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Water Budgets: Foundations for Effective Water Resources and Environmental Management

by

Richard W. Healy, Thomas C. Winter, James W. LaBaugh, and O. Lehn Franke
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A recent publication by the US Geological Survey provides an excellent introduction to the process of accounting for the movement and storage of water through the environment through the mechanism of drawing up a water budget. Water budgets provide a means for evaluating availability and sustainability of a water supply. A water budget simply states that the rate of change in water stored in an area, such as a watershed, is balanced by the rate at which water flows into and out of the area. An understanding of water budgets and underlying hydrologic processes provides a foundation for effective water resource and environmental planning and management.

Observed changes in water budgets of an area over time can be used to assess the effects of climate variability and human activities on water resources. Comparison of water budgets from different areas allows the effects of factors such as geology, soils, vegetation, and land use on the hydrologic cycle to be quantified.

Human activities affect the natural hydrologic cycle in many ways. Modifications of the land to accommodate agriculture, such as installation of drainage and irrigation systems, alter infiltration, runoff, evaporation, and plant transpiration rates. Buildings, roads, and parking lots in urban areas tend to increase runoff and decrease infiltration. Dams reduce flooding in many areas. Water budgets provide a basis for assessing how a natural or human-induced change in one part of the hydrologic cycle may affect other aspects of the cycle.

This report provides an overview and qualitative description of water budgets as foundations for effective water resources and environmental management of freshwater hydrologic systems. Perhaps of most interest to the environmental community, the concepts presented are also relevant to the fields of agriculture, atmospheric studies, meteorology, climatology, ecology, limnology, mining, water supply, flood control, reservoir management, wetland studies, pollution control, and other areas of science, society, and industry.

The first part of the report describes water storage and movement in the atmosphere, on land surface, and in the subsurface, as well as water exchange among these compartments. Our ability to measure these phenomena and inherent uncertainties in measurement techniques also are discussed.

The latter part of the report presents a number of case studies that illustrate how water-budget studies are conducted, documents how human activities affect water budgets, and describes how water budgets are used to address water and environmental issues. Calculations of water budgets are made for four different segments of the environment, including natural segments like a watershed and a lake and artificial segments like farmland and a waste disposal site. Applications to varied ecosystems are also presented, ranging from large river systems and high plains aquifers to urban water supply (for the city of Chicago). The universality of the water budgeting method is amply demonstrated.

This report is available on the Internet at: http://pubs.usgs.gov/circ/2007/1308

The Association of Arsenic with Redox Conditions, Depth, and Groundwater Age in the Glacial Aquifer System of the Northern United States

by

Mary Ann Thomas

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The US EPA recently lowered the Maximum Contaminant Level (MCL) for arsenic in drinking water from 50 micrograms per liter (µg/L) to 10 µg/L in recognition of the health effects, which include bladder, skin, and lung cancers; diabetes; and neurological dysfunction. The new MCL went into effect in January 2006 for public water systems but not for private wells. Private wells are not routinely tested for arsenic in most parts of the country, so homeowners may not know whether their well water is contaminated with arsenic.

Arsenic in nature is relatively abundant, and most instances of groundwater contamination come form naturally occurring minerals like pyrite and iron oxides. Arsenic in groundwater varies considerably from place to place and is difficult to predict on a well-by-well basis, since it does not dissolve from the aquifer minerals in a simple fashion, as the minerals can fall out of solution in certain circumstances. If the most susceptible aquifers (or parts of aquifers) could be identified, efforts for monitoring or public education could be targeted to areas of greatest need.

The US Geological Survey's National Water Quality Assessment (NAWQA) program has been systematically sampling groundwater since 1991. Between 1991 and 2003, NAWQA analyzed 813 samples of groundwater from glacial aquifers in the northern United States. The samples were selected randomly, to be representative of important hydrogeological settings found within the glacial aquifers, providing a large-scale survey of arsenic in groundwater under various conditions. Nine percent of the samples tested showed arsenic concentrations above the new MCL of 10 µg/L. A synthesis of the results is presented in this report, which seeks to document arsenic concentrations and their variations in glacial aquifers, describing how the chemistry of the aquifer (its reducing/oxidizing, or redox, conditions, similar to pH), the depth of the well, and the age of the groundwater all affect the amount of arsenic found.

In the eastern region of the study, based on the Appalachian Highlands, none of the 118 monitor and private wells showed elevated levels of arsenic. Wells in the central region (Ohio to Wisconsin, with heavy sampling in eastern Nebraska) were contaminated at the average rate of 9 percent. In the western region (Iowa to the Dakotas), wells in the older, southern section were more contaminated (median of 3.2 µg/L overall), but less likely to be contaminated than in the younger, northern stretch (11 percent versus 14 percent).

The study concludes that a model of arsenic contamination developed by Smedley and Kinniburg (*Applied Geochemistry* 17, 2002) provides a good predictor for problem areas. It relies on two requirements: a geochemical trigger, such as strongly reducing conditions or high pH; and sluggish groundwater flow from flat topography and thick accumulations of fine-grained sediments, which permit the arsenic to accumulate faster than it can be flushed away. In the East, aquifers are less likely to have reducing conditions (from a lack of dissolved organic carbon) and groundwater tends to flow faster due to steeper topography and thinner, coarser glacial deposits.

This report is available on the Internet at: http://pubs.usgs.gov/sir/2007/5036.

Passaic Valley Ground Water Protection Committee
Hon. Richard Plambeck, Chair
94 Mt. Bethel Road, Warren, NJ 07059
Phone: (908) 222-0315 Fax: (908) 222-0357
Email: prc@passaicriver.org Website: www.passaicriver.org