CHAPTER 10

Concluding Comments on Managing Water-resources Systems: Why “Safe Yield” is Not Sustainable

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> “For in the end we will conserve only what we love;
> we will love only what we understand;
> and we will understand only what we are taught.”
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> —*Baba Dioum*,
> African Conservationist

Water resources are essential to both economic development and the maintenance of natural systems. Few areas of public policy are as contentious as the issues surrounding management of our environment and natural resources, such as water.

Among the greatest challenges facing society today is the need to understand more fully the complex ecological processes that maintain our human life-support system and to integrate knowledge about these processes into management and policy decisions (Reichman and Pulliam, 1996). As Pulliam and O’Malley (1996) emphasized, knowing what we have, understanding how natural ecosystems work, and effectively communicating to decision-makers about environmentally sustainable practices are crucial if we are to ensure that the natural goods and services that we have enjoyed will continue to be available for both present and future generations.

Arrow et al. (1995) argue that the current economic system fails to account for the depletion of resource stocks and ecosystem services, and that the environmental resource base, of which water is part, is finite. When inventories are depleted and the physical plant is allowed to deteriorate, it is possible to make a profit in the short term while watching net worth waste away. Such is the road to bankruptcy. Businesses routinely make decisions that may have short-term costs but obvious benefits to their long-term sustainability. This comparison to the business world captures the sense of intergenerational equity and stewardship that are central to an ecosystem management philosophy (Christensen et al., 1996). Ecosystem management is the ecological analog to the economic stewardship of a trust or endowment dedicated to benefitting all generations.

During the past few decades we have gained a better understanding of soil and water ecosystems and related processes, but too little of this knowledge has been applied successfully to fundamental management programs. Although major gaps remain in our understanding of such systems and processes, of more importance are the gaps between what is known and what is applied (NRC, 1991). Therefore, we need to develop better ways to communicate results and facilitate their implementation.

One such gap between what is known and what is applied is the use of the sustainability concept of “safe yield” of ground water, which persists today despite being repeatedly discredited in the literature. Unfortunately, misconceptions and narrowmindedness about safe yield and ground-water management persist, leading to continued ground-water depletion, stream dewatering, and loss of wetland and riparian ecosystems. Hopefully this volume has contributed in elucidating some of the issues involved.

To protect ground-water supplies from overexploitation, some state and local agencies have enacted regulations and laws based on the sustainability concept of “safe yield.” Safe yield is traditionally defined as the attainment and maintenance of a long-term balance between the amount of ground water withdrawn annually and the annual amount of recharge. Therefore, safe yield allows water users to pump only the amount of ground water that is replenished naturally through precipitation and surface-water seepage. Although this traditional safe-yield concept sounds reasonable, it ignores discharge from the system. Under natural or equilibrium conditions, recharge to an aquifer results, in the long term, in an equal amount of water that is discharged from the aquifer into a stream, spring, or seep. Consequently, if pumping equals recharge, the streams, marshes, and springs eventually dry up. Continued pumping in excess of recharge also eventually depletes the aquifer. This has happened in various locations across the Great Plains and elsewhere, as we have shown in Chapters 2 and 3. Probably the best known example is the Ogallala or High Plains aquifer, in which water-table declines of more than 100 ft (30 m) have occurred in parts of Texas, New Mexico, and Kansas. Maps comparing the perennial streams in Kansas in the 1960’s to those of the 1990’s show a marked decrease in miles of streamflow in the western third of the state. Policy-makers are primarily concerned about aquifer drawdown and surface-water depletion, both unrelated to the natural-recharge rate (Balleau, 1988). Despite its irrelevance, natural recharge is often used in ground-water policy to balance ground-water use under the banner of safe yield. Adopting an attractive fallacy that the natural-recharge rate represents a safe rate of yield does not provide scientific credibility.

To better understand why this is happening, a knowledge of hydrologic principles (concisely stated by C. V. Theis in 1940) is required (see also Chapter 2). Under natural conditions, prior to development by wells, aquifers are in a state of approximate dynamic equilibrium: over hundreds of years, wet years in which recharge exceeds discharge offset dry years when discharge exceeds recharge. Discharge from wells upsets this equilibrium by producing a loss from aquifer storage; a new state of dynamic equilibrium is reached when there is no further loss from storage. This can be accomplished only by an increase in recharge, a decrease in natural discharge, or a combination of the two. Ground water pumped from the aquifer comes from two sources: aquifer storage and induced recharge of surface water (because natural recharge is balanced by natural discharge under equilibrium conditions). Initially, ground water comes from storage, but this source ultimately ceases. The timing of the change from storage depletion to induced recharge is a key factor in developing water-use policies. This transition takes a long time by human standards. Distinguishing between natural recharge and induced recharge to ascertain possible sustained yield is exceedingly difficult and is an area that needs further research. Calibrated stream-aquifer models could provide some answers in this regard.

Although the ideas of sustainable yield have been around for many years, a quantitative methodology for the estimation of such yield has not yet been perfected. A suitable hydrologic basis for determining the magnitude of possible development would be a quantification of the transition curve (from ground-water-storage depletion to full reliance on induced recharge), coupled with a projected pattern of drawdown for the system under consideration (Chapter 2). The level of ground-water development would be calculated using specified withdrawal rates, well-field locations, drawdown limits, and a defined planning horizon (Balleau, 1988). Since the 1980's, three-dimensional numerical models of the complete stream-aquifer hydrogeologic system have been employed to provide a predictive tool explaining the connection between well-field withdrawal and surface-water depletion, and are capable of generating the transition curve for most situations.

Ground-water management cannot be conceived of separately from management of surface waters. Because of the interdependence of surface and ground water, operations on any part of the system have consequences for the other parts. The impact of ground-water development on streams is highly variable. The management category of minable water may be a reasonable one to apply to well-field areas that would not progress beyond the earliest stages of the transition from storage depletion to induced recharge within a reasonable planning horizon, as shown in Chapter 4 on confined aquifers. Thus, wise management of water resources needs to be approached both from the viewpoint of focusing on the volume and quality (Chapter 5) of water resources available for sustainable use, and from the impact of ground-water exploitation on the natural environment, including ground water, surface water, and riparian ecosystems.

Initially, the effect of wells on surface water was simply not known, and even now there is too little information to allow a complete and efficient administration of conjunctive use in most areas. Those who first endeavored to establish laws for ground-water administration were required to do so without much knowledge about hydrology. The result was the establishment of a legal model before the physical model had developed. Eventually, however, the science of hydrology developed to the point of demonstrating the interconnection of surface and associated ground water. The failures and unintended consequences of conventional and safe-yield-based water-management and development strategies provide some of the strongest incentives to replace such strategies with the broader sustainable-resource-system management. A few examples of such failures are given in Chapter 3 and range from local to global.

Safe yield is often used as a single-product exploitation goal—the number of trees that can be cut, the number of fish that can be caught, the volume of water that can be pumped from the ground or river, year after year, without destroying the resource base. However, experience has repeatedly shown that a single-product goal is too narrow a definition of the resource, because other resources inevitably depend on, or interact with, or flow from the exploited product. We can maximize our sustainable yield of water by drying up our streams, but when we do, we learn that the streams were more than just containers of usable water.

The conventional safe-yield approach is ambiguous, limited, and restrictive. Any change in conditions such as vegetation or land use, urbanization, location of pumping wells, or incorporation of new water supplies, requires calculation of a new yield. Thus, the conventional safe-yield approach lacks an unambiguous quantitative definition. Also it fails to recognize the impact of ground-water exploitation on the natural environment (Chapter 2). Thus, it is not satisfactory.

A better definition of safe yield would address the sustainability of the "system" and its water yield—not just the trees, but the whole forest; not just the fish, but the marine food chain; not just the ground water, but the running streams, wetlands, and all the plants and animals that depend on them. Given the dynamic connectedness of a watershed, management activities can fragment and disconnect the habitat "patches" if they are not planned and implemented from an ecosystem and watershed perspective (Chapter 3). In-stream conditions are mainly determined by processes occurring within the watershed and underlying aquifers, and they cannot be isolated from or manipulated independently of this context. Such a holistic approach, however, is fraught with difficulty. We cannot use a natural system without altering it, and the more intensive and efficient the use, the greater the alteration.

Science will never know all there is to know. This calls for applying the best of what we know today—while, at the same time, providing sufficient management flexibility to allow for change and for what we do not yet know. Evidence shows that we have altered the hydrologic cycle as well as cycles of many chemical elements, that we seem to be affecting climate (Chapter 8), and that biodiversity may be declining rapidly (Meyer, 1993). As shown in several chapters of this volume, we must manage for change and for complexity because natural systems are inherently “patchy” and complex. This also implies managing in a probabilistic and risk-assessment framework (see Chapter 9) in which one recognizes the inherent unpredictability of nature. Instead of determining a fixed sustainable yield, managers should recognize that yield varies over time as environmental conditions vary (Meyer, 1993).

Our understanding of the basic principles of soil and water systems and processes is fairly good, but our ability to apply this knowledge to solve problems in complex local and cultural settings is relatively weak (NRC, 1991). Communication is vital. We need people who can transfer research findings to the field and who can also communicate water users’ needs to the researchers. As Christensen et al. (1996) pointed out, delivering a refereed journal publication to a manager’s desk is not sufficient if we wish our best science to move quickly into management application. This breakdown in communication most probably accounts for the persistence of simplistic but misguided concepts such as conventional ground-water safe-yield management today. Our education system has mostly failed to stress the importance of sustainability in water-resources management. As Balleau (1988) commended, “Hydrology as a science has not been markedly successful in communicating its basic principles, such as mass-balance,” especially in stream-aquifer systems. A water-policy study team (DuMars et al., 1986) advising the New Mexico Legislature concluded that “[t]his concept and its ultimate impact on the environment . . . is little understood by hydrologists and lay people alike.” A strong public-education program is needed to improve understanding of the nature, complexity, and diversity of ground-water resources, and to emphasize how this understanding must form the basis for operating conditions and constraints. This is the only way to positively influence, for the long term, the attitudes of the various stakeholders involved.

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