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FORUM

Ecosystem Restoration a Challenge for Unified Hydrologic Science

Will a unified, but increasingly interdisciplinary, hydrologic science provide the knowledge now needed by water managers to restore and conserve regional ecosystems? Or, will divisions now present in hydrologic science compel managers themselves to gather and synthesize information developed in narrow sub-fields of water-related science? On July 1, 1999, the U.S. Army Corps of Engineers announced a plan that would spend \$8 Billion over the next 20 years for the "primary and overarching purpose" of restoring the natural ecosystems of south Florida, in particular the vast wetlands of the Everglades and adjacent coastal areas. This plan signals a radical expansion in the goals for water management in south Florida to include responsibility for the health and sustainability of regional ecosystems. Water managers in several other areas of the U.S., such as San Francisco Bay, Chesapeake Bay and coastal Louisiana, face similarly expanded mandates. In order to address these new, broad ecological goals water managers are being driven outside of the traditional mainstream of hydrologic research to find the sources of knowledge they now need.

The emergence of ecosystem restoration as a goal for regional water management should interest hydrologic scientists and policy makers who view hydrologic science as a distinct discipline of the geosciences. This is the vision offered by a National Research

Council assessment of hydrological sciences in the U.S. that was published in 1991 as *Opportunities in the Hydrological Sciences* (OHS). The OHS report defines hydrologic science broadly to include physical, chemical and **biological** (emphasis added) processes that interact with the continental portion of the hydrologic cycle. Can this vision be realized now that scope for water management is expanding to include the objective of ecosystem sustainability? Or will the needs of water managers drive the development of a separate, ecology-based hydrologic science.

Divisions within hydrologic science are a consequence of its history as an applied science. In his introduction to OHS, Peter Eagleson observes that "the development of hydrologic science has followed rather than led application." Thus, the body of hydrologic knowledge surveyed by OHS in 1991 accrued from applied research in various separate academic disciplines, notably geology and civil and agricultural engineering. Specific applied problems that have driven development of the hydrologic science lend a particular flavor to the associated sub-fields. Together, the fields surveyed in OHS constitute the mainstream of hydrologic science still today. Water Resources Research serves as its primary outlet for research and the Hydrology Section of the AGU as its primary scientific association.

Since 1991, two new areas of water-related research have developed within applied sub-disciplines of ecology. These are wetland science and the more general field of conservation ecology. Broad public support for wetland preservation and ecosystem restoration fuels the development of these fields of research. Applied ecologists working in these fields are, in their turn, making their own contributions to the body of hydrologic knowledge. However, this work is distinctively different from the mainstream described by OHS. Wetland science, for example, derives its style and approach not from engineering science but from field ecology, which is the training of the leading wetland scientists. As a result, wetland hydrology is developing a body of hydrologic knowledge that is not integrated with mainstream hydrologic science.

Patterns of citation in the scientific literature illustrate the degree to which wetland hydrology is now isolated from mainstream hydrologic science. The Society of Wetland Scientists and its journal, *Wetlands*, embody wetland science as the Hydrology Section of AGU and *Water Resources Research* do in hydrologic science. Volume 18 of *Wetlands*, published in 1998, contains 61 papers covering the range research in wetland science. In this volume there are 17 papers in a special issue devoted to human impacts (including restoration) on and the diversity of riparian ecosystems, several papers on the scientific and philosophical bases for wetland policy and regulation, and two technical papers on the measurement of evapotranspiration. In all, the 61 published papers contain 2441 citations to all types of scientific literature, of which 418 (20% of the total) concern some aspect of hydrologic science, judged by keywords in the title. However, of these 418 hydrologic citations, only 11 (2.6%) refer to work published in *Water Resources Research*. While it is

evident that wetland science depends on a base of hydrologic science (20% of citations), there is relatively little reliance on the contemporary knowledge of mainstream hydrologic science.

This division of hydrologic science is costly to water managers, who face the unfamiliar and difficult task of merging information from two increasingly independent bodies of knowledge. It is evident to them that institutions of mainstream hydrologic science are not now capable of providing all the knowledge required for wise management of water resources in the U.S. As a result, water managers more and more are coming to rely on and support sources of hydrologic knowledge outside of the mainstream of hydrologic science. Where possible, managers will also seek to solve the problem of integrating hydrologic knowledge by altering established practices and institutions. In recent years, the South Florida Water Management District, which is a partner in the Corps' plan to restore the Everglades, has hired a staff of applied ecological scientists to complement their long-standing in-house expertise in engineering hydrology.

Whether or not the vision elucidated in *Opportunities in the Hydrological Sciences* is realized is really up to current hydrologic scientists, the Hydrology Section of the AGU and other institutions in the mainstream. To promote a unified, interdisciplinary hydrologic science, the mainstream must reach out to understand and incorporate nontraditional approaches to hydrologic research, particularly those of wetland scientists and other applied ecologists. Efforts by mainstream institutions that are aimed primarily at defending "core" elements of hydrologic science lead in the direction of a divided discipline. Mainstream scientists and

institutions may be disconcerted to encounter apparently new areas of hydrological research in which substantial progress has already been made by other scientists. This should be welcomed as an opportunity for growth and renewal of the science. The real challenge is to adapt the established tools and concepts of mainstream hydrologic science to the new questions emerging on the frontiers of research and application.

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