔS_L) and in river channels (ΔS_{ch}). For a glacier fed stream, water storage in glaciers (ΔS_{gl}) and in snow cover (ΔS_{sn}) should also be taken into account.

Moreover water balance may be computed for water bodies of any size, but the complexity of computation depends greatly on the extent of the area under study. A river basin is the only natural area for which large-scale water balance computations can be simplified, since the accuracy of computation increases with an increase in the river basin's area. As the basin area gets smaller, the more complicated is the water balance since it is difficult to estimate secondary components of the balance like groundwater exchange with adjacent basins; water storage in lakes, reservoirs, swamps, and glaciers; and the dynamics of the water balance of forests, and irrigated and drained land.

Water balancing presents solutions of important theoretical and practical hydrological problems. On the basis of the water balance approach it is possible to make a quantitative evaluation of water resources and their change under the influence of man's activities. Few applications of water balancing include: (i) Water balancing is a powerful tool to understand spring stressors. Water balance gives information on groundwater inflow and outflow i.e. which parameters dominates. It also provides estimation of aquifer size in context to amount of water. By knowing the other elements in the equation (spring resurgence, total precipitation, infiltration rates, future precipitation trends etc.) one may evaluate sustainability of certain spring, which in turn may be used to decide whether or not, the spring under consideration needs physical augmentation for its conservation; (ii) Water balance techniques are used to identify water deficit areas under climate change scenarios, or whether climate change will exacerbate or limit current water deficits, as climate change impacts water balances directly through changes in precipitation and indirectly with temperature changes that affects evapo-transpiration; (iii) with the water balance data it is possible to compare individual sources of water in a system, over different period of time, and to establish the degree of their effect in variation of water regime which in turn provides a basis for project design like construction of a dam and barrages for hydropower generation and irrigation, water intake structures for supplying water to an urban plot, computing frequency of irrigation of crop land etc; (iv) Initial analysis used to compute individual water balance components, and the coordination of these components in the balance equation makes it possible to identify deficiencies in the distribution of observational stations, and to discover systematic errors of measurements; and (v) Water balance studies provide an indirect evaluation of an unknown water balance component from the difference between the known components (e.g. long-term evaporation from a river basin may be computed by the difference between precipitation and runoff).

Reference:

Sokolov A A, Chapman T G (1974). Methods for water balance computations: An international guide for research and practice. Paris: *The UNESCO Press*, 41-43.

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