GROUND WATER Editorial

Safe Yield and the Water Budget Myth

by John Bredehoeft[a]

The editorial by Marios Sophocleous in the July-August issue of *Ground Water* is an especially important one. I agree with Marios, the idea of safe yield as it is generally expressed in which the size of a development if it is less than or equal to the recharge is considered to be "safe" is fallacious. As Marios indicates, Theis pointed out the fallacy of this notion of "safe yield" in a 1940 paper entitled: *The source of water to wells: essential factors controlling the response of an aquifer to development (Civil Engineering*, p. 277–280)—every practitioner of ground water should go back and read this paper. Theis' 1940 principle is one of the least understood concepts in ground-water hydrology.

Hilton Cooper, Stavros Papodopulos, and I reiterated Theis' paradigm in a 1982 paper entitled: *The water-budget myth (Scientific Basis of Water Management, National Academy of Sciences Studies in Geophysics*, p. 51–57). At the time, Theis said to me that this paper eliminated the need for a paper he had been contemplating. Unfortunately, our 1982 paper was printed in an obscure publication; and yet it may be one of the more important papers we wrote.

I have some additional remarks to add to Marios Sophocleous' editorial. As Marios correctly indicated, Theis stated: "*A new state of dynamic equilibrium is reached only by an increase in recharge (induced recharge), a decrease in discharge, or a combination of the two.*" Cooper, Theis, and others had a name for the sum of increased recharge plus the decreased discharge—they refer to it as capture. In order for a development to reach a new equilibrium, the capture must ultimately equal the new stress on the system, the development. Capture is dynamic, and depends upon both the aquifer geometry and the parameters (permeability and specific storage) of the system. This is why both well response and aquifer system response are so much a part of ground-water hydrology.

In my experience, the recharge, and certainly the change in recharge due to a development (induced recharge) is difficult, if not impossible, to quantify. Usually the recharge is fixed by rainfall and does not change with development. Marios leaves an impression that the change in recharge (induced recharge) is where our focus as ground-water hydrologists should be. It is on this point that we may differ.

Commonly the virgin discharge is what changes and makes it possible to bring a ground water system into balance. Capture is a dynamic quantity that changes through time until the system reaches a new equilibrium. Usually this is what we attempt to quantify with flow models—we estimate the magnitude of the capture from the virgin (natural) discharge. It is usually much more important to focus on the discharge, and the change in discharge—the capture. Capture from the natural discharge is usually what determines the size of a sustainable development.

Pumping does not have to exceed the recharge for streams to be depleted. Pumping is an additional stress on the system. The water pumped will usually be supplied from both storage and from reduced natural discharge. We define equilibrium as a state in which there is no more change in ground-water storage with time—water levels are stable in time. If no new equilibrium can be reached, as Theis showed for the high plains aquifer of New Mexico, the aquifer will continue to be depleted. Once a new equilibrium is reached, the natural discharge is reduced by an amount equal to the development—capture equals development. This statement has nothing to do with recharge. Often streams are depleted long before the pumping reaches the magnitude of the recharge.

It is important that the profession understand the concept of safe yield. Sustainable ground-water developments have almost nothing to do with recharge; as Marios correctly states, it is irrelevant. However, I continue to hear my colleagues say they are studying the recharge in order to size a development—I heard this again last week. The water budget as it is usually applied to scale development is a myth—Theis said this in 1940. Yet the profession continues to perpetuate this wrong paradigm.

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