Memorial to Luna B. Leopold (1915–2006)

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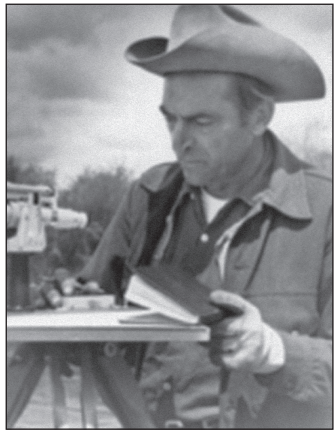

Luna B. Leopold's scientific career spanned 70 years. It was primarily devoted to the study of natural river channels, but an abiding concern with the ethical aspects of human land use, which he shared with his father, the pioneering ecologist Aldo Leopold, became more explicit during the last three decades of his life.

Leopold was born in Albuquerque, New Mexico, on 8 October 1915, one of five children, all of whom became naturalists, with three gaining election to the National Academy of Sciences. After a happy, largely rural childhood, during which he acquired many practical skills that proved invaluable in his field studies, Leopold went to the University of Wisconsin, Madison, where he graduated in 1936 with a B.S. in civil engineering. He worked for the U.S. Soil Conservation Service in New Mexico for four years and for the U.S. Army Weather Service for six, during which he received training in meteorology at the University of California at Los Angeles and gained an M.S. in physics–meteorology. Leopold was able to apply and develop these skills at the Pineapple Research Institute in Hawai'i, where he served as chief meteorologist until 1950.

That year, Leopold joined the Water Resources Division of the U.S. Geological Survey (USGS), but was given leave to complete the graduate studies he had begun some years earlier under Kirk Bryan at Harvard. His Ph.D. thesis was titled, "The erosion problem of the Southwest", an issue that was to stay with him the rest of his life. Leopold then embarked on a series of projects that changed the face of surface hydrology, as he and a small group of colleagues tackled quantitatively issues that on the whole had hitherto been treated descriptively. The work combined the methods promoted by R.E. Horton in his classic 1945 *Geological Society of America Bulletin* paper on the erosional development of streams and their drainage basins, and the reforming zeal of A.N. Strahler, with an extensive programme of field measurement aimed at understanding the mechanics of the processes shaping river channels.

Leopold joined the USGS as a hydraulic engineer. He was soon promoted to chief hydraulic engineer and then to senior research hydrologist, an appropriate distinction in view of his success in adding a powerful research component to a division that had traditionally focused on data collection. There is space here to list only a few of Leopold's key papers, but they suffice to illustrate two key characteristics: the ambitious sweep of their subject matter, and the calibre of his co-authors. Here we have at long last a concerted attack on the morphology and mechanics of ephemeral and perennial streams in plan view, in cross section, and in longitudinal profile, at a station and throughout the basin, instantaneously and traced over time, pragmatically and conceptually. In addition, the USGS Professional Paper format allowed ample space for tables, lucid graphs, and photographs, which Leopold saw as essential to making the raw data available for others to reassess. He was also vocal in his disapproval of cumbersome peer review processes

which, as we see today, tend to favour conformity. Under his management, publication was swift as well as thorough and transparent.

One of Leopold's collaborators in the morphometric work as well as in studies of alluvial history was a Harvard contemporary, John P. Miller. During a field trip in New Mexico, Miller contracted bubonic plague and died a few days later. Leopold went ahead with a book on fluvial geomorphology that he had been discussing with Miller and included him in the authorial line-up. His co-author was M.G. Wolman, with whom Leopold was to be awarded the 2006 Benjamin Franklin Medal in Earth and Environmental Science "for advancing our understanding of how natural and human activities influence landscapes, especially for the first comprehensive explanation of why rivers have different forms and how floodplains develop."

The citation continues, "Their contributions form the basis of modern water resource management and environmental assessment." Leopold's scientific work tends to overshadow his energetic and effective activities in defence of riverine and other natural systems. In 1969, he was successful in calling for the redesign of the trans-Alaska pipeline, which, in its original form, as he was able to show after flying over its entire route, was bound to cause widespread melting of permafrost with devastating effects on slope stability and river channels and, by extension, the associated ecosystems.

That same year saw the publication of a select committee report commissioned by the U.S. Department of the Interior and edited by Leopold on the proposed development of an aviation complex to serve south Florida. The Dade County Port Authority had selected a 101 km^2 site in the Big Cypress Swamp. Leopold and his team were asked to assess the possible effects on the park. Their report, *Environmental impact of the Big Cypress Swamp,* played a crucial role in blocking the proposal by showing that the jetport would permanently change the south Florida ecosystem, including the Everglades National Park. It has been aptly said that, quite apart from helping to safeguard the Everglades and awakening public awareness of their frailty, Leopold created what we now routinely call environmental impact statements.

The fate of rivers would evidently not be disregarded by Leopold's watchful eye. In the late 1950s, he and W.B. Langbein initiated what came to be called the Vigil Network, consisting of sections in small river basins where natural changes would be recorded regularly. Some of these have been operating continuously for half a century, and similar schemes are in operation in Israel and Sweden. Just as productive were some of Leopold's rafting expeditions down rivers for which he needed depth and velocity data. In 1965, he surveyed 450 km of the Colorado in this manner (and again many years later with his distinguished collaborator, the physicist, soldier, and desert explorer Ralph A. Bagnold). Besides feeding into the morphometric work, these investigations paved the way for a concerted attack on the problems of river control and restoration, presaged in a joint study of flood control with T. Maddock Jr. in 1954 and developed with T. Dunne in 1978 and D.L. Rosgen in the 1980s.

Leopold retired from the USGS in 1972 and joined the Department of Geology and Geophysics and the Department of Landscape Architecture at the University of California at Berkeley, where he taught until 1986. The following year, he was made professor emeritus. He continued to run field courses with Rosgen well into his 80s despite growing disability, and to write for the generalist as well as the specialist to the day of his death in an unceasing effort to enlighten the general public as well as legislators and policy makers. His concerns went beyond any single river basin, region, or nation: as he put it in *Water, Rivers and Creeks* (1997), availability of water will be as important as ethnic strife or religious difference as the cause of political and social unrest or conflict. The personal memoir he completed a few weeks before his death tells the story of his progression from observer to defender of the fluvial realm.

Leopold served on the board of directors of the Sierra Club, the Environmental Law Institute, and the Aldo Leopold Foundation, Inc. He received many honors, including the Kirk Bryan Award and the Penrose Medal of the Geological Society of America (1958 and 1994, respectively), the Distinguished Service Medal of the U.S. Department of the Interior (1958), the Warren Prize of the National Academy of Sciences (1973), and the Robert E. Horton Medal of the American Geophysical Union (1992). He was one of four geologists to receive the National Medal of Science (1991). Leopold was elected to membership of the National Academy of Sciences in 1968 and was a Fellow of the American Academy of Arts and Sciences (1969), the American Philosophical Society, the American Geophysical Union, the American Society of Civil Engineers, and the California Academy of Sciences. He received honorary degrees from the Universities of Ottawa, Wisconsin, St Andrews, and Murcia, and from Wesleyan College, Iowa.

The following bibliography is intended to demonstrate the range of Leopold's work and at the same time its strong coherence.

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